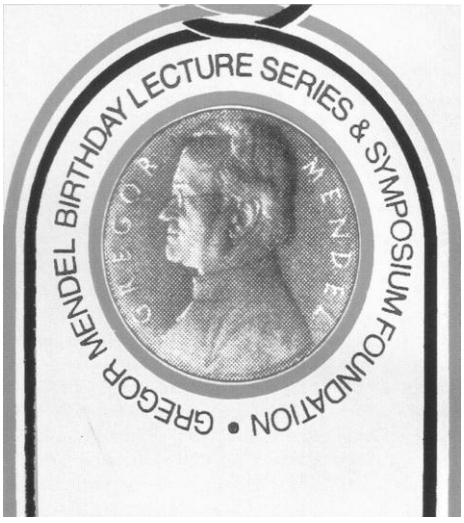
RECENT TRENDS
IN
CROP SCIENCE RESEARCH

(GREGOR MENDEL FOUNDATION PROCEEDINGS, 2006)



GREGOR MENDEL FOUNDATION
DEPARTMENT OF BOTANY
UNIVERSITY OF CALICUT
KERALA – 673 635
INDIA

Proceedings of the National Seminar on Recent Trends in Crop Science Research

held on

21st and 22nd January 2006

(Sponsored by
Gregor Mendel Foundation, University of Calicut;
Council of Scientific and Industrial Research, New Delhi;
Kerala State Council for Science, Technology and Environment, Thiruvananthapuram and
University Grants Commission, New Delhi.)

GREGOR MENDEL FOUNDATION
DEPARTMENT OF BOTANY
UNIVERSITY OF CALICUT
KERALA – 673 635
INDIA

RECENT TRENDS IN CROP SCIENCE RESEARCH
(GREGOR MENDEL FOUNDATION PROCEEDINGS, 2006)

Editor:
K.V.Mohanan
Organizing Secretary
Gregor Mendel Foundation
Department of Botany
University of Calicut
Kerala – 673 635
India.

Contents

Report of the National Seminar on Recent Trends in Crop Science Research (Gregor Mendel Foundation Seminar, 2006)

The National Seminar on Recent Trends in Crop Science Research (Gregor Mendel Foundation Seminar, 2006) organized by Gregor Mendel Foundation, Department of Botany, University of Calicut, Kerala- 673635 an academic foundation functioning in the Department of Botany of University of Calicut was held in the Department of Botany of University of Calicut on 21st and 22nd of January 2006. A total of 147 participants including 10 guests and 6 invitees attended the seminar. The seminar was inaugurated by Prof.C.Gopinathan Pillai, Hon. Pro Vice Chancellor of the University on 21 January 2006.

Inaugural session

The inaugural programme started at 10 am. Dr.K.V.Mohanan, Organizing Secretary of Gregor Mendel Foundation (GMF), Department of Botany, University of Calicut & General Convener of the Organizing Committee welcomed the gathering. The meeting was presided over by Prof.P.V.Madhusoodanan (Head of the Department of Botany, President of GMF & Chairman of the Organizing Committee).

The inaugural address was made by Prof.C.Gopinathan Pillai, Hon. Pro Vice Chancellor, University of Calicut. He stressed the need of applied studies and also the importance of efforts to disseminate knowledge. Prof.K.Pavithran, Professor of Genetics and Plant Breeding (Rtd.), Calicut University, the founder Organizing Secretary and the present Patron of GMF made the key note address. He stressed the importance of crop improvement and spoke on agricultural crop revolutions. He further spoke on the importance of *in vitro* technology on crop improvement. The inaugural programme came to an end by 11 am with a vote of thanks made by Dr.K.M.Jayaram, Joint Secretary of GMF.

Technical sessions

The first technical session (Invited Papers) started at 11.10 am. Four invited papers were presented in the session. The first presentation was on ‘’Spices and the Economy of India’ by Dr.M.Tamil Selvan, Director, Directorate of Arecanut and Spices Development, [Ministry of Agriculture, Government of India), Calicut, Kerala. He spoke on the wide range of agricultural zones prevalent in India that makes it possible to produce a wide range of spices and herbs. He stressed the importance of many of them in domestic requirement and export.

The second presentation in the session was by Dr.P.N.Ravindran (Retired Director, Indian Institute of Spices Research, Calicut, Kerala), who presently officiates as Consulting Scientist, Centre for Medicinal Plants Research, Arya Vaidya Sala, Kottakkal, Kerala on ‘Medicinal plants: diversity, conservation and utilization’. According to him India is one of the twelve megadiversity regions holding approximately 8% of the global biodiversity with about 45000 plant species, 16 agroclimatic zones and 15 biotic provinces. This biodiversity is the lifeline of about 4635 ethnic communities of India, who use about 9500 plants for their health care.

The third presentation in the session was made by Dr.P.M.Kumaran, Principal Scientist, Central Plantation Crops Research Institute, Kasaragod, Kerala on ‘Coconut breeding in India’. His paper explained the importance of *Cocos nucifera* as a plantation crop of India. India was the first country in the world to exploit and document hybrid vigour in coconut in a cross between WCT and CGD. The country has one of the largest collections of coconut germplasm. Coconut improvement in the country has been achieved by selection

and hybridization. So far the country has released 12 high yielding hybrids accounting for nearly one third of the total hybrids released through out the world and eight varieties.

The fourth presentation was by Dr.A.G.S.Reddy, Deputy Director of Research (Rtd.), Coffee Board, Bangalore on Coffee breeding in India. He said that coffee breeding in India was originally started as selection for high yield and good cup quality in arabica coffee. Since arabica coffee was highly susceptible to leaf rust disease, resistance breeding programmes were initiated. Robusta coffee was also introduced as a part of the breeding programmes. Breeding programmes were carried out for different agronomical purposes. Besides conventional breeding methods, biotechnological approaches were also utilized.

The second technical session was on Crop Improvement and Biotechnology. The session started at 2 pm. 20 research papers were presented in the session. Dr.R.D.Iyer, Principal Scientist (Rtd.), Central Plantation Crops Research Institute, Kasaragod, Kerala chaired the session and Dr.V.V.Radhakrishnan, Scientist, Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala was the rapportier. The session covered almost all the major crops like forest trees, plantation crops, spices, cereals, vegetables and fruit trees.

The third session was on crop protection and it started at 9 am on 22nd January 2006. Dr.Y.R.Sharma, Director (Retired), Indian Institute of Spices Research, Calicut, Kerala was the chairman of the session. Mr.P.Abdul Rahiman, Field Entomologist, Regional Coffee Research Station, Chundale, Wayanad, Kerala was the rapportier of the session.

The fourth technical session was on crop production and the session started at 11 am on 22nd January 2006. Dr.S.N.Potty, Director (Rtd.), Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala chaired the session. Fifteen papers were presented in the session. Dr.V.B.Sureshkumar, Asst. Specialist, Regional Coffee Research Station, Chundale, Wayanad, Kerala was the rapportier.

Plenary session

The plenary session of the seminar started at 2 pm on 22 January 2006. Prof.P.V.Madhusoodanan, the President of GMF and the General Chairman of the Organizing Committee of the Seminar welcomed the gathering. Prof.K.Pavithran, the veteran rice geneticist, retired Professor of Genetics and Plant Breeding (Calicut University) and the Patron of GMF was honoured by Prof.P.V.Madhusoodanan, President, GMF.

Prof.K.Pavithran presided over the function and delivered the presidential address. A book edited by Dr.K.V.Mohanan on 'Essentials of Plantation Science' and published by M/s. Penta Book Publishers & Distributors, Calicut and dedicated to Prof. Philip Mathew, Retired Professor of Botany, Ex Syndicate Member and Former Chairman of the Board of Studies in Plantation Development, Calicut University was released by Prof. K.Pavithran by handing over a copy to Dr. Philip Mathew. Dr. Philip Mathew, the Chief Guest of the Plenary Session spoke on the occasion. Dr.V.J.Philip, the famous Biotechnologist, Retired Professor of Biotechnology and Ex Syndicate Member, University of Calicut offered felicitations. Dr.V.V.Radhakrishnan, Mr. P.Abdul Rahiman and Dr.V.B.Sureshkumar, rapportiers of the different sessions presented brief reports of the deliberations of the sessions.

Dr.K.V.Mohanan, the Organizing Secretary of Gregor Mendel Foundation, Department of Botany, University of Calicut and the General Convener of Gregor Mendel Foundation Seminar, 2006 expressed his heartfelt thanks to the participants of the plenary session and to each and every one responsible for the successful conduct of the seminar including the guests, invitees, delegates, members of the organizing committee and all others who carried out their role excellently. He further thanked CSIR, New Delhi; UGC, New Delhi and KSCSTE, Thiruvananthapuram for providing financial support. He thanked all others who extended support by providing complements and other helps. The seminar came to a close by 3.30 pm with National Anthem.

Recent Trends in Crop Science Research

(Keynote address)

Pavithran K
Patron, Gregor Mendel Foundation, Department of Botany, University of Calicut, Kerala-673635.

Crop Science is a vast subject of great importance and concern to mankind. It could be discussed under various heads based on their significance in attaining sustainability of food production.

Crop improvement

Strategic genetic nobilization of crop plants is based on production of appropriate plat types suitable for different agro ecological situations. Present day breeding further aims at resistance against pests and diseases, abiotic stress tolerance, drought resistance, flood resistance, etc., and all these converging towards superior productivity with assured crop, soil and social security. Biotechnological manipulation of any crop genotype has to be done with caution and subtle understanding of the genome constitution and its scope for restructuring, thereby probing in to the possible alternative pathways of functional genomics.

Crop management

Systems of crop management strategies may help to maximize production potential of the crop species under varied agro climatic situations of cultivation. The incentive factor that becomes the third component of farmer satisfaction is about his control over the market for his produce. This is more a socio economic and political issue beyond the scope of a farmer. Keeping these facts in view, strategies are to be adopted in a three dimensional perspective targeting at the fundamental, applied or operational and market control oriented research.

Agricultural crop revolutions

Our better and bitter experiences of the past with 'Green Revolution' must be a pointer for the future, especially under the influence of new technologies ranging from the classical biotechnologies to the most recent functional genomics. Surveying the past streams of knowledge, one can find that the first green revolution was initiated with the rediscovery of Mendelism more than a century ago, though its incubation started more than one and a half century ago. This green revolution led to continuous and sustainable genetic improvement of many crop plants, though not so rapidly. Dr.E.H.Coe Jr. of Missouri University recently reminded the world that 'Mendelian Genetics is indeed alive and well in higher plants and we need only to continue forward with the challenging problems and rewarding possibilities'. Prof.Coe has also predicted that major advances in plant breeding methodology and theory will result exceeding the promise of *in vitro* technology for crop improvement. In this context you may remember that a simple alteration in the plant type concept could revolutionise crop production in the past. The adverse impacts were due to the prevailing socio political, agro industrial and commercial strategies imposed by the vested interests at transnational levels. An appropriate alternative strategy, scientifically implemented, could have rescued us from such serious consequences.

Genome and genomics

In the above context, Dr.Barbera Mc Clintock deserves mention. She in her very famous Nobel lecture has explained the significance of responses of the genome to challenges. Her experiments with transposable elements revealed how a genome may react

to conditions for which it is unprepared, but to which it responds in a totally unexpected manner. The mobility of these activated elements (transposons) allows them to enter different gene loci and to take over control of action of the gene wherever one may enter. Besides modifying the gene action, these elements can restructure the genome at various levels from small changes involving a few nucleotides to gross modifications involving large segments of chromosomes, probably even leading to speciation. Mc Clintock states 'We know about the components of genome that could be made available for such restructuring. We know nothing, however, about how the cell senses danger and instigates responses to that are often truly remarkable'. This is truly relevant even today.

The best reference genome

Let me explain the present situation of the rice genome. Ronald Philip and coworkers (2005) of Minnesota University found rice genome as the best reference genome for comparing with that of other cereals. The main reason is that rice has the lowest DNA content of the common cereals. It allows comparison in regard to genomic structure, gene constitution and gene expression. Sasaki and coworkers (2005) from Tsukuba, Japan report that a total 37,544 non transposable element related protein coding genes have been identified in rice. This will serve as a gold mine for genomics research in rice and other cereals. This has established rice as a model organism for both basic and applied research.

Further conceptual approaches

Qifa Zhang (2005) of China has proposed development of 'green super rice' with attributes like yield increase, quality improvement, multiple resistance to pests and diseases, high nutrient efficiency, drought resistance, reduced use of pesticides, chemical fertilizers and water. Dr.M.S.Swaminathan upholds the prospective proposition of ever green revolution or second green revolution mainly based on strategic management of farming systems. However, genetic manipulation of crop plants has vast scope in future. Santhoshlal and Pavithran (2005) have reported a new plant type in rice with axillary panicles (Vth Rice Genetic Symposium, IRRI, 2005). The mutant obtained from a local rice is rhizomatous and stoloniferous grassy type. Further studies on this mutant would give rise to a new plant type with axillary panicles or multipanicled tillers.

The foregoing prospects discussed on crop improvement and crop management may have some impacts in the minds of young scientists, students and research scholars and I hope you are likely to have a different approach to the research papers which are expected to be presented here. I do hope you will enjoy the seminar through excellent discussions in this context.

Gregor Mendel Foundation Proceedings 2006

Spices and the Economy of India

Tamil Selvan M
Directorate of Arecanut and Spices Development (Ministry of Agriculture, Government of India), Calicut, Kerala- 673005, India.

Introduction

Spices exports have registered substantial growth during the last fifteen years with an average annual growth rate of about 8%. It has increased from 109,636 tonnes valued US$ 135 million in 1990-91 to 335, 488 tonnes valued US$ 490.60 million in 2004-05.

During the year 2004-05, the spices export has touched an all-time high of 335,488 tonnes valued US $ 490.60 million (Rs. 2200 crores). Compared to last year's final figure of 254,382 tonnes valued Rs. 1911.60 crores (416.56 million US $), the spices export during 2004-05 has registerd an impressive growth of 32 in terms of quantity and 15% in rupee value. In dollar terms, the growth is 18%. During 2004-05, Chilli became the highest earner in the Spices Export Basket, contributing a lion's share of 41% in quantity and 23% in value, though chilli exports were threatened due to the Sudan controversy which erupted in 2003. The other major items, which contributed significantly in export earning, are Spice oils and oleoresins (21%), mint products (19%), turmeric (7%) and pepper (6%). These five spice items together account for about 76% of the total spices export earnings.

Our major constraints in the spices sector are weak marketing infrastructure, lack of export oriented production strategies. High cost of production owing to lower productivity, quality aspects like high pesticide residue and poor trading strategies have led to a decline in the India's share in the global spices trade.

Considering the potential of Indian spice sector, it is evident that there is lot to be exploited from this sector. India should take appropriate steps to overcome the problems so as to maintain the commendable position in global spices trade. Increasing productivity, quality thrust on value addition with brand building initiatives, expanding production base to non-conventional areas and exploring new markets with new uses and applications of spices are some of the major strategies we have to pursue.

Our motherland, is the centre of origin of a quite good number of spices and still the largest producer and consumer in the world. This important group among the horticultural crops is adapted to varied tropical and subtropical conditions; provide wide job opportunities in their production, processing, marketing and value addition. Spices and herbs are used for flavouring, seasoning and imparting aroma in foods, beverages, pharmaceuticals and in cosmetics. They have no nutritive value, but they stimulate the appetite, add zest to food, enhance the taste, and delight the gourmet.

Spices in trade, consists of different plant parts like fruits/seeds/berries, rhizomes, bulbs, barks, flower buds and leaves. Major fruit/seed/berry spices are back pepper, allspice (pimento), cardamoms, nutmeg, coriander, cumin, fennel, fenugreek, poppy etc.; rhizome spices are ginger and turmeric; bulb spices being garlic; bark spices are cinnamon, cassia, flower spices are clove and saffron and leaf spices like curry leaf, bay leaf, tejpat etc. and a group of herbal spices which are of importance with their high fragrance like marjoram, mint, rosemary, thyme etc.

The use of spices is increasing day by day in the modern cookery, various pharmaceuticals and cosmetic preparations. The concept of flavour in spices comprises a range of olfactory and tastes perceptions. The constituents responsible for these sensations are the volatile essential oil and oleoresins. They are of wide range of different natural organic chemicals and generally have little or no nutritional value. They are the basis of a

number of spice flavourings and seasonings employed in food manufacturing, where oils and oleoresins are preferred to the whole or ground spices for the preparation of certain products.

As food from Africa, Asia Pacific, Latin America, India and the Middle East have emerged into the main stream in western countries, spice and spice combinations are finding new opportunities leading to fusion of traditional flavour profile.

World trade in spices

Annual world trade of spices over the recent years (1998-2002) averaged 1.25 million tonnes, valued at US $ 2.59 billion. Imports, mostly into the developed world, have recorded strong growth averaging 6 per cent a year in terms of quality over the past five years. The main cause for the growth of consumption of spices has been the increasing trend towards eating ethnic or oriental foods in the developed countries and the increasing affluence of consumers in Asian and Latin American & Middle Eastern developing countries. In the developed countries, the growth in consumption of ethnic and oriental foods has been spurred by the larger numbers of people travelling abroad and replicating their favourite new dishes at home, the influence of their growing ethnic communities as well as a general trend to eat and greater variety of foods. The usage of spices and herbs by consumers is increasing also because they are appreciated as completely natural, rather than artificial, additives.

United States of America is the single largest importer of spices of in the world with 17% of the total volume 22% of the total value of spices imports. Other major importers are Japan, Singapore, Germany, Netherlands, Malaysia, United Kingdom, Saudi Arabia, Spain, Mexico, France, Pakistan, Canada and Hong Kong.

Major suppliers of spices in terms of value in the global market are China, Madagascar, Indonesia, India, Guatemala, Brazil, Vietnam and Sri Lanka.

India scenario of spices

Production zones

The wide range of agro-climatic zones prevalent in India makes it possible to produce a wide range of spices and herbs. There are 60 different spices crops grown in the country. Among them, atleast a few are grown in almost all the states. Among the spices grown in the country, more than 17 spices are important with regard to domestic requirement and export demand and they occupy more than 95 percent of the total area covered under spices. They are chilli, black pepper, ginger, turmeric, garlic, cardamoms, coriander, cumin, fennel, fenugreek, ajwain, poppy seeds, dill seed, clove, nutmeg, cinnamon, tamarind, allspice, curry leaf, saffron, celery, etc.

The moist, humid fertile mountains and valleys of Western Ghat Region from Kerala to Gujarat and North-Eastern Region grow most of the major spices like black pepper "the King of Spices", cardamom "the queen of spices", ginger, and tree spices. Though chilli is grown in almost all the states of India, important among them are Andhra Pradesh, Karnataka, Orissa, Maharashtra, West Bengal, Rajasthan, Tamil Nadu, etc. India has the monopoly in turmeric production centred in the states of Andhra Pradesh, Tamil Nadu, Orissa, Maharashtra and Karnataka.

Rajasthan, Gujarat, Madhya Pradesh, Bihar, Tamil Nadu, Karnataka, Haryana and Punjab account major share of seed spices. The Pampoor Valley of Jammu and Kashmir accounts for saffron production.

Area of Production

The spices production in India is in the order of 3.6 million tonnes from an area of about 2.60 million hectares. Chilli is the major spice crop occupying about 29 percent of

area under cultivation and contributing 6% of area, Seed spices 17% of production and 41% of area, Pepper 2% of production and 9% of area of the total spices in the country.

Table 1. Estimates on area and production of spices in India.

Crops	2002-03		2003-04	
	Area ('000 ha)	Production ('000 tonnes)	Area ('000 ha)	Production ('000 tonnes)
Pepper	224.40	71.70	233.75	73.42
Ginger	88.20	280.20	87.60	291.60
Chilli	827.40	894.60	758.60	1237.80
Turmeric	150.10	522.20	145.60	506.80
Cardamom	88.50	15.40	93.10	14.40
Garlic	111.50	457.00	137.60	683.40
Coriander	285.80	174.00	478.40	373.90
Cumin	521.25	134.76	521.25	134.76
Other seed spices[1]	93.28	101.44	93.28	101.44
Tree spices[2]	80.07	202.17	80.07	202.17
Other spices[3]	5.43	0.10	5.43	0.10
Total	2475.92	2853.57	2634.67	3619.78

1. Other seed spices include Fennel, Fenugreek, Ajwan, Dill Seed and Celery
2. Tree spices include Tamarind, Tejpat/Cinnamon, Nutmeg, Clove
3. Other spices include Saffron and Vanilla

Rajasthan occupies the major area under spices owing to seed spices cultivation in the country followed by Andhra Pradesh, Kerala, Karnataka, Madhya Pradesh and Gujarat. Andhra Pradesh, which is the foremost state producing chilli and turmeric in the country, ranks first in terms of production followed by Rajasthan, Madhya Pradesh, Tamil Nadu, Orissa, Karnataka, Kerala.

Export of spices

Spices trade in the country play a pivotal role in the national economy because of the huge internal consumption and substantial foreign exchange earnings. Indian spices accounts 5.18% of the total agricultural export in the country. More than 0.30 million (10-12% of the total spices production) tonnes of spices are exported annually to more than 150 countries around the world. According to Spices Board, India commands a formidable position in the World Spice Trade with 37% share in Volume and 23% in Value (2003-04).

United States of America (USA) is the major importer of Indian Spices. During 2002-03, 23% of the total spices export earnings came from USA with a quantity of 17 of the total Indian Spices exports. Other major spices export destinations of India are Sri Lanka, Bangladesh, UAE, Nepal, Malaysia, UK etc.

In India, Spices exports have been consistently moving up during the past years. Spices exports have registered substantial growth during the last fifteen years with an average annual growth rate of about 80%. It has increased from 109,696 tonnes valued US $ 135 million in 1990-91 to 335,488 tonnes valued US $ 490.60 million in 200405. However, during 2003-04, export declined to 246,566 MT valued US $ 415 million. The decline was mainly due to decline in export of Mint products and also because of low volume of pepper exports coupled with low unit value realization.

During the year 2004-05, the spices export has touched an all-time high of 335,488 tonnes valued US $ 490.60 million (Rs. 2200 crores). Compared to last year's final figure of 254,382 tonnes valued Rs. 1911.60 crores (416.56 million US $), the spices export during 2004-05 has registered an impressive growth of 32% in terms of quantity and 15% in rupee value. In dollar terms, the growth is 18%. The other significant achievement is that the spices export in 2004-05 has reached an all time high in both quantity and value recorded

so far. The highest ever spices exports previously recorded is 264,107 tonnes valued Rs. 2087 crores in 2002-03.

During 2004-05, Chilli became the highest earner in the Spices Export Basket, contributing a lion's share of 41% in quantity and 23% in value, though chilli exports were threatened due to the Sudan controversy which erupted in 2003. The other major items, which contributed significantly in export earnings, are Spice oils and oleoresins (21%), mint products (19%), turmeric (7%) and pepper (6%). These five spice items together account for about 76% of the total spices export earnings.

Compared to last year April-March 2003-04, the export of Chilli, ginger, turmeric, coriander, cumin, fennel, fenugreek and spice oils and oleoresins during April-March '2004-05 have shown significant increase both in terms of quantity and value. Spices such as cardamom (large) and vanilla, have shown increase in volume whereas mint products have shown increase in value. The spices that have shown decline in both quantity and value are pepper, cardamom (small), celery, garlic, nutmeg and mace, curry powder and other seed spices.

The export of chilli and chilli products during April-March '2004-05 is 138,000 tonnes valued Rs. 499.01 crores as against 86,575 tonnes valued Rs. 366.88 crores of last year, registering an increase of 59% in quantity and 36% in value. The export of chilli during the year 2004-05 is also an all time record achieved so far. This significant achievement is because of our price competitiveness in the international markets with increased production besides the control system introduced by the Spices Board to eliminate contamination/adulteration, resulting in substantial intake of Indian chilli by major buyers such as USA, Malaysia, Sri Lanka and Bangladesh.

During April-March, 2004-05, 13,000 tonnes of ginger valued Rs. 59.50 crores has been exported as against 4,696 tonnes valued Rs. 22.76 crores of last year, registering an increase of 177% in quantity and 161% in value. The export of spice oils and oleoresins during 2004-05 has been 5,600 tonnes valued at Rs. 463.75 crores as against 5133 tonnes valued at Rs. 379.92 crores during 2003-04. During the year, 43,000 tonnes of turmeric valued at Rs. 156.50 crores has been exported as against 37,044 tonnes valued at Rs. 131.12 crores of last year. Coriander exports stood at 33,750 tonnes valued at Rs. 82.66 crores during 2004-05 as against 21,018 tonnes valued at Rs. 72.01 crores during 2003-04. In the case of mint products, export during th year is 9,300 tonnes valued Rs. 407.77 crores as against 10,110 tonnes valued Rs. 394.36 crores in 2003-04. Pepper export suffered this year also and the export has come down to 14,150 tonnes valued Rs. 121.40 crores from 16,635 tonnes valued Rs. 142.77 crores in the international market against the competition from Vietnam with a production of more than 85,000 tonnes and negligible domestic demand. Similarly, the export of cardamom (small) during the current year has declined to 650 tonnes valued Rs. 23.90 crores from 757 tonnes valued Rs. 36.92 crores in 2003-04 because of sever competition from Guatemala.

The export of value-added spices during 2004-05 has also increased in value terms in line with the increase in the total export earnings of spices. The export earnings of value-added spices have increased to Rs. 1263.66 crores in 2004-05 from Rs. 1154.64 crores in 2003-04. The average unit value realization of value-added spices has increased by 10% during the current year when compared to last year. The export of value-added spices accounts for 23% in quantity and 57% in value in the total spices exports during 2004-05. The major items of value-added spices are oils and oleoresins of spices, mint products, curry powder/paste/condiments, and spice powders.

Though there is a decline in total pepper exports, the export of value-added products of pepper has increased by 11% in volume and 45 in value during 2004-05 over 2003-04. During 2004-05, 8269 tonnes of value-added pepper products worth Rs. 133.52 crores has been exported as against 7486 tonnes valued Rs. 129.00 crores in 2003-04. The major

items of value-added pepper products are pepper oleoresin, pepper oil, pepper powder, milled/crushed pepper and green pepper products.

The item-wise estimated exports of spices from India during 2004-05 compared with the figures of 2003-04 are given in Table 2.

Table 2. Estimated export of spices from India during 2004-05 compared with 2003-04

	2004-05		2003-04	
Item	Quantity (Tonnes)	Value (Rs. In Tonnes)	Quantity (Tonnes)	Value (Rs. In Lakhs)
Pepper	14150	12140.00	16635	14276.96
Cardamom (Small)	650	2389.00	757	3691.70
Cardamom (Large)	950	1134.00	924	1234.46
Chilli	138000	49900.50	86575	36687.81
Ginger Fresh/Dry	13000	5950.00	4696	2275.45
Turmeric	43000	15650.00	37.44	13111.73
Coriander	33750	8266.00	21018	7200.95
Cumin	13750	10190.00	7957	5883.79
Celery	4100	1300.00	4815	1520.33
Fennel	7100	2529.50	5007	2211.48
Fenugreek	13750	2660.50	6932	1554.56
Other Seeds (1)	11100	2613.50	14031	3396.85
Garlic	2250	560.50	3691	1422.64
Nutmeg & Mace	1250	2235.00	1420	2638.14
Vanilla	38	2759.00	27	3872.04
Other Spices (2)	16000	5960.00	19291	5948.75
Curry Powder/Paste/ Condiment	7750	6610.00	8318	6805.28
Mint Products (3)	9300	40776.50	10110	39435.51
Spice Oils & Oleoresins	5600	46375.00	5133	37991.76
Total	335488	220000.00	254382	191160.09

Constraints

India has a large domestic market and its spices production is unsteady and the quality varies from season to season, region to region. Our major constraints in the spices sector are weak marketing infrastructure, lack of export oriented production strategies. High cost of production owing to lower productivity, quality aspects like high pesticide residue and poor trading strategies have led to a decline in the India's share in the global spices trade.

India, in the past had almost monopolized the World Pepper Trade with over 80% market share. But the figure has dropped to less than 50% now, owing to increased competition from Vietnam, Brazil and Indonesia. Vietnam has emerged as the major producer during the period. The main problem faced by Indian pepper is the high cost of production due to the low yield when compared with other countries.

In the emerging scenario quality is becoming an important criterion. Besides physical characteristics, macro-cleanliness, microbial loads, mycotoxins and aflatoxin, tract metals and pesticide residues etc. are becoming barrier in trade. Therefore there is a need for developing mechanism to ensure the quality to match the international standards. Each importing country has its own quality standards like ASTA, ESA and Nippor creating difficulties for the exporting countries.

Potential

Considering the potential of Indian spice sector, it is evident that there is lot to be exploited from this sector. India is losing its export share, owing to high price and low productivity, poor quality. India should take appropriate steps to overcome the problems so as to maintain the commendable position in global spices trade. India can sustain increase spices exports by exploiting its potential exporting organic spices and value added products in which it has the capability.

With a growing consciousness for health there is an increasing demand for green spices. The world demand for organically produced foods are growing rapidly in developed countries like Europe, USA, Japan, Australia and Middle East. India with its intrinsic 'quality spices' grown under wide agro-ecological regions, can definitely utilize this expanding organic spice sector. With one of lowest per capita consumption of fertilizers and pesticides in the world, it is rather easy for Indian farmers to embrace organic spice farming to meet the growing global demand. The present trend shows that export of organic spices will get a significant boost in the coming years, as more farmers are switching over to organic methods.

Value added products are less susceptible to price competition compared with spices in the raw form. Export of value added spices products have achieved commendable position in the World market and more than 70% of the total world supply of spice oils and oleoresins is met by India. The increased export share of spice oils and oleoresins proves the distinct competitive advantage India has in this product category. Though the country has witnessed significant growth in export of value added products, efforts should be made in the direction of effectively and efficiently utilizing the existing capacity to stand out in the international market.

India should be able to offer the produce at the most competitive prices at the desired levels. Increasing productivity, quality thrust on value addition with brand building initiatives, expanding production base to non-conventional areas and exploring new markets with new uses and applications of spices are some of the major strategies we have to pursue. The market for spices is expanding, as there is growing awareness on health and nutritional aspects of spices. These functional attributes have to be authenticated by research and new product developed based on these characteristics. The market trend moving away from synthetic to natural colours will open up tremendous growth opportunities for spices like turmeric and chillies. Promoting new spices like vanilla and popularising its cultivation all over the country is another major growth area. Increasing demand from domestic market in India is another factor, which has to be taken into account. Export oriented production has to be expanded to ensure that sufficient exportable surplus is made available after containing domestic pull.

Coconut Breeding in India

Kumaran PM, Niral V, Samsudeen K, Augustine Jerald B and Arunachalam V
Central Plantation Crops Research Institute, Kasaragod, Kerala- 671124.

Abstract

Coconut, Cocos nucifera L., the tree of life, is an important plantation crop of India. It occupies an area of 1.93 million hectares, with an annual production of 12,147 million nuts. The average national productivity is 6285 nuts per hectare. Therefore, there is ample scope for enhancing the productivity. India was the first country in the world to exploit and document hybrid vigour in coconut in a cross between West Coast Tall and Chowghat Green Dwarf. This discovery was a significant landmark in the history of coconut improvement and paved the way for the successful exploitation of this phenomenon in many of the coconut growing countries. The country also has one of the largest collections of coconut germplasm. Coconut germplasm collection in India began in 1924 with the introduction of cultivars from Fiji, Indonesia, Malaysia, Philippines, Sri Lanka and Vietnam at the Central Coconut Research Station, Pilicode. Presently the coconut germplasm repository at CPCRI, Kasaragod, has 132 exotic and 222 indigenous types. The exotic collection from 27 countries comprises 106 talls, 24 dwarfs, one semi-tall and one hybrid. The indigenous collection comprises 199 talls and 23 dwarfs. Further, the country hosts the International Coconut Genebank for South Asia. Presently, CPCRI and 10 coordinating centres under the All India Coordinated Research Project on Palms and a few SAUs are involved in coconut research in the country. Coconut improvement in the country has been achieved through selection and hybridization. So far our country has released 12 high yielding hybrids, accounting for nearly one-third of the total hybrids released through out the world, and eight varieties.

Introduction

Coconut, *Cocos nucifera* L., the tree of life, is an important plantation crop of India. It occupies an area of 1.93 million hectares, with an annual production of 12,147 million nuts. The average national productivity is 6285 nuts per hectare. The fact that coconut belongs to a monotypic genus with no known wild/domesticated relatives limits the possibilities of tapping gene pools of related sources. Moreover, the available variability within coconut is being slowly depleted through large scale replanting programmes, thereby necessitating immediate collection and conservation of existing native populations.

The first organized coconut breeding was started in 1916 at the erstwhile Central Coconut Research Stations (CCRS) at Kasaragod and Nileshwar, now under Central Plantation Crops Research Institute (CPCRI) and Kerala Agricultural University, respectively. The Indian Central Coconut Committee set up in 1945 initiated intensive research activities from 1947. During the same period the Kayamkulam Research Station was established for controlling the coconut root (wilt) disease. From 1947 onwards, many research institutes/ stations were established for research on coconut. In Kerala, Kumarakam Coconut Research Station and Coconut Resaerch Station, Balaramapuram were established in early fifties. Regional Coconut Research Stations were established at Veppankulam in Tamil Nadu, Arsikere in Karnataka, Ambajipet in Andhra Pradesh and at Ratnagiri in Maharashtra in the fifties. Besides these, other research stations were started in West Bengal (Mondouri), Assam (Kahikuchi), Chattisgarh (Jagdalpur) and Orissa (Konark, presently shifted to Bhubaneshwar). These research stations cater to the needs of the different agroclimatic regions.

The Indian Council of Agricultural Research (ICAR) took over the CCRS at Kasaragod from Indian Central Coconut Committee subsequent to its dissolution in 1966. Seventies saw intense research on coconut by CPCRI and the coordinating centres under the All India Coordinated Research Project on Palms. These research institutes along with CPCRI have

released eight varieties and 12 hybrids, accounting for nearly one-third of the total hybrids released through out the world. Besides, India has the world's largest collection of coconut germplasm. Drought tolerant and disease resistant varieties have been identified and are being used to develop high yielding hybrids.

Crop Improvement

Crop improvement in coconut through selection and hybridization has been one of the major objectives of coconut research workers. However, genetic improvement in coconut is a tedious and long process because of the long gestation period of the crop, requirement of huge area for experimental planting, resources required for experimentation, low seed multiplication rate and lack of a reproducible clonal propagation technique. Despite these limitations, India was the first country in the world to exploit and document hybrid vigour in coconut in a cross between West Coast Tall x Chowghat Green Dwarf (Patel, 1937). This discovery was a significant landmark in the history of coconut improvement and paved the way for the successful exploitation of this phenomenon in many of the coconut growing countries. John and Narayana (1943) found that these hybrids (Tall x Dwarf) gave higher yields, combining the nut and copra characters of tall with early bearing of the dwarf parent. The evaluation of the 25 year old T x D planted at Nileswar has shown that they were early bearing, high yielding and attained steady bearing earlier than the tall parent with higher number of functional leaves (Bhaskaran and Leela, 1964).

Germplasm collection and evaluation

In India, germplasm collection began in 1924 with the introductions from Indonesia, Fiji, Malaysia, Philippines, Sri Lanka and Vietnam at the Central Coconut Research Station, Pilicode. Subsequently selfed and open pollinated progenies were planted at CPCRI (then CCRS), Kasaragod, in 1940s. The germplasm collection was further intensified in 1952 and in 1958 the first indigenous germplasm survey and collection was started. During 1981, with the financial assistance of IPGRI, 24 accessions were collected from the Pacific Ocean Countries of Solomon Islands, Fiji Islands, Tonga Islands, American Samoa, French Polynesia and Papua New Guinea. Subsequently, from 1997-2002, under ADB Phase I and ADB Phase II, 31 accessions were collected from the Indian Ocean Islands of Mauritius, Madagascar, Seychelles, Maldives and Comoros and Reunion and from the South Asian countries of Sri Lanka and Bangladesh. Indigenous germplasm collections were strengthened considerably during 1999-2005, with financial assistance from NATP under the mission mode project on Sustainable Management of Plant Biodiversity.

The coconut germplasm repository at CPCRI has 132 exotic and 222 indigenous types (Table 1). The exotic collections from 27 countries comprise 106 talls, 24 dwarfs, one semi-tall and one hybrid. The indigenous collection comprises 198 talls and 24 dwarfs.

Table 1. Coconut germplasm collection at CPCRI, Kasaragod

Region	Number of Accessions				
	Total	Tall	Semi-Tall	Dwarf	Hybrid
Indigenous	222	198	-	24	-
Kerala	30	28	-	2	-
Tamil Nadu	18	13	-	5	-
Karnataka	14	7	-	7	-
Andhra Pradesh	5	4	-	1	-
Goa	8	8	-	0	-
Gujarat	2	1	-	1	-
Orissa	14	14	-	0	-
West Bengal	12	11	-	1	-
Andaman and Nicobar Islands	69	67	-	2	-
Lakshadweep Islands	36	31	-	5	-
Maharashtra	6	6		0	
Assam	8	8		0	

Exotic	132	106	1	24	1
South East Asia	20	16	1	3	-
Central & South America, Atlantic Region	7	6	-	1	-
African Regions	7	4	-	2	1
Pacific Ocean Is.	45	39	-	6	-
Indian Ocean Is.	38	30	-	8	-
South Asia	15	11	-	4	-

In addition, sub samples of these collections are maintained at the centres under the All India Coordinated Project on Palms, namely, Aliyarnagar, and Veppankulam in Tamil Nadu, Ambajipet in Andhra Pradesh, Arsikere in Karnataka, Bhubaneshwar in Orissa, Jagadalpur in Madhya Pradesh, Kahikuchi in Assam, Mondouri in West Bengal and Ratnagiri in Maharashtra, for testing their regional adaptability. Germplasm characterization is undertaken using the IBPGR descriptor. CPCRI has so far prepared a descriptor for 74 different coconut accessions (Ratnambal *et al.*, 1995, 2000).

Comparative performance of cultivars

Screening of the available coconut cultivars for their performance under different ecological conditions is a promising method of obtaining ecotypes suited for the different regions of our country.

Evaluation of the germplasm in the country has resulted in the release of eight varieties through selection. The cultivar Lakshadweep Ordinary was released by CPCRI during 1985 under the name Chandra Kalpa, based on its evaluation at various Research Centres in Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Kerala. This variety yields 25% more nuts and 27.5% more copra than local tall. Banawali Green Round from Ratnagiri (Maharashtra) was released in 1987 by Konkan Krishi Vidya Peeth, Dapoli, for cultivation in Konkan Coast as Pratap. The exotic cultivar Philippines Ordinary was tested under three different agroclimatic regions and found superior with respect to the nut and copra yield. The mean nut yield is 110 nuts/palm/year while, copra yield is 20.8 kg/palm/year, an increase of 37.5% and 50.7%, respectively, over West Coast Tall. The increase with respect to nut and copra yield over the released variety Chandra Kalpa was 12.2% and 20.9%, respectively. This cultivar was released as Kera Chandra, a National variety, in 1995 during the XII Workshop of AICRPP. It was released for Andhra Pradesh as Double Century. VPM 3, a selection from Andaman Ordinary, was released by Tamil Nadu Agricultural University during 1994. This cultivar has greater tolerance to drought and produces 92 nuts/palm/year, with high copra weight (131g/nut) and 70% oil content. Assam Tall was released as Kamrupa by the Assam Agricultural University during the AICRPP Workshop in February 1999. This variety recommended for cultivation in Assam produces annually 106 nuts/palm with a copra content of 162g/nut, and 64% oil content. The Aliyarnagar 1 (ALR 1), a selection from the local Arasampatti Tall was released by Tamil Nadu Agricultural University during the AICRPP Workshop in 2001. The annual yield per palm is 126 nuts with copra content of 131g/nut. The oil content in the copra is 67%. Based on the organoleptic and quantitative analysis of tender nut water quality and in view of the superior quality of tender nut water, Chowghat Orange Dwarf (COD) was released by C.P.C.R.I during 1991 as a tender nut variety. The annual average nut yield is yield 63 nuts/palm. The performance of these cultivars is presented (Table 2).

Table 2. Performance of released cultivars

Cultivar	Nut yield (palm/year)	Copra yield (g/nut)	Oil content (%)	Year of release
Chandra Kalpa (Laccadive Ordinary)	98	195	70	1985
Pratap (Banawali Green Round)	151	160	59	1987
Philippines Ordinary (Kera Chandra) (Double Century)	110	198	66	1995
VPM 3 (Andaman Ordinary)	92	131	70	1994

Kamrup (Assam Tall)	101	162	64	1999
Aliyarnagar 1 (Arasampatti Tall)	126	131	67	2001
Chowghat Orange Dwarf	63	-	-	1991
Local Tall (West Coast Tall)	80	180	68	

Hybridization and exploitation of hybrid vigour

In India, Patel initiated the hybridization programme with three intravarietal and one intervarietal cross at the Coconut Research Station, Nileshwar, in the year 1932, and was the first to report hybrid vigour in coconut (Patel, 1937). Ever since the report of heterosis in Tall x Dwarf hybrids, more than 100 hybrid combinations have been evaluated at CPCRI, SAUs and the various coordinating centres. In the immediate years following the discovery of hybrid vigour in coconut, the emphasis was on the production of Tall x Dwarf hybrids. These hybrids were precocious and high yielding compared to local cultivar West Coast Tall under irrigation and good management. Subsequently, Tall x Tall hybrids are also being evaluated. So far 12 hybrids have been released for cultivation, the yield potential of which varies from 95-156 nuts/palm/year and 13.2- 25.20 kg copra/ palm/year (Table 3).

The hybrids, COD x WCT, LCT x COD and WCT x COD were released by CPCRI in various years starting from 1985 under the names Chandra Sankara, Chandra Laksha and Kera Sankara, respectively. Subsequently, the Kerala Agricultural University (KAU) and Tamil Nadu Agricultural University (TNAU) evaluated and released eight more hybrids viz., Laksha Ganga (LCT x GBGD), Ananda Ganga (ADOT x GBGD), Kera Ganga (WCT x GBGD), Kera Sree (WCT x MYD), Kera Sowbhagya (WCT x SSAT) from KAU and VHC-1 (ECT x MGD), VHC-2 (ECT x MYD) and VHC-3 (ECT x MOD) from TNAU. The Andhra Pradesh Agricultural University has released a hybrid, Godavari Ganga (ECT x GBGD).

Table 3. Performance of released hybrids

Hybrids	Annual nut yield/ palm	Annual copra yield		Oil content (%)	Year of release
		g/nut	kg/ palm		
Chandra Sankara (COD x WCT)	116	215	25	68	1984
Kera Sankara (WCT x COD)	108	187	21	68	1991
Chandra Laksha (LCT x COD)	109	195	21	69	1984
Laksha Ganga (LCT x GBGD)	108	195	21	70	1987
Ananda Ganga (ADOT x GBGD)	95	216	21	68	1988
Kera Ganga (WCT xGBGD)	100	201	21	69	1988
Kera Sree (WCT x MYD)	112	216	24	66	1992
Kera Sowbagya (WCT x SSAT)	130	195	25	65	1994
VHC-1 (ECT x MGD)	98	135	13	70	1982
VHC-2 (ECT x MYD)	107	152	16	69	1988
VHC-3 (ECT x MOD)	156	161.5	25	64.5	2000
Godhavari Ganga (ECT x GBGD)	140	150	21	68	1992

Breeding for specific traits

Coconut breeding programmes, in addition to yield improvement, are also aimed at development of drought tolerant and pest resistant varieties. Further, qualitative parameters of tender nut water are studied for selection of the best tender nut varieties.

Drought tolerance:

In India, coconut is grown under different agro climatic conditions and in varying soil types. However, the coconut palm requires an average monthly rainfall of 150 mm for ideal palm growth and good nut yield and any erratic/low rainfall would adversely affect the yield of the palm and the adverse effects, unlike annuals, would persist for the subsequent 2-3 years. In India, peninsular India, which accounts for 90% of the coconut area in the country, is subjected to frequent drought spells. Therefore, to enhance coconut production there is a need to evolve drought tolerant hybrids/varieties.

Studies at CPCRI revealed the possibility of identifying drought tolerant cultivars on the basis of accumulation of epicuticular wax on the leaf surface, low stomatal frequency and leaf water potential, the activity of enzymes like glutamate oxaloacetate transaminase (GOT) and acid phosphatase (Rajagopal *et al.,* 1991; Chempakam *et al.,* 1993). Among the 23 cultivars and hybrids screened for drought tolerance, WCT x WCT, Federated Malay States (FMST), Java Giant, Andaman Giant and LCT x COD were identified as drought tolerant (Rajagopal *et al.,* 1988a). Subsequently, Rajagopal *et al.* (1988b) proved the superiority of the hybrids LCT x COD and LCT x GBGD for drought tolerance. The reduction in yield during drought affected years for LCT x COD and LCT x GBGD was 15 % and 44 %, respectively, compared to 75 % in drought affected COD x WCT hybrid. The identified drought tolerant lines are currently being utilized in the breeding programme at CPCRI, Kasaragod, to evolve high yielding, drought tolerant hybrids.

An attempt was made to understand the genetics of physiological traits responsible for drought tolerance. Coconut cultivars with desirable characters were selected and crossed in a 2x4 line x tester mating design to study combining ability and gene action. Physiological parameters like transpiration rate, leaf water potential, lipid peroxidation and net photosynthesis rate were recorded in seedlings under non stress, water stress and recovery conditions. Analysis of variance for combining ability revealed significant differences among parents and hybrids for most characters. Seedling transpiration rate showed higher sca effects than gca effects due to predominance of non-additive gene action indicating heterosis for this character. Leaf water potential showed a similar trend. Net photosynthesis rate under stress was additive with good combining ability, while non stress and recovery were governed by non-additive gene action that could be exploited for heterosis. In case of lipid peroxidation, gene action was unpredictable in non stress with additive gene action being nil with low dominance. In case of stress and recovery, non-additive gene action was observed. The nature of gene action governing drought sensitive traits can be exploited for selecting proper breeding strategies (Rajagopal *et al.*, unpublished).

Insect resistance:

Eriophyid mite has become a major problem in the major coconut growing regions of the country and has drastically reduced the nut yield as well as quality of nuts. As it is extremely difficult to completely eradicate the pest through conventional plant protection measures, the necessity of having mite resistant varieties assumes greater importance. Therefore the germplasm is being screened to identify mite resistant genotypes.

In addition, the germplasm is screened for resistance/tolerance to other coconut pests like Rhinoceros beetle, leaf eating caterpillar and root knot nematode. Preliminary screening of cultivars/hybrids against leaf eating caterpillar, *Nephantis serinopa* Meyr., (Kapadia, 1981) and rhinoceros beetle, *Oryctes rhinoceros* Linn., (Sumangala Nambiar, 1991) indicated variations in susceptibility among cultivars, though no resistant variety was observed.

Disease resistance:

Coconut is affected by a number of diseases, of which the major ones are *Phytophthora* bud rot, stem bleeding, Thanjavur wilt/Ganoderma disease and root (wilt) disease. Among these, root (wilt) disease is the most serious and in the absence of effective control measures against the disease, evolving resistant cultivars is of utmost importance.

The root (wilt) disease of coconut is the most serious problem causing an annual loss of 968 million nuts in eight districts of Kerala (Anon., 1985). The disease is characterized by flaccidity, yellowing and necrosis of leaflets (Menon and Pandalai, 1958) followed by a progressive decline in the yield. Systematic studies carried out at CPCRI have shown the presence of mycoplasma like organisms (MLOs) in the sieve tube of roots, tender stem, inflorescence and petiole of diseased palms (Solomon *et al.,* 1983).

Studies on identifying coconut genotypes resistant/tolerant to root (wilt) disease were initiated by Varghese in 1934. Since 1961, the CPCRI Regional Research Station, Kayangulam, has made considerable efforts to screen the available cultivars for tolerance to root (wilt) disease. However, screening of the available coconut germplasm and hybrids has not yielded any resistant type. Only the cultivar Chowghat Green Dwarf has been found to have field tolerance of over 90% to the disease (Anon., 1972). However surveys of the 'hotspot' areas have identified a few high yielding disease free palms in the midst of heavily diseased palms. Iyer *et al.* (1979) located 162 high yielding apparently healthy WCT palms and 19 CGD palms, which were then subjected to serological and physiological tests. Based on these tests 26 WCT and 19 CGD palms were identified as phenotypically and serologically disease free and crossed. These seedlings were planted and evaluated for the disease incidence. The CGD x WCT seedlings planted at CPCRI, Research Station, Kayamkulam showed lesser disease incidence indicating their tolerance to the disease. The relative tolerance/resistance to the disease of these D x T hybrids, coupled with their high yield potential has highlighted the scope of developing this hybrid as a suitable planting material for the disease endemic areas.

Presently, phenotypically, serologically and physiologically disease-free WCT, CGD and COD palms identified in the disease tracts are being used for controlled pollination to produce quality seedlings with tolerance to the disease. In addition, mixed pollen from all selected healthy palms in the diseased tract is also used for pollination to develop a gene pool of field tolerant palms.

Further, the available coconut germplasm is being evaluated to identify genotypes resistant to bud rot caused by *Phytophthora palmivora*, stem bleeding disease and Thanjavur wilt/Ganoderma disease for utilization in the future breeding programme.

Tender nut water quality:

The consumption of tender nuts as a natural, nourishing and refreshing drink is becoming increasingly popular in our country. At CPCRI, Kasaragod, a study was initiated to identify cultivars suitable for tender nut purpose. A total of 46 cultivars were screened through organoleptic tests and biochemical evaluation. The cultivar Chowghat Orange Dwarf (COD) had the maximum amount of total sugars (7g/100ml) and reducing sugars (4.7g/100 ml) coupled with optimum sodium and potassium content (Dhamodaran *et al.,* 1991). On the basis of the superior nut water quality, the Xth Workshop of the All India Coordinated Project on Palms (September, 1991) recommended the release of COD as a tender nut variety in Kerala (Anon, 1991). Presently, various Dwarfs, Talls and Hybrids are being evaluatedfor their tender nut water quality. In addition, Dwarf x Dwarf hybrids are under evaluation for their suitability for tender nut purpose.

Conclusion

From the foregoing discussion, it is clear that the research on genetics and breeding of coconut is going on for the past eight to nine decades and the major research is being carried out in India. However, in the post WTO regime, with the removal of trade barriers,

the prices for copra and coconut fruit will be subjected to a lot of fluctuation and therefore, diversification and value addition are essential to rescue coconut farmers from poverty. The concerted efforts in coconut improvement have also resulted in the assemblage of a vast germplasm in the National Field Genebank maintained at the Central Plantation Crops Research Institute, Kasaragod. Sub samples of the coconut germplasm are also maintained in the AICRPP centres. Further it is our endeavour to preserve the coconut germplasm available in all the coconut growing countries of the world. In this direction the Regional Coconut Gene Bank for South Asia has been established at the CPCRI, Research Centre, Kidu. This would prevent coconut varieties from becoming extinct and also serve as a nodal point for international collaborative research in the future.

Identification of varieties suitable for specific industrial needs is a dire necessity. Variant forms such as Makapuno/Thayiru Thengai, Aromatic types, Soft endosperm types etc., need to be identified, conserved and utilized in breeding programme. Similarly, identification of accessions with long, stiff fibers would be suitable for the coir industry. Coconut oil is increasingly used as lubricating oil. Screening germplasm for composition of oil and fatty acid profiles is necessary to identify suitable genotype for promotion of this product. Further, genotypes suitable for production of coconut chips, inflorescence sap, and preparation of shell products need to be identified. The Central Plantation Crops Research Institute, Kasaragod is undertaking research on some of these aspects.

References

Anonymous 1972. Annual report 1971-72. Central Plantation Crops Research Institute, Kasaragod, India.

Anonymous 1985. Proceedings of 7th Workshop of All India Coordinated Coconut, Arecanut, Spices and Cashew Improvement Projects. Trivandrum, 6-9 November, 1985. Central Plantation Crops Research Institute, Kasaragod, India.

Anonymous 1991. Proceedings of Tenth All India Coordinated Project on Palms, Kasaragod, 26-28 Sep. 1991. Central Plantation Crops Research Institute, Kasaragod, India.

Bhaskaran UP and Leela K 1964. Hybrid coconut Tall x Dwarf – A comparative study with parental types. *Agric. Res. J. Kerala* 1(2): 67-84.

Chempakam B, Kasturi Bai KV and Rajagopal V 1993. Lipid peroxidation in relation to drought tolerance in coconut (*Cocos nucifera* L.) *Plant Physiol. Biochem.* 20: 5-10.

Dhamodaran S, Ratnambal MJ, Chempakam B, Pillai RV and Viraktamath BC 1991. Evaluation of coconut cultivars for tendernut water. In: *Proc. International Symp. in Cocon. Res. & Dev. II Abst.* No.34:26-29th November, 1991. CPCRI, Kasaragod, India.

Iyer RD, Bhaskhar Rao EVV and Govindankutty M P 1979. Super yielders in coconut. *Indian Fmg.*: 28: 3-5.

John CM and Narayana GV 1943. Note on the improvement of coconut by cross breeding. *Madras Agric. J.* 31: 75-77.

Kapadia MN 1981. Susceptibility of three cultivated coconut varieties to *Nephantis serinopa* Meyr. *Indian Coconut J.*: 12(9): 4-5

Marechal H 1928. Observations and preliminary experiments on the coconuts with a view to developing improved seednuts. *Fiji Agric. J.*: 1: 16-45.

Nampoothiri KUK, Niral V and Parthasarathy VAP 1997. Genetics and improvement of Coconut in India. *Botanica* 47: 69-80.

Parthasarathy VAP, Ratnambal MJ and Kumaran PM 1998. Coconut Varietal Improvement - A Reflection of 50 years of Research. *Indian Coconut J.:* 29: 68-73.

Patel JS 1937. Coconut Breeding. *Proc. Assoc. Biol.* 5: 1-16.

Rajagopal V, Kasturi Bai KV and Shivashankar S. 1988 a. Physiological and biochemical criteria for breeding for drought tolerance in coconut. Proc. National Symposium on coconut Breeding and Management (Eds.: Sailas, EG, Aravindakshan M, Jose AI). Kerala Agricultural University, Vellanikkara, Thrissur, India, 23-26th November, 1998: 136-143.

Rajagopal V, Kasturi Bai KV, Voleti SR and Shivasankar S 1988b. Leaf water potential as an Index of drought tolerance in coconut. *Plant Physiol and Biochem.* 15: 80-86.

Rajagopal V, Voleti SR, Kasturi Bai KV and Shivashankar S 1991. Physiological and biochemical criteria for breeding for drought tolerance in coconut. In: *Coconut Breeding and Management* (Eds.: Silas EG, Aravindakshan M and Jose AI). Kerala Agricultural University, Vellanikkara, Thrissur, India: 136-143.

Ratnambal MJ, Nair MK, Muralidharan K, Kumaran PM, Bhaskara Rao EVV and Pillai RV 1995. Coconut Descriptors. CPCRI, Kasaragod, Kerala, India.

Ratnamabal MJ, Niral V, Krishnan M and Ravi Kumar N 2000. Coconut Descriptors, Part II, CD-ROM, CPCRI., Kasaragod, Kerala, India.

Solomon JJ, Govindan Kutty MP and Ninhans F 1983. Association of Mycoplasma like organisms with the coconut root (wilt) disease in India *Z. Pfikrankh pflschutz*. 90: 295-297.

Sumangala Nambiar S 1991. Susceptibility of hybrid coconut varieties to *Oryctes rhinoceros* Linn. (Scarabaeidae) under rainfed conditions at Pilicode. In: *Coconut Breeding and Management* (Eds.: Silas EG, Aravindakshan M and Jose AI) Kerala Agricultural University, Vellanikkara, Trichur, India: 158-160.

Varghese MK 1934. Diseases of the coconut palm. Govt. Press, Trivandrum, India.

Coffee breeding in India- A review

Reddy AGS
Former Deputy Director (Research), Coffee Board, Bangalore, India.
(No. 1081, Jnana Jyothi, 4th Main 10th cross, Vijayanagar 1st Stage, Mysore, Karnataka-570017. E-mail: agsreddy@yahoo.co.in)

Introduction

Coffee containing the alkaloid caffeine is a stimulating beverage derived from the endosperm of the coffee bean (Ukers, 1948, Subramanyan *et al.*, 1954). World production of coffee is placed around 109 to 112 million 60 kg bags *i.e.*, around 68,00,000 metric tonnes. Coffee is known as brown gold and is next to petroleum in foreign exchange earnings. Coffee is mainly produced by developing countries and consumed by developed countries. India's share in world production and exports is 4.45% and 4.68% respectively (Anonymous 2005).

The genus *Coffea* belongs to the family Rubiaceae and includes around 100 species (Van der Vossen, 2000) and they are without exception indigenous to the forests of tropical Africa. They are all diploid (2n=22) species save *C. arabica* which is an allotetraploid (2n=44) along with its hundreds of varieties and cultivars (Sybenga 1960). Commercial production of coffee in the world relies on one more species i.e., *C. canephora* a diploid (2n=22) besides *C. arabica*. Kaffa province in Ethiopia is the centre of origin of *C. arabica* while Central Africa is the centre of origin of *C. canephora*. A few diploid species viz., *C. bengalensis, C. travancorensis* and *C. wightiana* with nil or traces of caffeine content and indigenous to India are also considered important in breeding low or caffeine free coffees (Narasimhaswamy and Vishveshwara, 1963). Now these three species have been included in a separate genus, *Psilanthus* (Kumar and Sreenath, 2004).

I. Coffee in India

Coffea arabica was introduced to India during 1600 A.D. in Bababudan Hills in Chikmagalur district, Karnataka, from Mecca by a muslim piligrim. *C. canephora* sub var. 'robusta' was introduced to India during 1906 in Wayanad (Kerala). Although both are cultivated they are contrasting in many respects (Table 1). *C. arabica* is a high land species, an allotetaploid and self fertile while *canephora*, a low land species, a diploid and self sterile species. Since reproductive systems of both the species are different, breeding strategies adopted are also different (Table 2). Further, many beneficial natural mutants were spotted in arabica (Table 3) and they could be exploited in India and elsewhere (Sybenga, 1960). Although a few mutants were found in *C. canephora* (Table 4) they could not be much harnessed because of cross fertile nature of the species (Sybenga, 1960).

Since its introduction to India, coffee has grown leaps and bounds, both in area and production with various selections of arabica and robusta developed at Central Coffee Research Institute, Balehonnur, Karnataka, in the last 8 decades (Anonymous 2005). Traditional coffee areas confine to Karnataka, Kerala and Tamilnadu in which Karnataka is foremost in area and production followed by Kerala. The latter is purely a robusta growing state with a very small area of arabica. Non traditional coffee growing areas include Andhra Pradesh, Orissa and north eastern states of India. India is producing 48% of *arabica* and 52% of *robusta* coffee.

Dreaded leaf rust: Coffee industry in the then Ceylon, presently Srilanka was wiped out because of dreaded coffee leaf disease caused by *Hemeleia vastatrix B & Br*, around 1856. Similar situation was also encountered in coffee plantations in India during 1860s. But enterprising planters stalled the disaster by introducing exotic coffee material and by spotting/ developing natural hybrids in India (Narasimhaswamy 1952). Arabica varieties

such as Mocha, Amarillo (golden drop) Bourbon and Maragogipe from Brazil and Blue Mountain from Jamaica were introduced to India, were grown in small scale and found to be susceptible to leaf disease. Maragogipe and Amarillo are coffees of Brazil, the former noted for its robust habit and larger beans, and the latter for its orange red berries. Maragogipe is an uncertain bearer and gives small yields. Blue Mountain is from Jamaica and its bluish heavy beans excelling others in quality are highly priced (Narayanan 1954). All these varieties of *arabica* have failed being susceptible to the leaf rust. So also several exotic diploid (2n=22) species viz., *C. excelsa, C. liberica, C. quillo, C. uganda*, *C canephora, C. congensis, and C. stenophylla* introduced and tried but were discarded as they did not prove successful though resistant to leaf disease (Narasimhaswamy 1952, 1961).

Natural/ developed hybrids: Enterprising planters found natural hybrids between rust susceptible *liberica* and *arabica* parents with remarkable resistance in the rust-ridden arabica fields. Although these hybrids not economic from the production point of view, planters raised subsequent generations of the hybrid. Mr. Hamilton, a Mysore planter is recorded to have multiplied plants upto fifth generation and handed them out to planting in an experimental plot at Ben Hope estate, Nilgiris in 1912. (Anstead, 1913: c.f. Thomas, 1954). They were called Hamilton's hybrids. Mr. Jackson, a Coorg planter, claimed to have produced from selection through several generations, a coffee known as Jackson's hybrid, which though enjoyed popularity for a while, was soon attacked by leaf disease. A resistant hybrid originated at Kewisare estate in Jawa was cultivated in a fairly large scale in some estates of South India and later found it to be non-performer economically (Thomas 1954). Other spontaneous hybrids of *arabica* x *liberica* parentage i.e., Brown's hybrids, Elliot's, and Broke Mockett's hybrids met the same fate ultimately. They approximated to *arabica* in their vegetative characters but the vast majority was completely futile on account of severe abnormalities of their flowers and fruits (Van der Vossen and Walyaro, 1981.)

Varieties developed by planters: Since the time leaf disease began to assume importance, coffee planters in India have been on the look out for disease resistant plants. Some of the old *arabica* varieties developed by them are as follows:

Chicks: This is an earliest variety tried in India, the name having been derived from Chickmagalur in the then Mysore state. It yields large round beans, known for their liquoring quality and commanding a premium in foreign markets. Due to its high susceptibility to leaf rust and white stem borer its cultivation declined.

Coorgs: This is another old variety of *C. arabica*, a selection from 'chicks' represented the greater part of coffee grown then in South India. Their beans are greenish or bluish in colour, larger and flatter than those of 'chicks'. The Coorg variety also vanished due to high susceptibility to leaf disease.

Kent's: Kent's *arabica* produced by a planter L. P. Kent around 1918 and is reported to be a selection from 'Coorgs' variety enjoyed popularity in 1940s and 1950s. It was found to be more resistant to leaf disease than 'Coorgs' and 'Chicks'. Kent's variety produced rectangular and bolder beans greyish in colour. It had vigour and was a good yielder too. Finally Kent's variety also fell for *Hemeleia vastatrix*, the leaf disease causing organism (Narayanan 1954).

II. Coffee research in India

In 1892 United Planters Association of South India (UPASI) was formed to tackle various problems of the plantation industry including coffee. Under Madras Agricultural Department during 1918 a Coffee Experimental Station was established at Sidapur, Coorg with 20 acres of land headed by Mr. Anstead as planting expert and Deputy Director of the station. Reports of work done on coffee hybridization, in Ben Hope Estate in Nilgiris, and work done at Sidapur Coffee Experimental Station on fertilization , crop botany, coffee pests and manure application from 1913 to 1925 were brought out (Iyengar 1954). The station was later closed by the Madras Government and passed into the hands of UPASI.

Coffee breeding at Coffee Research Station, Balehonnur: With the establishment of Mysore Coffee Experimental Station, at Balehonnur, Chikmagalur, Karnataka under the stewardship of Dr. Leslie C. Coleman, the then Director of Agriculture, Mysore in 1925 systematic breeding of coffee was initiated from 1926 onwards. The main objective of breeding was to evolve strains of *arabica* resistant to coffee leaf rust caused by *Hemeleia vastatrix* with vigorous growth and fairly average to high yielding habit. The plant breeding work proceeded on two lines viz., pureline or selection work and cross breeding. The initial years of this programme entailed an extensive survey of the coffee areas in S. India for plants of rust tolerant nature, with high vigour and good crop. More than 260 plants from different zones were selected, they were selfed and hybridized. More than 25000 seedlings were raised in observational plots at the station. From these, 80 mother plants of desirable types were selected (Narayanan 1954). From among them again three best mother plants viz., S. 26, S. 31 and S. 44 were chosen for further propagation. Thus S. 288 a Selection released in 1938 to 16 estates for trial after selfing of S. 26, a highly resistant plant from Doobla estate in Chikmagalur (Thomas, 1960). The programme was however complicated at early stage by the identification of multiplicity of races of coffee leaf rust (Wilson Mayne 1932). Wilson Mayne a coffee Scientific Officer deputed by UPASI to Coffee Experimental Station, Balehonnur, pioneered in coffee research and established the existence of four physiologic races, (I, II, III, IV) of coffee leaf rust attacking the coffee which formed the sheet anchor for further studies on susceptibility and resistance of coffee varieties. According to his studies, the variety 'Coorg' was found susceptible to all the four races, while Kent's was resistant to his race I and race III but susceptible to race II and race IV (Ramanathan *et al.,* 1951).

Coffee improvement and germplasm: Coffee improvement means gradual and easy access to intra and interspecific genetic variation. All the species of the genus *Coffea* are of monophyletic origin and there is general absence of strong interspecific crossing barriers. They provide avenues for harnessing the genetic variation of several other species for the purpose of introgressing agronomically and biochemically interesting characters into the two species viz., *C. arabica* and C. *canephora* of commercial value (Van der Vossen 2000). Coffee germplasm in this direction is of paramount importance so as to explore it systematically.

A gene bank was established at Coffee Research Station, Balehonnur, i.e., present Central Coffee Research Institute (CCRI), during 1954 with the mutual cooperation of other world coffee institutes. This is in addition to the collections made during the coffee expeditions organized by FAO. As of now the gene bank comprises of 416 genotypes of *arabica*, 18 types of *robusta* and 18 diploid species of C*offea* inclusive of four indigenous species belonging to related genera. Confined and close studies on these genotypes with special regard to coffee leaf rust (CLR), high yields and quality and suitability to different agroclimatic conditions have given rise to 12 genotypes in *arabica* and 3 in *robusta*. Many more are on the anvil. Right now more than 80% of coffee area in India is occupied by varieties bred and released by CCRI (Sreenivasan, 1986).

Reproductive systems: The basic number of chromosomes for the genus *Coffea* is 11 (Sybenga 1960). *C. arabica*, the only known tetraploid is self-fertile, however 7-9% natural crossing also observed (Krug and Carvalho, 1951). Thus there is heterosis giving scope for selection. Flowers are frequented by many insects and wasps for their colour and fragrance that pollination is doubtlessly both entomophilous and anemophilous (Gorden Wrigley 1988). While *C. canephora* the diploid is markedly self-incompatible, 0.5% of self-pollination is said to have been recorded in Jawa (Thomas 1940a).

Coffee being a long life cycle plant, breeding for an improved variety involves much labour, space and time. Finding of elite mother trees require replicated progeny tests in many locations recorded over a number of years. Unless precocious, normally coffee comes to bearing 4-5 years after the cross is made and trees take ten years and more to reach their maximum production level and during each of these years yields vary considerably.

Therefore six consecutive years' yields have been considered necessary as a sound basis for selection. Van der Vossen and Walyaro (1981), considered that selection based on the first 2-3 years yield records along with measurement of stem girth and percent of bearing primaries was sufficient for merited selection towards higher productivity of *arabica* coffee. In India Srinivasan (2002) has reported four year yields sufficient for efficient selection in both *arabica* and *robusta*. Selection for disease resistance in new crosses is made at very early stage in nursery by screening method or by leaf disc method (Ramachandran *et al.,* 1979).

First selections: Selection S.288 (Sln.2) had resistance to common races I and II of leaf rust but susceptible to race III and IV and gave satisfactory yields upto 1000 kgs per acre, at the same time had high bean abnormalities resulting in elephant beans and triage. Some other selections then released were S. 333 (S.31 x S.22), S.645 (second generation of the progeny of S.333). But they did not impress the planting community for long (Thomas, 1960). Hence breeding continued to arrive at noted cultivar S. 795 (Sln.3) from the utmost cross, S.288 x Kent's *arabica*. S. 795 was a breakthrough in coffee breeding and was released in 1945-46. Both S. 288 and S. 795 were widely planted in South India at one time representing a third of arabica coffee. S. 795 is popular for its high yielding habit from its early years of cropping. During the test period at the Coffee Research Station, Balehonnur the selection averaged the yield from 5-8 cwts per acre (250-400 kgs per acre) and tended to uniform bearing over years. Since the parents S. 288 and Kent's are susceptible to race IV now called race VIII, S. 795 and its progeny also inherited susceptibility to this race. Resistance to race IV in this selection had to be looked for from elsewhere (Narasimhaswamy, 1961).

However it is pertinent to see that S. 795 and one of its parents S. 288 is special showing resistance to races I and II of leaf rust while all other world collections of coffee are prone to these two races. It is thereby judged that they carry the SH3 gene for resistance to rust derived from liberica, the diploid species. This gene is not to be seen in any other world arabica types (Srinivasan 2002). S. 795 continued to show some bean abnormalities leading to triage. Added to this in about 25% of the plants of S. 795 race I and II were found to occur subsequently. Hence further selection through selfing culminated in S. 1934 i.e., F4 of S. 288 X Kent's having as low as 5-6% bean abnormalities and higher (90+) percentage of plants showing resistance to races I and II (Ramachandran and Srinivasan, 1979). Nevertheless this cultivar had reduced vigour and yield in comparison with S. 795. Still S. 1934 is popular in non traditional areas like Andhra Pradesh, Orissa and some parts of north eastern states.

Ethiopian arabicas: The arabica collections established in Coffee Research Station, Balehonnur, apart from others included Ethiopian arabicas like Agaro, Cioccie, Kaffa, Geisha and Dhilla and Alghe screened for rust resistance in India as well as at Coffee Rust Research Centre, Portugal exhibited resistance to not less than 10-11 races (Narasimhaswamy *et al.,* 1961). As rust races VIII, XII, XIV and XVI are capable of attacking S. 795 its further improvement was paramount by crossing it's selfbred progeny, S. 1934, with Ethiopian varieties, Cioccie and Agaro. The hybrids released in 1964 as selection 3.4 indicating cross between Sln. 3 and Sln. 4. The selections S.2492 to S. 2498 were more vigorous than parents, spreading, branches semi - erect, fruits generally oblong with beaked disk as in Cioccie and Agaro. Leaf rust can be severe in certain plants. Resistance was seen to races VIII, XII and XXIII but susceptible to XIV and XVI. The pureline selections among the Ethiopian arabicas introduced into the CCRI in 1953-54 also released for cultivation around that time under Selection 4 carrying cultivars Agaro, Cioccie and Tafarikela. In field performance they are area- specific. For example Agaro and Cioccie did well in coffee tracts of Andhra Pradesh (Dharmaraj and Gopal 1986). Their yield is not satisfactory in other areas (Sreenivasan 1968). Arabicas under Selection 4 were semi-erect as well as drooping as in Tafarikela. Tip leaves are green in Cioccie but dark bronze (copper coloured) in Tafarikela. They are resistant to CLR races VII, VIII and XII but susceptible to many other races. They are also early ripeners.

Interspecific hybrids: While looking for other sources of resistance to leaf rust a natural hybrid between robusta x arabica called Devamachy from Kodagu in Karnataka was located along with the diploid species *C. canephora* (Vishveshwara 1975). Utilizing Devamachy as female parent a cross was effected in 1940s with tetraploid arabica from Rume Sudan which has field resistance to leaf rust and found that F2 lines S. 2267, 2268 and S. 2269 were promising. Further progenies of F3 were evolved from S. 2268 and S. 2269 lines which were leaf rust tolerant. They are performing well in Tamil Nadu and Andhra Pradesh and are drought tolerent. Devamachy crosses as referred above have been released as Sln. 5 by CCRI. Under Sln. 5B, the hybrid S. 2931 between arabica cultivar S. 333 x Devamachy was released and found to be doing extremely well in Tamil Nadu and is tolerant to coffee berry disease also (*Colletotrichum coffeanum*), though not present in India so far.

On the same lines during 1940s robusta x arabica Kent's hybrids were evolved at CCRI. The F1 thus derived was triploid (2n=33) which was in turn backcrossed to *arabica* parent. Three back-crosses were effected totally. In the third generation of the second back-cross promising progenies obtained were released as Sln. 6. They are like *arabica* in morphology with bold fruits and beans and in cup quality too with more vigour in plant growth (Visveshwara, 1975). Sln.6 released to Swarnagiri estate in Coorg has been performing extremely well by being rust tolerant as well as in good yields and in cup. Hence this strain is being multiplied and distributed commercially.

Dwarf series: So far the selections dealt with as above, are tall types which require wider spacing. Dwarf types therefore have been developed by CCRI so as to enhance the productivity per unit area through high density of plant population. San Ramon hybrid also is one such type. San Ramon is described as a double dominant dwarf mutant in *arabica.* Good yielder but highly susceptible to CLR. In order to exploit its dwarf and profuse fruiting habit hybrids between this and S.795 in 1958 as also Cioccie, Agaro, Dhilla and Alghe of Ethiopian origin in 1965 were established (Visweshwara and Chinnappa 1969). They are categorized under Sln. 7 series. The seedlings from these hybrids in nursery were found to segregate into dwarfs and normal in a proportion of 70:30 (Visveshwara and Suryakantha Raju 1973). The dwarfs can be made out in the nursery when the seedlings are either in the 6^{th} or 7^{th} pair of leaves. As in the original San Ramon and in its selfbred line, dwarfs in crosses also showed gradation in height and spread of the bush, but crosses with Ethiopian varieties such as Cioccie, Agaro, Dhilla and Alghe, showed increase in overall size of dwarfs. Leaf retention and tight clusters of fruits of San Ramon are reflected in the hybrids also. Extent and size of flat beans have perceptibly been improved with Ethiopian *arabica* crosses. Incidence of rust under field conditions although varied, resistance to all the known races except XIV and XVI was seen in double crosses upto 50% of plants and full resistance to all known races in the triple cross hybrids with HDT. The Sln 7.3 as this is called is a late ripener and the yield in shaded condition is low. There are merits and demerits as well of these hybrids of Sln. 7 to Sln 7.3. An important factor is that yield potential can be increased by increasing the density of the population of plants in a unit area or by interplanting in vacant spaces (Vishveshwara 1974). Some of these hybrids with San Ramon have not been very promising in all areas of Karnataka but are doing well in higher reaches as in Honnamatti estate in B. R. Hills. As they have better tolerance to drought they are performing well in pockets of Tamil Nadu and coffee regions of Andhra Pradesh (Dharmaraj and Gopal 1986).

Hybrid from Timor Island (HDT): Coffee breeders in India hit a fortune in HDT i.e., Hibrido-de-Timor, when its original collection was landed in CCRI in 1961 from Portugal. The variety has high vertical resistance to leaf rust i.e. high resistance to many races, only 5% of plants showing severe rust (Srinivasan 2002). It is a spontaneous hybrid between *robusta* and *arabica* (Visveshwara and Govindarajan 1970). This hybrid regularly is being employed in breeding programmes. Pureline selections of HDT raised from original material received have been released from CCRI as Sln. 8 (S.2769 and S. 2770). It is a moderate yielder with 800 to 1000kgs per hectare with relatively low drought tolerance. In one estate in Idukki district of Kerala 80 acres planted to HDT yielding one tonne per hectare from 13

to 18 year old plants. It has been shown in studies elsewhere that besides high resistance to leaf rust, HDT also possesses high degree of resistance to coffee berry disease which is any way not prevalent in India so far therefore holds out great promise. The cup quality is near to *arabica*.

HDT crosses: High vertical resistance of HDT to as many races has favoured coffee breeders to effect crosses with a number of exotic accessions like *arabica* var. Tafarikela, Geisha, S 12 Kaffa, Agaro, Cioccie and Bourbon. Of all the crosses, the cross with Tafarikela proved best by being very uniform, vigorous and resistant to leaf rust. The seed from this cross was released as Sln.9 and is popular in most of the coffee areas. The selection is gradually replacing old S. 795. One of the parents of this strain, Tafarikela has good drought tolerance as well as field tolerance to coffee leaf rust despite the fact that it shows symptoms of susceptibility to common races I and II in laboratory conditions. The plant produces longish smaller beans. The cup quality has been appreciated very much by International Cup Testing Panel as in India International Coffee Festival, 2001.

Caturra crosses/double hybrids: Caturra is a single dominant medium type dwarf with longer internodes than San Ramon. Caturra as such is highly susceptible to CLR but a high yielder. In order to incorporate resistance to rust and exploit the medium bush habit and high yields into the progeny, double cross hybrids were evolved at CRRC Portugal. Under exchange programme seeds of double cross hybrid between Caturra x S. 795 and Caturra x Cioccie were received from CRRC, Portugal in 1975. They were tested in 30 different estates in India and later released as Sln. 10. Extensive planting of the variety has not been taken up except in one estate in Pulney Hills, in Tamil Nadu where about 100 acres planted to this cultivar. Leaf rust is seen but because of bold bean size i.e., upto 70% A grade, the planter is exporting the produce (Srinivasan, 2002). The selection can very well be maintained under good care with good yields and the productivity per unit area enhanced because of the medium plant. Thus there is choice for the grower to select the cultivars according to size of the plot he owns, with this variety.

Catimor/Cauvery: Since Caturra has high yield potential and HDT has vertical resistance to CLR, CRRC Portugal under the international programme of *arabica* breeding for rust resistance and high yield, effected crosses between Caturra and HDT and later selection of plants for 'A' type of rust reaction (resistant to all known races) from F1 to F5 generations was practiced at different world centres viz., CRRC, Portugal, IIAA, Angola, UFV, Brazil, and EPAMIG, Brazil. CCRI received seeds collected from two F4 generation progenies and four F5 generation progenies in 1981 from which F5 and F6 generation plants were raised respectively. Plants were precocious and by second year flowering and fruiting was seen as compared to normal three years in *arabica*. Internationally known as 'Catimor', it was released in India during 1985 under the name 'Cauvery' (Sreenivasan and Ramaiah 1985). Although the plants exhibited resistance to rust in the initial years of its release, started showing build up of rust from 1992 onwards. Spore samples sent to CRRC, Portugal indicated evolution of 6 new rust races capable of attacking many plants of 'Cauvery'. The variety failed in nonconventional *arabica* coffee areas like Wayanad, Kerala. Under intensive cultivation practices and at higher altitudes of 1000 to 1300 m MSL the variety showed less build up of rust and satisfactory yields ranging from 1500 to 1800 kgs per hectare were obtained (Srinivasan 2002).

Tetraploid from Diploid F1: In order to establish genetic distance and crossability, a series of crosses were effected at CCRI in 1950s utilizing several diploid species (2n=22), which are exclusively cross-fertile. The species in different combinations used were *C. liberica, C. excelsa, C. canephora, C. racemosa* and *C. eugenioides*. Like the parents the F1 of various combinations were diploid and highly sterile. But the tetraploid interspecific hybrid between two diploid species viz., *C. liberica x C. eugenioides* released under Sln. 11 by CCRI is worth consideration (Narasimhaswamy and Vishveshwara 1961). The hybrid originated as somatic mutation due to natural doubling of chromosomes from diploidy (2n=22) to tetraploidy (2n=44) in an orthotropic shoot of diploid F1 of the said cross. The tetraploid continued to

maintain the same ploidy status through seed propagation also. The hybrid resembles *arabica* and possesses tolerance to leaf rust as well as drought. With tetraploidy the hybrid has regained self-fertility status to an extent of 39.6% (Reddy *et al.*, 1981; 1984). It is found to perform well in marginal areas in Chickmagalur and in Andhra Pradesh as drought tolerant material. It has small fruits and seeds with low percentage of 'A' grade beans. Cup quality is near *arabica* (Dharmaraj and Gopal 1986). This hybrid has been taken as a good genetic source for future breeding programmes at CCRI and a few lines are promising (Table. 12).

The yield pattern, resistance level to CLR and bean and cup quality of *arabica* selections detailed in foregoing paras have been given in the tables, (5, 6, 7 and 8) Earlier when the older susceptible coffee selections were ruling, growers used to contain the leaf rust attacks by resorting to Bordeaux mixture to as many as five applications which cannot be afforded by all as it is high on the exchequer (Narayanan 1954). Today with the release of so many *arabica* selections, resistant to leaf rust (Table 5), Bordeaux application is not mandatory considering leaf rust alone. However, there are other diseases like, black rot to prevent which Bordeaux mixture needs to be applied once or twice. Coffee cultivation with new resistant lines has turned out to be economical provided the coffee prices are remunerative. They are also drought tolerant (Table 6). Sln 7.3 (San Ramon x HDT) is the most tolerant to drought followed by Sln 9, Sln 10 and Sln 4 (Tafarikela) in that order (Venkataraman, 1985).

In some of the *arabica* selections heterosis for yield has been recorded to be high to very high (Table 7 and 9). For example HDT x S12 Kaffa where 218.2% of heterosis was seen. This was followed by Sln 9 where 217.4% was seen, and S.795 showed 100.4% of heterosis for yield (Srinivasan *et al.*, 1979, Sreenivasan and Santha Ram, 1993).

From the point of view of bean grades all the selections showed 60 to 70% of 'A' grade beans save Sln 5A (Devamachy x S. 881), Sln 4 Tafarikela and Sln 11 (amphidiploid *C. liberica x C. eugenioides*) where the 'A' grade percent ranged between 10-42% (Table 8). Some of these lines have been improved upon for bold fruits and beans by taking up further crosses like HDT crosses with Sln 4 and Sln 9, Sln 11 x HDT ie. S.4595 (Table 12). All these *arabica* selections have been studied for their adaptation to different agroclimatic zones as well as their economic performance and accordingly they are being recommended by the Coffee Board (Srinivasan 1984, 1985, Sreenivasan 1985, Jamsheed Ahmad 1985, Dharmaraj 1985, Gopal 1985, Jamsheed Ahmed et al., 1995, Reddy, 1985). Further more there are as many as 15 to 17 new genotypes of both *arabica* and *robusta* under evaluation by CCRI (Ganesh *et al.,* 2002; Srinivasan *et al.,* 2002).

Robusta coffee breeding: Self sterility in *C. canephora* causes poorer production from plots of coffee trees all belonging to the same clone. It is an allogamous diploid species consisting of polymorphic population, strongly heterozygous. Therefore breeding has to orient to create synthetic varieties (seed propagated) or clones. The strict self incompatibility of *robusta* directly influences the genetic structures of progenies and controls breeding. The coefficient of variation for yield is found to be in the order of 30-60% due to allogamous nature. It is observed that clonal progeny trials had lower levels of variation for individual yield than seedling progeny. Hence crossing between specific mother plants based on the mean performance is suggested (Srinivasan and Visveshwara, 1980; Sreenivasan and Visveshwara, 1981). Even for morphological characters like stem girth, bush spread, number and girth of primaries, and leaf size of clonal progenies showed higher mean and lower coefficient of variation as compared to seedling progenies to the uniformity of the clones. Heritability estimates were also higher in clones (Subbulakshmi *et a*l., 1981).

Breeding procedure in *Coffea canephora:* The breeding procedure adopted in CCRI includes, selection of mother plants, clonal progeny vs. seedling progeny trials and selection, diallelic crosses for general combining ability (gca) and specific combining ability (sca) to arrive at synthetic hybrid and F1 hybrids respectively and interspecific hybridization and

back-crossing to arrive at synthetic hybrids for compact bush, low caffeine, early ripening and drought tolerance.

Breeding programme: *Robusta* variety as the name indicates is robust in size and tolerant to diseases like coffee leaf rust and pests like white stem borer and nematodes. Nevertheless cup quality and size of the bean is inferior to that of *arabica*. Breeding is aimed at improving cup quality in *robusta* coffee while also improving the size of bean and in identifying medium/dwarf types and in inducing drought tolerance so as to facilitate easy cultivation and enhance the density of the population per unit urea and in turn production and productivity. Thus three *robusta* selections (Sln 1R, 2R and Sln, 3R) have been evolved (Reddy and Srinivasan 2005).

Selections evolved at CCRI: Plants of *robusta* cultivated in South India prior to 1950, were either from Indonesia or from Srilanka. After the establishment of CCRI in 1925, individual plant selections were made from a few indigenous collections under accession numbers S.267 to S.278 during 1931. After having evaluated their performance for 15 years cultivar S. 274 *robusta* was identified as high yielding in a progeny row trial and redesignated as Sln 1R. Seventeen individual plant selections named as BR 1 to BR 17 also from among S. 267 to S. 278 were selected during 1950s and clonal and seedling progeny trials were established. BR 9, BR 10, and BR 11 (descendants of S. 274) were found to be promising in both the trials. Seed mixture of these was released as Selection 2R. Both these selections are known for bolder bean size and soft neutral cup quality.

In order to bring in compact bush nature and to improve the bean size and cup quality of *robusta* further, interspecific hybridization was carried out between *Coffea congensis* and *C. canephora* and the F1 hybrid evolved in 1942. Backcross was done with *C. canephora.* Seed from open pollinated progeny of backcross was released to private estates in 1970 and named as Sln 3R (S.2570). Since it is an interspecific hybrid there used to be a lot of segregation in C x R plants into robusta types, intermediate types and congensis types. Uniformity of the bush is very much essential. Therefore further improvement of C x R plants was taken up by inbreeding through sibmating of elite plants of C x R from the original progeny. Thus 14 progenies were established (Sureshkumar *et al.*, 1999). Taking bush habit, fruit size and cup quality further selection was made from the 14 progenies and three elite sibs namely Sib 4, Sib 5 and Sib 7 were selected (Table 11). These are known for higher average yield, bolder bean size and superior cup quality. It is interesting to note that further inbreeding resulted in genetic decline for morphological characters and yield. (Nikhila *et al.*, 2002).

Study of selection 2R: Studies in Sln, 2R have further indicated that the BR series viz., BR 4, 5, 9, 10 and 11 are potentially capable of fruit set ranging from 47.10 to 56.11% under open pollination in un-irrigated conditions (Sreenivasan and Visveshwara, 1981). The percent set is superior to the results reported elsewhere. Their best performance has further been confirmed based on the hybrids generated between these clones viz., BR 9 x 11, BR 4 x 9 and BR10 x 5 which showed least C.V. for yield over a period of eleven years. Hence all the clones are best planted in a plolyclonal design (Reddy and Srinivasan 2005). The other choice for better fruit set and yield from the BR clones has been the contiguous row planting of these clones. The diallelic crosses among BR clones have indicated BR 9, BR 10 and BR 5 as best general combiners. Biclonal gardens of BR 9 and BR 11, BR 10 and BR 5, BR 10 and BR 11 or BR 9 and BR 10 can be encouraged to exploit specific combining ability of these lines. However level of CV in some of these crosses has been much higher. Average of initial four yields in the clonal robustas was the indicator for selection of the best performer among BR clones (Srinivasan 2002). The same conclusions are reported for *C.arabica* from Brazil (Carvalho *et al.,* 1969). Diallelic crosses involving five high yielding superior clones viz., BR 4, 5, 9, 10 and 11 of *C. canephora* were studied at CCRI. Higher magnitude of both positive and negative heterosis was observed for growth characters. Per cent of bearing primaries, bearing nodes and berries per node were found to be the main attributes for total yield (Dharmaraj and Sreenivasan 1992).

Even among robustas there are new genotypes under evaluation especially among exotic robutas (Table 10) and among C x R, three sibs under evaluation (Table 11). The genotypes of robustas as well as C x R, showed better per cent of 'A' grade beans with cup quality of FAQ to GOOD in C x R sibs as compared to exhisting robusta selections. Among the exotic robusta accessions, S.1932 (Madagascar) and S.1979 (Uganda) were found to be more drought tolerant than S.274 and other selections of robusta (Saraswathy *et al.*, 1992).

Propagation in coffee:

Propagation of coffee both in self fertile *C. arabica* as well as self sterile *C. canephora* is mainly by seed as it is far more economical and facile. Seed plots/nurseries are maintained in Coffee Research Station at Balehonnur and its sub stations as well as Technology Evaluation Centers. Private seed plots or nurseries are certified since a few years. In the seed blocks thus selected, all off type plants and unhealthy plants are marked and converted into desirable types by top-working. For nematode infested areas *robusta*/*arabica* grafted seedlings are supplied by Coffee Board. In robustas for selection 2R, mixed seeds of BR 9, 10, and 11 are supplied to ensure good fruit set.

Clones: Clonal propagation or top working methods are practiced in hybrid multiplication either in *arabica* or *robusta*. Importance of clonal propagation in cross-fertile *canephora* is realized to reduce variation for yield hence clonal planting is being recommended. Therefore compatible clones in robutas are identified and biclonal and polyclonal planting being encouraged in BR series and C x R (Reddy and Srinivasan 2005).

III. Biotechnological approaches towards coffee improvement

From the foregoing it is seen that, coffee is an important beverage crop world over and without exception in India too (Purseglove, 1968). In India, *arabica* and *robusta* are equally distributed in cultivation. Production of *robusta* is slightly more as compared to *arabica* (Anonymous, 2005). From the foregoing it is also assessed that commercial production of coffee in India has many fold increased. This manifold increase in production of coffee is undoubtedly attributed to conventional plant breeding methods adopted in the last 75 to 80 years in Central Coffee Research Institute (CCRI). India is now producing an average 3 lakh tonnes of coffee which is export oriented. New varieties both of *arabica* and *robusta* have been developed and released with high yield and resistance to leaf rust, drought and nematodes. Varieties of compact stature also have been developed so as to accommodate more number of plants per unit area and thus enhance production. Some of the breeding methods adopted successfully in India after introduction have already been discussed in the earlier paragraphs. However, methods such as back crossing and hybridization are specially applied to transfer specific traits such as compact bush stature, disease resistance, etc. to *C. arabica* from other cultivars or related species.

Coffee as is well known is a long life cycled plant, has long gestation period before cropping. It requires space and time to evolve new varieties. It is estimated that, at least 24 years of continuous breeding is necessary to arrive at a single variety. Thus conventional methods are supposed to have limitations in quick arrival of varieties. Further, to bring out interspecific hybrids the two species involved are diploid and tetraploids with different chromosome numbers. The reproductive systems are different of the diploid species and tetraploid *arabica*. The diploid *robusta* is self incompatible while tetraploid *arabica* is self fertile. Breeding methods are different. Although, both the species are different in ploidy as well as reproductive systems, propagation in India is still by seed, for, it is more economical. Clonal propagation at least in cross fertile *robusta* is possible but has many hassles. It is here the micropropagaion that has to come in handy to enable mass multiplication. Some inroads have been made in coffee biotechnology research in India in the past two decades. It is focussed on micropropagation, anther culture, embryo rescue and culture, endosperm culture, genetic transformation, marker aided selection (MAS) and *in vitro* preservation (Naidu and Sreenath, 1999). These approaches have potential application in genetic improvement of coffee. In order to genetically modify coffee plants in their improvement,

interest has been bestowed on *in vitro* cell culture and recombinant DNA techniques (Sreenath and Naidu, 1997).

Micropropagation: Central Coffee Research Institute has carried out tissue culture studies to develop protocols on large scale multiplication of elite coffee plants and their improvement. Raghuramulu *et al.*, (1989) reported plant regeneration through somatic embryogenesis using stem orthotropic explants. Harinath Babu *et al.* (1993), achieved high frequency somatic embryogenesis and plant regeneration through leaf tissues in two cultivars of coffee. Muniswamy and Sreenath (1995) have reported the same in the diploid *C. canephora*. Thus plant regeneration through somatic embryogenesis in more than 20 Indian accessions of *arabica* and *robusta* has been achieved. Genotypic differences were noticed in regard to callus induction, somatic embryogenesis and plant regeneration in *arabica* accessions (Naidu *et al.,* 1999a).

Encapsulation techniques for producing synthetic seeds have been standardized (Muniswamy and Sreenath, 1995a). Hardening protocols for regenerated plantlets are also made available for small and medium scale production (Muniswamy *et a*l., 1994). Trial plots of tissue cultured plants are established in different agro-climatic zones (Sreenath, 1998). Further studies on field evaluation of micropropagated plants versus seedlings of selected genotypes of improved selections viz., Cauvery, Sln.9 and C x R cultivars are in progress. Other tissues like apical buds and nodal explants also have been used (Samuel Ganesh and Sreenath, 1997) in achieving plant regeneration albeit some more refinement of technology is needed. Interestingly, integument tissues of C x R cultivar gave raise to plant regeneration which is a first report in coffee and record in any plant species (Sreenath *et al.,* 1995).

Genetic improvement: With one and only aim of using the tissue culture technology towards genetic improvement of coffee, investigations were done on embryo culture, anther culture and endosperm culture. Embryo culture is one of the important ways of dealing with genetic variability in coffee. Cultures of immature embryos of *C.arabica* and *C. canephora* has been raised (Sreenath *et al,* 1989) and plant regeneration from three interspecific crosses in coffee through immature embryo culture has been reported (Sreenath *et al.*, 1992). Somatic embryogenesis and plant regeneration achieved from cultured immature zygotic embryos of *C. canephora* is reported (Muniswamy *et al.,* 1993). Plant *in vitro* development is achieved from the zygotic embryos of a wild indigenous *Psilanthus bengalensis which* is having only traces of caffeine (Muniswamy and Sreenath, 1998).

Plants regenerated from three interspecific crosses through embryo rescue method were established in the field for evaluation (Sreenath *et al.*, 1992). Raghuramulu (1989a) first reported the development of callus from anthers of *C. arabica*. Subsequently, successful induction of somatic embryogenesis and plant regeneration was achieved from cultured anthers of diploid cultivar of C x R (Muniswamy and Sreenath, 2000). Endosperm tissues also have been utilized in establishing callus cultures (Raghuramulu, 1989a). Subsequently, somatic embryogenesis and plant regeneration was obtained from endosperm tissues of *C. arabica* cultivar S.2803 (Muniswamy and Sreenath, 2001). Besides the above, protocols have been optimized for isolation of protoplasts (Mamatha and Sreenath, 1998).

***In vitro* preservation:** Coffee seeds are recalcitrant to traditional seed storage methods. It is reported that, coffee seeds are short lived and they show responses intermediary to true chilling- desiccation tolerance and sensitivity (Ellis *et al.*, 1990). They also reported that, seeds of coffee can be stored at 15^0 C for 1-2 years when the moisture content is around 10%. As such there is no adequate procedure for long term storage of coffee seeds. In that case any development of storage methods for zygotic and somatic embryos is a welcome feature for the conservation of genetic resources of the genus *Coffea*. In India, i*n vitro* preservation of zygotic embryos under slow growth conditions are studied (Naidu and Sreenath, 1999) and also successful cryopreservation of zygotic and somatic embryos for two years was achieved in three species viz., *C. arabica, C. canephora* and *P. bengalensis*

followed by plant regeneration from these cryopreserved embryos (Krishna and Sreenath, 2000).

Molecular marker studies: Identification of molecular markers will be useful not only for gene tagging but also to study the genetic diversity in coffee (Sreenath and Muniswamy, 2000). Nuclear variability analyzed by RAPD markers and organelle variability examined by using primers specific to chloroplast and mitochondrial genes. RAPD markers showed wide genetic variation in *Coffea* species (Orozco-Castillo *et al.*, 1994). RAPD markers and isozyme analysis are also used to analyze phylogenetic relationship in the genus *Coffea* (Maekawa *et al.,* 1995). In India, molecular marker studies have been initiated in the analysis of the species of the genus *Coffea and Psilanthus* by RAPD and ISSR markers and polymorphism between the species has been detected (Sreenath et *al.*, 1999; Santa Ram and Sreenath.1999; Kumar and Sreenath 2004). Finger printing of interspecific hybrids through RAPD and SSR markers and *robusta* germplasm by ISSR markers has been attempted. F1 hybrids of S.2800 and their parents (Hybrid from Timor Island (HDT) and *arabica* var. Bourbon) were analyzed by RAPD and ISSR markers. Out of 15 RAPD markers tested, 3 primers detected polymorphism and among the 15 SSR markers tested, only one detected polymorphism between the parents. In addition, 44 genotypes including station bred arabica selections, some well-known *arabica* genotypes with few rust differentials and 3 diploid species were finger printed using 32 SSR, 40 RAPD, 21 ISSR primers which detected considerable polymorphism among the genotypes. AFLP analysis of introgression in coffee cultivars derived from a natural interspecific hybrid is reported by Prakash *et al.* (2002). The ultimate objective of all these studies is to develop specific markers which can be used for marker aided selection (MAS) in coffee breeding.

Genetic transformation studies in coffee: Genetic engineering opens new vistas to the genetic improvement of coffee. Possible applications are the use of genes for pest resistance, disease resistance, gene manipulation towards caffeine free beans and use of male sterility for production of F1 hybrids (Sreenath and Muniswamy, 2000). Potential use of *Agrobacterium* strains to transform coffee has already been highlighted (Ocampo *et al.*, 1991). In India, genetic transformation studies have been carried out using *Agrobacterium*, towards leaf rust resistance. Thus putatively transformed plants of *C. canephora* and C. *arabica* were regenerated using *Agrobacterium tumefaciens* mediated T-DNA delivery. The technique will be useful for future studies.

Since early reports on coffee tissue culture in the world and India there has been a steady progress in coffee biotechnology research and it is quite interesting and encouraging. There is plenty of choice for coffee improvement through biotechnology. It could be through micropropagation, embryo culture, or any other tissues of coffee that have given encouraging results. Somatic embryos can be induced from a variety of tissues. In vitro germplasm preservation, molecular markers and genetic engineering are other weapons available and already in practice in other coffee growing countries that could be safely used for coffee improvement in India. For early results micropropagation should receive the highest priority and attention.

Challenges to Coffee plant improvement

There are certain challenges to be addressed in the coffee plant improvement (Van der Vossen 2000). Number one in the direction is surpluses in the world market causing low prices and low returns to the producers. To cope up with this although in a small way one has to look for speciality and/ or organically grown coffees but it is a small but expanding market with premium prices.

What is specially required is the adaptation of agronomic and socio-economic aspects of coffee production, processing and marketing. Production costs can be lowered, high bean and cup quality can be brought about and organically grown coffee is encouraged. It is here plant breeding both of conventional means as well as by molecular methods can contribute to high yields per unit area, easier harvesting by evolving compact bush, by

increasing host resistance to pests and diseases, evolving superior robustas (as in C x Rs), caffeine free coffees and by adaptation to agro-forestry systems where minimal/ nil use of pesticides is practiced.

Table1. Characteristics of *C.arabica* and *C. canephora*

Factors	*C. arabica*	*C. robusta*
Suitable elevation	1000-1500m MSL	500-1000m MSL
Ploidy	Allotetraploid and self fertile (2n = 44)	Diploid and self sterile (2n=22)
Fruit maturity	8-9 months	10-11 months
Leaf rust	Susceptible	Tolerant
Pest	Susceptible to white stem borer and nematode	Tolerant
Quality	Superior	Inferior
Caffeine	Low (around 1 to 1.5%)	High (around 2 to 2.5%)

Table 2. Breeding methods adopted in coffee in India

Arabica coffee (Self pollinating)		**Selections evolved**
1	Pureline selection	Agaro, Cioccie, Tafarikela, HDT Sln. 4
2	Pedigree selection	S.795, S.1934, Sln. 3
3	Intraspecific hybridization	Sln. 3.4, Sln. 7 series, Sln. 8, Sln.9, Sln. 10
4	Interspecific hybridization and Back cross breeding	Sln. 5 (Devamachy x *arabica*) Sln.6 (*robusta* x *arabica*) Sln.11 (*liberica* x *eugenoides*)
Robusta coffee (cross pollinating)		**Selections evolved**
1	Mass selection	S.274
2	Family and clonal selection	BR series (BR 8 9 10 11)
3	Interspecific hybridization and Back cross breeding	Sln.3R (*congensis* x *robusta*)

Table 3. Mutants of *C. arabica* which are of practical significance to breeding

Name of Mutant	Gene symbol	Dominance relation	Original population	Main characteristics
Caturra	Ct	Almost complete dominance	Bourbon, Brazil (1935)	Compact growth due to short internodes, small beans
Purpurascens	Pr	Recessive	Brazil (1935)	Purple leaves
Cera	Ce	Recessive	Brazil (1935)	Yellow endosperm
Erecta	Er	Incomplete dominance	Brazil, Indonesia, Kenya	Orthotropic branch growth
Maragogipe	Mg	Complete dominance (Typica)	Brazil (1870)	Large leaves and seeds, long internodes, low yield
Laurina	Lr	Recessive	Bourbon Brazil	Narrow leaves low yield, seed narrow and pointed at one end, low caffeine content (0.62%)
Mokka	Mo, lr	Double recessive	Very old introduction from Yemen	Very small leaves and beans, very compact growth
Sao bernado	SB	Almost complete dominance	Typical Brazil	Short internodes and compact growth like caturra
San Ramon	SR	Complete dominance	Typica Brazil	Extremely short internodes
Genes for rust resistance	SH1 to SH9	Dominance	Different cultivar	Governs resistance to rust

Table 4. Mutants in *C. canephora*

Name of mutant	Gene symbol
Faclata	Fs^c
Nana	na^c
Angustifolla	Ag^c
Xanthocarpa	xc^c
Developed sepals	sd^c
Purpurascens	Pr^c
Cera	ce^c

Table 5. Arabica selections and their field reaction to leaf rust

Sln. 3 (S. 795)	75% plants tolerant to Race 1
Sln. 4 Ethiopian Arabicas (Tafarikela/Cioccie/Agaro)	Susceptible but less build up seen in the field
Sln. 3.4 (S. 1934 x Cloccie/Agaro)	Moderately tolerant
Sln. 5° (Devamachy x S.881)	Highly tolerant
Sln. 5B (S. 333 x Devamachy)	60% plants tolerant to rust
Sln. 6 (S. 274 x Kents with back cross)	80% plants tolerant to rust
Sln. 7.3 (San Ramon Hybrid)	80% plants tolerant to rust
Sln. 8(Hibrido-de-Timor)	80% plants tolerant to rust
Sln. 9 (HDT x Tafarikela)	80% plants tolerant Moderately tolerant to rust
Sln. 10 (Caturra x Cioccie) x (Caturra x S. 795)	Moderately tolerant
Sln. 11 (amphiploid of *C. liberica* x *C. eugenioides*)	Highly tolerant
Sln. 12 Cauvery (Caturra x HDT)	Initially tolerant, now shows 60-70% susceptibility due to new races

Table. 6. Arabica selections- yield, grade and cup quality

Selections	A-Grade	Yield potential clean coffee kg/ha	Cup quality
Sln.3 (S.795)	60-65	1000-2000	FAQ – Good
Sln.4Ethiopian			
Arabicas : Tafarikela	42	1000	--
Cioccie/Agaro	65	1000	Good
Sln. 3.4. (S. 1934 x Cioccie/Agaro	65	1000	FAQ
Sln. 5A (Devamachy x S. 881)	30	1000	FAQ- Good
Sln. 5B (S. 333 x Devamachy)	60	1500	-,,-
Sln. 6 (S. 274 x Kents with back cross)	65	1200	-,,-
Sln. 7.3 (San Ramon Hybrid)	62	1200	-,,-
Sln. 8 (Hibrido - de- Timor)	60	1200	-,,-
Sln. 9 (HDT x Tafarikela)	65	1200	-,,-
Sln. 10 (Caturra x Cioccie) x Caturra x S. 795	70	1500	Good
Sln. 11 (Amphidiploid of C.liberica x C. eugenioides)	10	600-1000	FAQ
Sln. 12 Cauvery (Caturra x HDT)	65	(1500-2500) in higher elevation	FAQ- Good

Table 7. Drought tolerance in some of the *arabica* selections in the decreasing order.

Sl. No.	Selections
1	Sln.7.3 (San Ramon x HDT)
2	Sln.9 (HDT x Taffaikela)
3	Sln.10 (Caturra x Cioccie x Caturra x S.795)
4	Sln. 4 (Tafarikela)
5	Sln.5B (S.333 x Devamachy) (S.2931)
6	Sln.1 (S.288)
7	Sln.11 (liberica x eugenioides)
8	Sln.3 (S.795) (S.288 x Kents)
9	Sln.12 (Cauvery/Catimor)
10	Sln.5A (Devamachy x S.881)
11	Sln.6 (RxA hybrid)
12	Sln.8 (HDT)

Table 8. Percent heterosis and coefficient of variation for yield of arabica genotypes

Genotype	Mean yield (clean coffee kg/ha)	% Heterosis (S.795=100)	C.V. %
HDT x S. 12 Kaffa	3014	218.2	44
Sln. 6	3002	217.4	38
Sln. 6	2748	199.0	45
HDT x Tafarikela	2123	153.7	45
HDT open pollinated	1979	143.3	47
HDT x Geisha	1944	140.8	46
HDT self	1857	134.5	52
Cioccie x S. 1934	1844	133.5	33
S.288	1813	131.3	61
Sln. 7.2.1	1386	100.4	53
Sln. 795	1381	100.0	66
C.D. 5% 1%	381 508		

Table 9. Robusta selections and their characters

Selections	Resistance to rust (% of plants)	'A' Grade Bean (%)	Yield potential clean coffee (Kg/ha) (under intensive cultivation)	Cup quality
Sln.1(R)	95	45	2000-2500*	FAQ
Sln.2(R)	95	50	2000-2500*	FAQ
Sln.3(R) C x R	90	60-70	2000-2500*	FAQ

Table 10. Performance of exotic robustas and S. 274

Acc. No.	Origin	Average yield (kg/ha)	% 'A' Grade	% PB	Cup quality
879	Java	514	53	18	FAQ-
880	East Africa	535	50	14	FAQ+
1481	Malaysia	265	33	16	FAQ
1509	Ivory coast	313	58	19	FAQ-
1902	Saigon	275	54	14	FAQ
1932	Madagascar	501	63	16	FAQ
1977	Uganda	379	37	20	FAQ
1979	Uganda	395	62	18	FAQ
3399	Costa rica	769	61	14	FAQ+
3400	Costa rica	387	53	15	FAQ

3655	Ivory coast	447	34	23	FAQ-
3656	Ivory coast	312	50	16	FAQ
3657	Ivory coast	442	50	21	FAQ+
S.274	India	619	45	17	FAQ

Table 11. Performance of Sib-mated C x R

Progeny	Average yield (kg/ha)	% 'A' Grade	% PB	Cup quality
Slb 1	476	52	28	FAQ+
Slb 2	482	60	25	FAQ+
Slb 3	666	52	24	FAQ+
Slb 4	946	57	22	FAQ+ to good
Slb 5	713	57	18	FAQ
Slb 6	736	49	23	FAQ+ to good
Slb 7	875	55	22	FAQ+ to good
Slb 8	777	58	27	FAQ
Slb 9	586	57	28	FAQ
Slb 10	639	56	23	FAQ
Slb 11	541	45	17	FAQ
Slb 12	433	62	16	FAQ
Slb 13	537	54	28	FAQ
Slb 14	376	46	26	FAQ+ to good
S.274	619	45	17	FAQ

Table-12. New genotypes of *arabica* and *robusta* under evaluation

Accession No.	Parentage
S. 4178,79,80	Catimor x Catuai
S.4202	Villa Sarchi x HDT (Sarchimor)
S.4371	S.2328 x S. 1156 (Sln.6 Back cross)
S. 4634	Catimor x Sarchimor
S.4643,44,45	Brazilian Catimor
S.4033	Sln.7.3 x Sln.6
S. 4595	Sln.11 x HDT
S.4855	Cauvery X Tafarikela
S.4695	Ruiru 11 (Kenya)
C x R	C x R dwarf
S.1932, S.3399, S.880	Exotic robustas

References

Anonymous 2005. Data base on coffee economic and market intelligence unit. Coffee Board, Bangalore.

Anstead D Rudolph 1913. Coffee hybridization work in South India. Planters Chronicle 8: 486-488.

Carvalho A, Ferwerda FP, Frahm-Leliveld JA, Medina DM, Mendes AJT and Monaco LC 1969. Coffee (*Coffea arabica L.* and *Coffea canephora* Pierre ex Froehner): In 'Outlines of Perennial Crop Breeding in the Tropics' (Eds.: Ferwerda FP and Wit Veenman F). Wageningen, Netherlands: 189-241.

Dharmaraj PS 1985. Adaptation of coffee selections in Andhra Pradesh. Journal of Coffee Research 15: 32.

Dharmaraj PS and Gopal NH 1986. Genetic variability of growth and yield characters in some selections of coffee. Proceedings of Placrosym- XII: 351-356.

Dharmaraj PS and Sreenivasan MS 1992. Heterosis and combining ability in C*offea canephora.* Proceedings of Placrosym IX: 157-161.

Ellis RH, Hang TD and Roberts EH 1990. An intermediate category of seed storage behavior. *J. Expt.. Bot.* 41: 1167-1174.

Ganesh D, Ram AS, Prakash NS, Padmajyothi D, Misra MK, Jamsheed Ahmed, Jagadeesan M, Reddy AGS and Srinivasan CS 2002. Evaluation of *Coffea liberica x Coffea eugenioides* and its progenies for yield, leaf rust tolerance and quality. Proceedings of Placrosym XV: 72-77.

Gopal NH 1985. Performance of coffee cultivars of Andhra Pradesh region with reference to drought. *Journal of Coffee Research* 15: 58.

Gorden Wrigley 1988. Coffee. Longman Scientific and Technical. Co-published in the United States with John Wiley and Sons, Inc., New York,

Harinath Babu K, Shantha HM, Samuel Ganesh D and Sreenath HL 1993. Plant regeneration through somatic embryogenesis from leaf tissues in two cultivars of coffee. *J. Plantation Crops* 21 (Supplement): 307-312.

Iyengar BN 1954. Some pioneers of coffee research in South India. *Indian Coffee* 18: 4-11.

Jamsheed Ahmed 1985. Adaptation of selections in traditional areas. *Journal of Coffee Research* 15: 30-31.

Jamsheed Ahmed., Mishra MK and Srinivasan CS 1995. Performance of five *arabica* coffee selections in Karnataka and Tamil Nadu zones. *Indian Coffee* 59: 3-9.

Krishna G and Sreenath HL 2000. Cryopreservation of zygotic embryos of *Coffea* and *Psilanthus* species. Proc.Inter. Coffee. Symp. Bangalore, India: 78-82.

Krug CA and Carvalho A 1951. The genetics of *Coffea*. *Advances in Genetics*. 4: 127-158.

Kumar SA and Sreenath HL 2004. Genetic diversity in Indian arabica germplasm collection through RAPD markers. Proceedings of 20th ASIC, Bangalore: 801-806.

Maekawa N, Azuma T, Uchida N and Yasuda T 1995. RAPD markers and isozyme analysis as an indicator of phylogenetic relationship in the genus *Coffea*. Proc. 16th Inter. Coffee Science Conference, Kyoto.

Mamatha HN and Sreenath HL 1998. Isolation and culture of coffee protoplasts from embryogenic calli. In : 'Recent Advances in Plantation Crops Research. (Eds: Muralidharan N and Rajkumar R, Allied Publishers Ltd., India:): 49-51.

Muniswamy B, Naidu MM and Sreenath HL 1993. Somatic embryogenesis and plant regeneration from cultured immature embryos of *C. canephora. J. Plantation Crops* 21(Suppl): 346-350.

Muniswamy B, Naidu, M.M and Sreenath HL 1994. A simple procedure for hardening of *in vitro* raised plantlets of *Coffea canephora. J. Coffee. Res.* 24(1): 49-53.

Muniswamy B and Sreenath HL 1995. High frequency somatic embryogenesis from cultured leaf explants of *Coffea canephora* Pierre on a single medium**.** *J. Coffee Res.* 25(2): 98-101.

Muniswamy B and Sreenath HL 1995a. Standardization of encapsulation techniques for producing synthetic seeds in coffee. *J. Coffee. Res.* 25(1):24-29.

Muniswamy B and Sreenath HL 1998. *In vitro* plant development from cultured zygotic embryos of *Coffea bengalensis*. In: 'Developments in Plantation Crops Research', (Eds: Mathew NM and Kuruvilla Jacob C): 83-85.

Muniswamy, B and Sreenath, HL 2000. Plant regeneration through embryogensis from cultured anthers of C x R cultivar of coffee. *J. Plantation Crops* 28 (1): 61-67.

Muniswamy B and Sreenath HL 2001. Embryogenesis and plant regeneration from endosperm tissues of *C. arabica*. *J. Plantation Crops* 29 (3): 18-21.

Naidu MM and Sreenath HL 1999. *In vitro* culture of coffee zygotic embryos for germplasm preservation. *Plant Cell, Tissue and Organ Culture* 55: 227-230.

Naidu MM, Jayashree G, Ganesh D and Sreenath HL 1999a. Effect of genotypes on somatic embryogenesis and plant regeneration in coffee. In : 'Plant Tissue Culture and Biotechnology', (Ed: Kavikishore KB), Hyderabad.

Narasimhaswamy RL 1952. Leaf disease resistance and its importance in Coffee. *Indian Coffee* 16: 26-28.

Narasimhaswamy RL 1960. Arabica selection S. 795- its origin and performance- A study . *Indian Coffee* 24: 197-204.

Narasimhaswamy RL 1961. Coffee leaf disease in India. *Indian Coffee* 25: 382-385.

Narasimhaswamy RL and Visveshwara S 1961. Progress report on hybrids between diploid species of *Coffea* L. *Indian Coffee* 25: 104-109

Narasimhaswamy RL, Narayanan Nambiar KK and Sreenivasan MS 1961. Report on work on testing races of leaf disease fungus on coffee selections at Central Coffee Research Institute. *Indian Coffee* 25: 333

Narasimhaswamy RL and Visveshwara S 1963. A note on the occurrence of three species of *Coffea* indigenous to India. *Indian Coffee* 5: 65-71.

Narayanan BT 1954. A note on coffee culture. *Indian Coffee* 18: 30-33.

Nikhila KR, Reddy AGS, Suresh Kumar VB and Mohanan KV 2002. Consequences of sib-mating in CxR (*Coffea congensis x C. canephora*) coffee. Proceedings of PLACROSYM XV: 83-87.

Ocampo CA, Hazbon MH and Acuna R 1991. Advances in genetic manipulation of the coffee plant. In:' Proc. 14th Inter. Conf. Coffee Science, San Fransisco: 378-382.

Orozco-Castillo CA, Chalmers KJ, Waugh R and Powel WR 1994. Detection of genetic diversity and selective gene introgression in coffee using RAPD markers. *Theor. Appl. Genet.* 87:934-940.

Prakash NS, Marie-Combes, Naveen Somanna and Philippe Lashermes 2002. AFLP analysis of introgression in coffee cultivars *(Coffea arabica L)* derived from a natural interspecific hybrid. *Euphytica* 124: 265-271.

Purseglove JW 1968. Tropical Crops, II. Dicotyledons. Longman, London.

Raghuramulu Y 1989. Anther and endosperm culture of coffee. *J. Coffee Res.* 19(2): 71- 81.

Raghuramulu Y, Sreenivasan MS and Ramaiah PK 1989. Regeneration of coffee plantlets through tissue culture techniques in India. *J. Coffee Res.* 19(1): 30-38.

Ramachandran M, Srinivasan MS and Visveshwara S 1979. Preliminary survey of physiological races of coffee leaf rust in South India. *J. Coffee Res*. 9: 51-68.

Ramachandran M and Srinivasan CS 1979. Four generations of selections for resistance to race I of leaf rust in *Coffea arabica* Cv. S.288 X Kents. *Indian Coffee* XL III: 159-161.

Ramanathan, Rao Bahadur V, Bal DV and Thomas KM 1951. A review of the past experimental wok on coffee in South India with suggestions to the future. Coffee Board, Bangalore.

Reddy AGS 1985. Adaptation of selections in non-traditional areas. *Journal of Coffee Research* 15: 32-33.

Reddy AGS and Srinivasan CS 2005. Performance of Balehonnur robusta selections – An assessment and future strategy. Coffee Board, Bangalore.

Reddy AGS, Raju KVVS and Dharmaraj PS 1981. Fruit set in coffee under different modes of pollination in Andhra Pradesh. Proceedings of PLACRYOSYM-IV: 252-256.

Reddy AGS, Raju KVVS and Dharmaraj PS 1984. Allopolyploidization in a spontaneously doubled hybrid of two diploid species of *Coffea*. Proceedings of PLACRYOSYM-VI: 31-39.

Samuel Ganesh D and Sreenath HL 1997. Clonal propagation of coffee through apical bud culture. *J. Plantation Crops* 25(2): 169 - 174.

Santaram A and Sreenath HL 1999. A method for isolation and amplification of coffee DNA using random octamer and decemer primers. *J. Plantation Crops* 27(2):125- 130.

Saraswathy M, Venkataramanan D and Ramaiah PK 1992, Drought tolerance in exotic robustas. *J. Plantation Crops* 20: 123-130.

Sreenath HL and Naidu R 1997. Quarter Century of Research in Coffee Biotechnology— A Review. In: 'Recent Advances in Biotechnological Approaches of Plant Tissue and Cell Culture', (Eds: Ravishankar GA and Venkataraman LV): 14-27. Oxford and IBH Publishing Co. Ltd., New Delhi.

Sreenath HL 1998. Micropropagation of superior coffee genotypes. *Indian Coffee* 4: 17-19.

Sreenath HL and Muniswamy B 2000. Biotechnological Approaches for Coffee Improvement. In: 'Plant Biotechnology - Recent Advances', (Ed.: Trivedi PC): 238-256. Panima Publishing Corporation, New Delhi.

Sreenath HL, Muniswamy B, Naidu MM, Dharmaraj PS and Ramaiah PK 1992. Embryo culture of three interspecific crosses in coffee. *J. Planatation Crops* 20 (Suppl): 243-247.

Sreenath HL, Muniswamy B, Raghuramulu Y and Ramaiah PK 1989. Immature embryo culture in coffee. In: 'Advances in Plant Tissue Culture in India', (Ed: Pramod Tandon): 113 – 121.

Sreenath HL, Prakash CS and Guahao HE 1999. Procedure for generating silver stained AFLP markers in coffee. *J. Coffee Res.* 27(2): 67-77.

Sreenath HL, Shanta HM, Harinath Babu K and Naidu MM 1995. Somatic embryogenesis from integument (perisperm) cultures of coffee. *Plant Cell Reports* 14: 670-673.

Sreenivasan MS 1985. Varieties of coffee in relation to drought tolerance. *J. Coffee Res***.** 15: 58.

Sreenivasan, MS and Visveshwara S 1981. Compatibility studies in *Coffea canephora.* Proceedings of PLACROSYM – IV: 278-282.

Sreenivasan MS and Santa Ram A 1993. Heterosis for yield in coffee. Proceedings of PLACROSYM X: 248-252.

Sreenivasan MS 1968. Progress report on screening coffee selections and collections with races of coffee leaf rust fungus at Central Coffee Research Institute. *Indian Coffee* 32: 299-304.

Sreenivasan MS 1986. Coffee germplasm in India. Proceedings of PLACROSYM – VII: 313-319.

Sreenivasan MS and Ramaiah PK 1985. Cauvery - a new selection from CCRI. *Indian Coffee* 49: 5-6.

Srinivasan CS 1984. Performance of arabica varieties at 3 locations in Coorg. *Indian Coffee* XLVIII: 11-13.

Srinivasan CS 1985. Adaptation of selections in Coorg. *J. Coffee Res.* 15: 3-32.

Srinivasan CS 2002. Assessment of coffee breeding programmes and development of strategy for medium and long term breeding in India. Central Coffee Research Institute, Balehonnur, India.

Srinivasan CS and Visveshwara S 1980. Selection in coffee: some criteria adopted and results obtained in India. *J. Coffee Res*. 10: 53-62.

Srinivasan CS, Visveshwara S and Subramanya H 1979. Genotype environment interaction and heritability of yield in *C. arabica* L. *J. Coffee Res*. 9: 69-73.

Subbulakshmi V, Sundar KR and Srinivasan CS 1981. Clonal vs. seedling performance in robusta coffee: An evaluation of morphological characters related to yield. Proceedings of PLACROSYM- IV: 175-182.

Subrahmanyan V, Bhatia DS and Natarajan CP 1954. Coffee as a beverage. *Indian Coffee* 18: 12-14.

Sureshkumar VB, Ramachandran M, Reddy AGS and Srinivasan CS 1999. A dwarf plant in *Coffea congensis x C canephora* (C X R). *Agricultural Science Digest*. 19: 245-247.

Sybenga J 1960. Genetics and cytology of coffee – A literature review. *Bibliographia Genetica* XIX**:** 217-316.

Thomas AS 1940. In: 'Agriculture in Uganda. (Ed: Tothil JD). Oxford University Press.

Thomas KM 1954. Coffee Breeding – A retrospect. *Indian Coffee* 18: 17-18.

Thomas KM 1960. Station Selections. *Indian Coffee* 24: 18- 27.

Ukers WH 1948. Romance of coffee, Tea and coffee. *Trade Journal*, NewYork.

Van der Vossen HAM 2000. Challenges to coffee plant improvement in the 21st century. Proc. International Scientific Symposium on Coffee, Bangalore, India: 20-39.

Van der Vossen HAM and Walyaro 1981. The coffee breeding programme in Kenya. A review of progress made since 1977 and plan of action for the coming years. *Kenya Coffee* 46: 113-130.

Venkataramanan D. 1985. Drought tolerance in coffee. *J. Coffee Res*. 15: 57.

Visveshwara S 1974. Performance of dwarfs in coffee. *Indian Coffee* 38: 222-227.

Visveshwara S 1975. Coffee: Commercial qualities of some newer selections. *Indian Coffee* 39: 363-366.

Visveshwara S and Chinnappa CC 1969. A spontaneous somatic mutation in arabica coffee. *Indian Coffee* 38: 100-102.

Visveshwara S and Govindarajan AG 1970. Studies on Hybrido-de-Timor coffee collection. *Indian Coffee* 34: 71-77.

Visveshwara S and Surayakantha Raju K 1973. Dwarf hybrid in coffee. *Indian Coffee* 37: 343-345.

Wilson Mayne, W 1932. Annual report of the Coffee Scientific Officer. 1931-32. The Mysore Coffee Experimental Station Bulletin No. 7. Department of agriculture, Mysore State.

Acknowledgement

The author is indebted to Dr. C. S .Srinivasan Joint Director of Research (Retd), Coffee Board; Dr. H. L. Sreenath, Head of the Division, Biotechnology Centre, Coffee Board, Mysore and Dr. V. B. Suresh Kumar, Asst Botanist, Regional Coffee Research Station, Chundale, Wayanad, Kerala for valuable suggestions and all assistance extended at one stage or the other of preparation of the manuscript.

Use of microsatellite markers in seed orchard management in Teak

Indira EP, Sabna Prabha S and Nair Pramod N
Kerala Forest Research Institute, Peechi, Kerala- 680 653, India.

Abstract

Teak seed orchards were established by Kerala Forest Research Institute (KFRI) and other Institutions to mass produce genetically improved seeds. Genetically superior plus trees were assembled in these seed orchards. Generally seed orchards are isolated or managed to avoid pollination from genetically inferior out side sources. A pollen dilution zone is normally given on all the sides for this purpose and the width of pollen dilution zone is given on the basis of the distance of pollen dispersal. Though clonal seed orchards were established in a systematic way, low flowering and fruiting affected the teak improvement programmes in India as well as in other teak growing countries. Low pollinator activity with less inter tree flights in combination with the partial self incompatibility were the main reasons attributed to low seed production. Studies were conducted at KFRI to study the pollen dispersal and contemporary gene flow as well as the percentage of natural selfing, for which microsatellite markers were employed, so as to suggest improved methods for seed orchard management. Information on contemporary gene flow will also help in evolving in situ genetic conservation measures in this important forest tree crop.

Introduction

Teak (*Tectona grandis* Linn.f.) is one of the most valuable tropical timber species naturally grown in few countries of South-East Asia. Due to its unique wood properties, it also has been widely planted outside its natural range. Today it is of major importance in many plantation programmes throughout the tropics. Teak is preferred for large scale plantation programmes in India since it adapts to a wide range of climatic and edaphic conditions. Teak improvement programmes were started in India during early sixties and through these programmes, seed production areas and seed orchards were established through out the teak growing states.

Seed orchards are aimed at mass production of improved quality seeds. A seed orchard is a plantation of genetically superior trees isolated or managed to avoid pollination from genetically inferior out side sources and encouraged to cross pollinate between different clones with in the orchard and intensively managed to produce abundant seeds which can be easily harvested (Zobel *et al.*, 1958). Open pollinated seeds from these stands are expected to produce high yielding progenies. But the poor flowering and low seed production have hampered the teak improvement programmes in India as well as in other countries to a great extent. Though thousands of flowers are produced per tree in plantations and natural forests, only less than 1 percent turns to mature fruits. In seed orchards the situation is still worse where flowering also is found be very low. As a result, the forest managers are forced to raise planting materials from whatever seeds available.

The field studies as well as laboratory experiments at Kerala Forest Research Institute (KFRI) lead to the conclusions that inadequate pollinator activity, low pollen-ovule ratio, self incompatibility and also the fruit abortion due to the dominance effect and fungal infection are the main causes for low fruit productivity in teak (Indira and Mohanadas, 2002).

By natural pollination, only about 1% fruit setting could be observed as mentioned above. The artificial pollination experiments conducted at KFRI resulted in 4% fruiting through self pollination and 10% fruiting by cross pollination which clearly shows that

insufficient pollination is one of the reasons for low fruit productivity as suggested by Hedegart (1973) and Tangmitcharoen and Owens (1996). When cross pollinated and self pollinated pistils were subjected to fluorescent microscopy, pollen tubes were found to be growing at the stylar region in both the cases. When the pollen tubes reached the micropyle region, there was no obstacle for the entry of pollen tubes into ovules with respect to cross pollinated flowers while, in self pollinated ones the pollen tubes coiled round the ovary region failing to make an entry. All these observations lead to the conclusion that teak prefers cross pollination and it is partially self incompatible.

In seed orchards it is assumed that flowering and pollen exchange among genotypes will be uniform. Teak is a species pollinated by insects, mainly hymenopterans. It is very difficult to choose the seed orchard designs in entomophilous species because insects and their behaviour play an important role. In yellow poplar seed orchard, the bees do not visit trees randomly but concentrate only one tree at a time (Taft, 1968) resulting in selfing. In teak (*Tectona grandis*) also most of the insects spend their time among the inflorescences of a single tree (Indira and Mohanadas, 2002), which may lead to selfing.

Isolation from surrounding stands of the same species has to be ascertained to avoid pollination from unselected trees. Isolation strips or buffer zones have to be given around each seed orchard. Absolute minimum pollen dilution zone differs from species to species depending on the pollinators and pollen dispersal. The pollen flow distance has to be ascertained in teak to estimate the pollen dilution zone in seed orchards and seed stands/ seed production areas.

The relative contribution of pollen and seed dispersal to gene flow is not well understood in most tropical tree species. This information is important for determining the size of buffer zones and conservation areas. In teak, so far not much study were conducted on contemporary and long term gene flow as well as migration pattern.

In seed orchards, management practices can be followed utilizing chloroplast DNA markers (cpDNA) to monitor seed orchard pollination, pollen contamination and gene flow. Microsatellite markers are used in seed orchard management in various ways such as i) to study the mating pattern, ii) to study the male fertility pattern, iii) to estimate the percentage of selfing, iv) to estimate the pollen dilution zone, v) to estimate the pollen contamination from out side sources and vi) to identify the clones for mass propagation. In natural forest they are used to study the mating system and contemporary gene flow so that we can put forth effective utilization and conservation measures.

Hence, studies were conducted at KFRI to find out the percentage of natural selfing and crossing, to estimate the pollen flow distance as well as contemporary gene flow.

Materials and Methods

Natural teak population was selected in the Peechi –Vazhani wild life sanctuary. All the 190 trees in the plot were marked and GPS coordinates were taken. The population was mapped using the software Mapinfo professional. Fruits were also collected from 6 randomly selected fruit bearing trees (mother trees) and were put for germination. Leaf samples were collected from all the marked adult trees as well as 20 germinated progeny seedlings from each of the 6 mother trees. Few seeds did not germinate and hence, embryos were collected. Hundred fruits were cut opened and the number of seeds per fruits was noted.

DNA was extracted from juvenile leaves using modified CTAB procedure (Doyle and Doyle, 1987). DNA samples were quantified using Ultra Lum Total Lab software. In order to maintain uniform concentration, 30ng DNA samples were taken after quantification.

Hyper variable microsatellite DNA markers were used for this study. They are Co-dominant markers and considered as neutral. Hence they are suitable for paternity analysis and pollen flow studies. Power to discriminate among male parents depends on the number

of markers, amount of allelic variability and frequency of alleles in the population. Specific primers were designed by Dr. Hugo Volkaert, Kasetsart University, Thailand (Scientific coordinator in one of our multi institutional project on teak funded by European Union). Eight microsatellite primers namely AC01, AC28, AG04, AG14, AG16, ADHMS, CPIMS and AC44 were selected. DNA amplifications were done in 12µl master mix and each with 2µl of DNA, 0.1µl of Taq polymerase, 1.2µl of primer, 2.4 µl dNTP's and buffer (Taq buffer supplied along with polymerase enzyme). DNA amplification was performed in a Programmable Thermal Cycler (PTC– 100, MJ Research, USA) equipped with a heated lid to minimize sample fluxing. The Thermal Cycler was programmed to denature DNA at 94^0 C for 45 seconds, anneal DNA to primer at 48^0C for 45 seconds and to polymerase DNA at 72^0 C for 1 minute. After 32 cycles a final extension of 3 minutes was allowed. The amplified products were separated on 4.5% denaturing poly acrylamide gel at 90 watts constant for 1 hour 30 minutes in 1X TBE buffer. The gels were silver stained and photographed by EPSON Photo PC 3100Z. Based on the banding pattern in the gel, alleles were identified manually.

As mentioned above all the 190 trees in the population as well as the 120 progeny seedlings were fingerprinted in the Poly Acrylamide Gel Electrophoresis. The genotypic fingerprints of each of the seedlings are compared to the known seed parent and the potential pollen parents using the software Cervus. Through exclusion method, by comparing each and every microsatellite band, the male parent could be identified. From this the distance between pollen parent and seed parent could be measured. The number of pollinations in each distance class like 1-50m, 50-100m, 100-150m etc. were also computed. The percentage of selfing and crossing was also estimated.

Results and Discussion

The study shows that more than 45 percent (45.32) of the fruits are seedless, 43.17 % with one seed, 7.91% with 2 seeds, 3.24 % with 3 seeds and only 0.36% with 4seeds. The pollen parents of the selected progenies could be identified through Cervus analysis. The percentage of crossing was hence computed, which shows that 98.3 % of the total seeds are set through cross pollination and the rest by selfing. Pollen reception by a female parent was found to be from almost all sides (Fig.1). It is also revealed that pollen donors are different trees. In few cases pollen were received more than once from the same male parent. With regard to tree no.151, 15 male parents pollinated to produce the total of 20 progenies analysed. Out of these 20 progenies, three seedlings have the same male parent, tree 66, two from tree 41, two from 17 and two from tree 183. All other 11 progenies have 11 different male parents. Even though this population is highly disturbed, high cross pollination rate with flowers of a single tree pollinated by many different trees will definitely lead to high within population diversity. This may be the reason that teak is having very high within population diversity as reported by Nicodemus *et al.* (2005) and Indira *et al.* (2006). The very high out crossing rate in teak definitely ensure the quality of seeds from seed orchards.

The studies conducted by Aldrich and Hamrick (1998), using hypervariable genetic markers, at the University of Georgia in *Symphonia globulifera* in southern Costa Rica show that out of nearly 250 seedlings studied from a single forest fragment, some 68 percent were produced by adults in pastures, not from adults within the fragments themselves. Moreover, of the seedlings produced by pasture trees, 77 percent came from only two trees. They note that trees left standing in pastures can actually dominate the reproduction in nearby remnant forests, creating a "genetic bottleneck". Our results showing reception of pollen from so many different trees really encourage teak breeders in general.

The Distance of pollen dispersion was found to be up to 400 m but pollen flow is mainly in between 150-200 metres (Fig 2). Hence, pollen dilution zone may be limited to 200 metres around seed orchards. While studying contemporary gene flow in teak using molecular markers, Palupi (2005) reports that teak pollen is dispersed as far as 180m, but majority within 100m from its source indicating the flight coverage of pollinators. Even if there are flowering trees in the neighbourhood, the female parents receive and accept pollen

from different trees, there by ensuring the diversity. Hence, seeds from the same tree may have different genetic constitution leading to high within population genetic diversity. Studies of historical and contemporary gene flow levels, via genetic structure surveys and parentage analyses, demonstrate that gene flow is generally extensive in both wind- and animal-pollinated forest tree species (Slavov *et al.*, 2003). Our studies with teak also agree with the above observation.

Table.1 Primers and number of alleles present in the population

	Primers	No. of alleles
1	AC01	8
2	AC28	6
3	AC 44	7
4	Ag04	5
5	Ag14	6
6	Ag16	6
7	ADH-Ms	2
8	CPI-Ms	2

Table 2. Distance between male and female parents

Offspring ID	Known parent (Mother parent)	Male parent	Pollen flow Distance in m	
Offspring 1	151	104	85.37	Cross
2	151	66	175.61	Cross
3	151	165	170.73	Cross
4	151	41	180.49	Cross
5	151	66	175.61	Cross
130	100	100		*Self*
131	100	144	160.98	Cross
132	100	139	114.63	Cross
133	100	139	114.63	Cross
134	100	75	243.90	Cross

References

Aldrich PR and Hamrick JL 1998. Reproductive dominance of pasture trees in a fragmented tropical forest mosaic. *Science* 281 (5373): 103- 105.

Doyle and Doyle 1987. CTAB DNA extraction in plants. *Phytochem. Bull.* 19: 11-15.

Hedegart T 1973. Pollination of teak (*Tectona grandis* L.). *Silvae Genet.* 22: 124- 128.

Indira EP and Mohanadas K 2002. Intrinsic and extrinsic factors affecting pollination and fruit productivity in Teak (*Tectona grandis* L.f.). *Indian J. Genetics & Plant Breeding* 62 (3): 208- 214.

Indira EP, Pramod N Nair and Sabna Prabha S 2006. Evaluation of Genetic diversity in teak populations in Kerala using DNA markers. *In:* Proc. National Conference on Tree Biotechnology: Indian Scenario, Tropical Forest Research Institute, Jabalpur during 9th and 10th February 2006 (in press).

Nicodemus A, Nagarajan B, Narayanan C, Varghese M and Subramanian K 2005. RAPD variation in indian teak populations and its implications for breeding and conservation. Proc. International Conference on Quality Timber products of teak from sustainable Forest Management, KFRI, Peechi, India, Dec. 2003: 347- 351.

Slavov GT, DiFazio SP and Strauss SH 2003. Gene flow in forest trees: Gene migration patterns and landscape modeling of transgene dispersion in hybrid poplar. In 'Introgression from Genetically Modified Plants into Wild Relatives', (Eds: M den Nijs HC, Bartsch D and Sweet J) CAB International, UK. : 89-106.

Taft KA 1968. Hardwood seed orchard management. Southeastern Area for nur. Conf., Stone Mountain, Ga.: 90-91.

Tangmitcharoen S and Owens JN 1996. Floral biology, pollination and pollen tube growth in relation to low fruit production of teak (*Tectona grandis* Linn.f.) in Thailand. In: Tree improvement for sustainable tropical forestry. (Eds: Dieters MJ, Matheson AC, Nikles DG, Harwood CE and Walker SM) Proc. QFRI-IUFRO Conf., Queensland, Australia, 27th Oct.-1st Nov.1996.

Zobel BJ, Baker J, Brown CL and Perry TO 1958. Seed orchards- their concept and management. *J. For.* 56 (11): 815-825.

Fig 1. Pollen Flow from different trees (male donors) to mother tree number 151

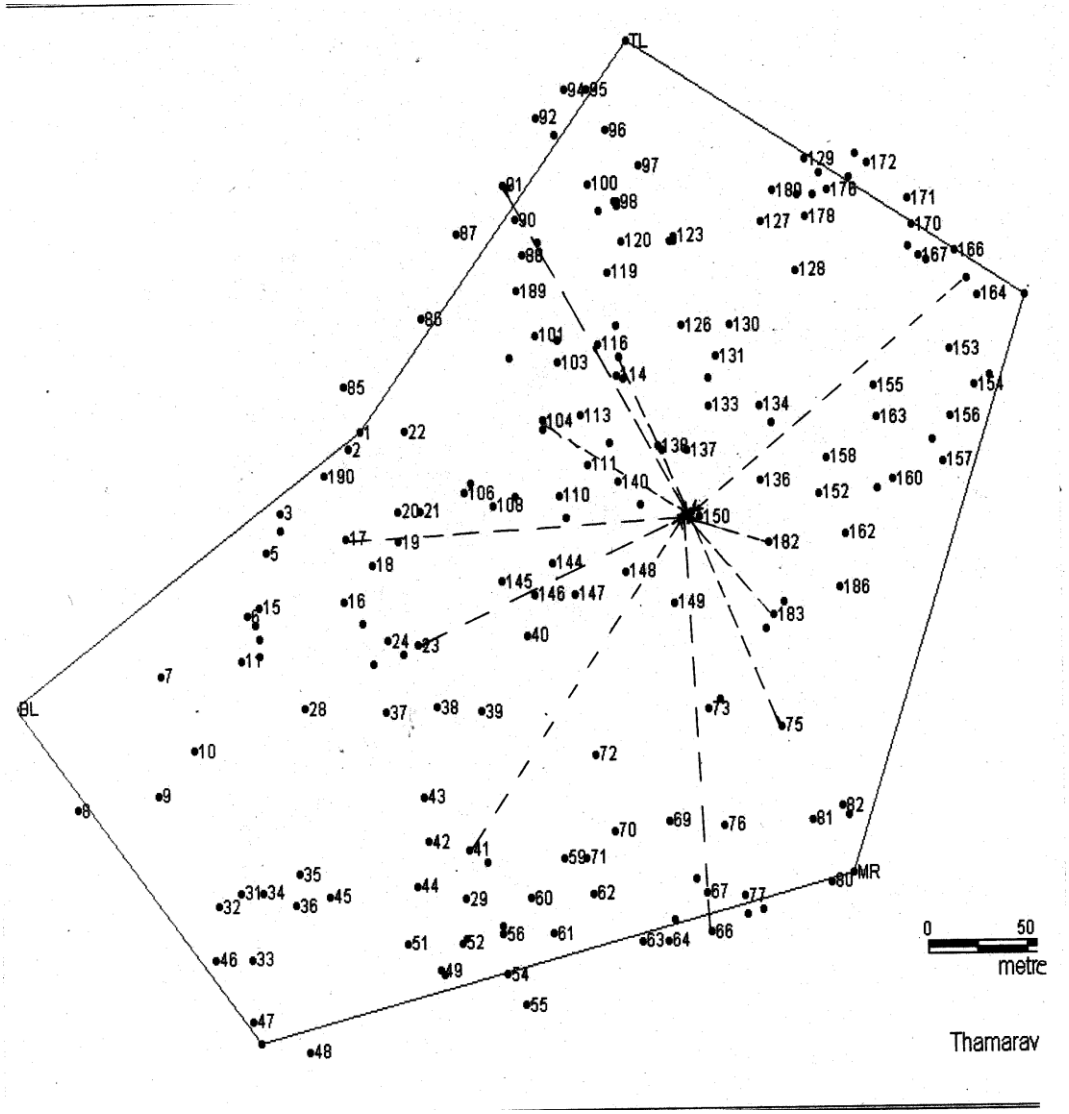
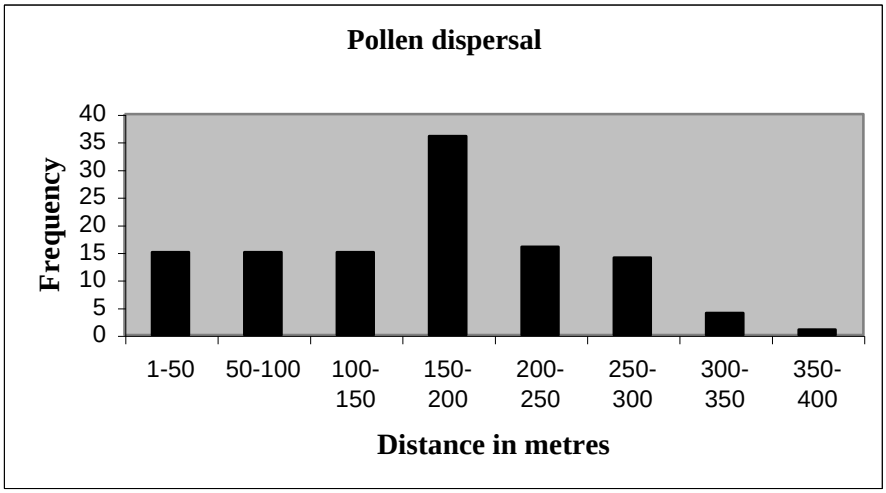


Fig. 2. Graph showing the frequency of pollen transfer in different distance classes



Acknowledgement

The authors would like to express their sincere gratitude to Dr. Hugo Volkaert, Kasetsart University, Thailand for providing the primers and for the help in standardizing the methods. Authors also acknowledge the financial assistance by the European Union to carry out the studies. Thanks are due to The Director, KFRI for encouragement and facilities provided.

Non destructive method of leaf area measurement in medicinal plants

Balakrishnan K[1], Vincent S[2], Rajendran C[1] and Vivekanandan P[1]
1 Agricultural College and Research Institute, Madurai, Tamil Nadu, India.
2 Regional Research Station, Agricultural College and Research Institute, Madurai, Tamil Nadu, India.

Abstract

With a view to devising a simple, easy and convenient method for non-destructive estimation of leaf area in medicinal plants, a study was conducted in 10 important medicinal plants by taking the maximum length (L) and breadth (B) of the leaves. The plants taken up for the study were viz., Tulsi, Periwinkle, Tuthi, Marunthu kathiri, Aswagandha, Notchi, Vasampu, Kasini keerai, Chekurmanis and Senna. One hundred leaves from each medicinal plants were randomly selected and their maximum length and breadth were measured. Their actual leaf area was measured in electronic leaf area meter and the K value was obtained from the ratio of actual leaf area to the product of length and breadth. Leaf area constant (k) was evolved for the ten medicinal plants which varies depending upon the leaf morphology. The K value ranges from 0.37 in Senna to 0.76 in Aswagandha. Leaf area can be estimated non-destructively by multiplying the leaf area constant (K) with L and B, i.e., Leaf area = K x L x B).

Introduction

Leaf area plays an important role in the photosynthetic activity of the plant. They are the main sites of food manufacturing and carbohydrates assimilate in photoautotrophs which ultimately contributes to the expression of various morphological attributes and yield. There is a direct relationship between the leaf area and the amount of light trapped which inturn plays an important role in the photosynthetic production of crops (Dey and Gayen 2001). Leaf area can be estimated by different methods which require complex tools, high tech instruments for which the leaves are to be removed from the plant. The linear measurement of the leaf area is simple, precise, inexpensive and non destructive. It also facilitates to follow the development of same leaf through out the crop growth simple and convenient model for this estimation with high accuracy is, therefore, the basic need for the growth analysis and agronomic studies in crop plants.

Leaf area estimation by linear methods for various crops has been standarised (Balakrishnan 1989). However, such non destructive methods are not available for medicinal crops which are gaining momentum in recent years. In most of the medicinal plants foliage is harvested as economic yield. Hence, the objective of the present study is to evolve K value for the selected 10 medicinal plant. So that the leaf area can be measured nondestructively.

Materials and Method

The experimental material consists of 10 herbaceous medicinal plants where foliage is used as economic yield viz.,

1. *Ocimum sanctum* (Tulsi)
2. *Cathranthus roseus* (Periwinkle)
3. *Abutilon indicum* (Tuthi)
4. *Solanum torvum* (Marunthu kathiri)
5. *Withania somnifera* (Aswagandha)
6. *Vitex negundo* (Notchi)
7. *Acorus calamus* (Vasampu)
8. *Chicorium intypus* (Kasini keerai)
9. *Saurapus androgynus* (Chekurmanis)
10. *Cassia angustifolia* (Senna)

These crops have been cultivated by following normal agronomic practices during the year 2003-2004 at Agricultural College and Research Institute, Madurai. One hundred leaves from each medicinal plant were collected randomly at peak vegetative phase. Leaf length was measured from the tip to the place where the leaf lamina is attached to the petiole (L). Leaf width was measured at the widest region across the lamina or right angle to the length (B). Leaf area of the individual leaves was measured by using electronic leaf area meter. The leaf area was predicted using the formula A= K (L x B), where A=leaf area per leaf, K = leaf area constant, L = maximum leaf length and B = maximum leaf width (Padalia and Patel 1980). The leaf area constant (K) was worked out by the formula

$$K = \frac{\text{Actual leaf area}}{\text{Length x Breadth}}$$

The leaf area was estimated for each medicinal plant by using the respective (K) value. The actual leaf area measured in leaf area meter was subjected to correlation coefficient with predicted leaf area. The data are presented in the table 1. Deviations from actual leaf area was calculated from the estimated leaf area and the significance was tested by paired't' test. Correlation coefficients were worked out between estimated leaf area and the actual leaf area.

Results and Discussion

The mean leaf area constant K varies among the medicinal plants depending upon the leaf morphology and it ranges from 0.37 in senna to 0.76 in Aswagandha (Table 1). Since the K value has been worked out for the leaves collected randomly from each medicinal plant at all positions and sizes, the K value of the concerned medicinal plant can be used irrespective of the position of the leaves. The leaf area was predicted for each medicinal plant with the use of respective constant. The predicted leaf area is nearly equals to the actual leaf area. The correlation coefficient between actual and predicted leaf area was found to be positive and highly significant for all the medicinal plants. The highest positive correlation (r = 0.9512**) was obtained in O*cimum sanctum*.

It was concluded from the study that the leaf area for the above ten medicinal plants can be measured (L x B x K) non destructively by using the leaf area constants [K values). The K value for each medicinal plants may hold good for all the varieties of the respective medicinal plants because of the similarity in leaf morphology.

Table 1. Estimation of leaf area constant (k) for medicinal plants

Sl. No.	Name of the medicinal plant	Range of leaf length (cm)	Mean leaf length (cm)	Range of leaf breadth (cm)	Mean leaf breadth (cm)	LxB	Actual leaf area (cm^2 $leaf^{-1}$)	Leaf area constant (k)	Predicted leaf area (LxBxK) mean	Correlatio coefficien ("r" value
1.	*Ocimum sanctum*	1.9.-3.9	2.90	0.8-2.3	1.27	3.68	2.182	0.59	2.172	0.9512**
2.	*Cathranthus roseus*	2.8-4.7	3.78	1.4-2.1	1.80	6.80	3.985	0.59	4.012	0.9041**
3.	*Abutilon indicum*	7.9-10.9	9.43	8.6-12.2	10.97	103.45	77.446	0.74	76.553	0.9832**
4.	*Salanum torvum*	9.2-15.8	12.48	8.9-12.2	10.50	131.04	82.627	0.63	81.245	0.8607**
5.	*Withania somnifera*	6.3-7.4	6.83	3.7-5.6	4.70	32.10	24.603	0.76	24.396	0.9447**
6.	*Vitex negundo*	7.7-11.4	9.45	2.2-3.8	3.00	28.35	16.108	0.56	15.309	0.8345**
7.	*Acorus*	24.5-	30.49	0.5-1.3	0.92	23.05	13.302	0.57	14.050	0.9217**

	calamus	36.5								
8.	*Chicorium intypus*	14.3-19.7	16.98	1.8-3.7	2.77	47.03	23.493	0.50	22.575	0.8905**
9.	*Saurapus androgynus*	3.2-5.6	4.40	1.4-2.9	2.12	9.32	6.196	0.66	6.084	0.8013**
10.	*Cassia angustifolia*	11.5-16.5	14.04	2.5-3.9	3.18	44.65	15.741	0.35	16.520	0.8610**

**: Significant at one per cent level

References

Balakrishnan K 1988. Estimation of leaf area in crop plants – A mini Review. *Agric. Rev.* 9**:** 189-194.

Padalia MR and Patel CI 1980. Note on length –width method for estimating leaf area of groundnut. *Indian J. Agric. Sci.* 50: 880–882.

Dey C and Gayen P 2001. Estimation of area of trifoliate leaf in urd bean by linear measurements. *Ann. Agric. Res.* 22: 67–70.

Yeboah SO, Lindasay JT and Gumbs F 1983. Estimating leaf area in cowpea from linear measurements of terminal leaf let. *Trop. Agric.* 60: 149–150.

Studies on sensitivity of Co1 and Co2 Chrysanthemum to gamma rays, EMS and their combinations

Balakrishnan S
Agricultural College and Research Institute, Madurai, Tamil Nadu- 625 104.

Abstract

Chrysanthemum (Dendranthema grandiflora Tzueleu) is considered as one of the best and the oldest among the commercially cultivated flower crops. In India, Chrysanthemum occupies a place of pride both as commercial flower crop and as a popular cut flower for exhibition. In Tamil Nadu, small flowered Chrysanthemum varieties viz., Co.1 and Co.2 are commercially grown. Genetic variability in Chrysanthemum can be induced either by hybridization or mutation breeding. Mutation breeding is advantageous over hybridization. The successful application of mutation breeding in chrysanthemum is possible since this crop forms an aneuploid, hexaploid complex and is heterozygous. An investigation on the induction of mutation in Chrysanthemum was conducted. To start with, rooted cuttinga of Co1 and Co2 cultivars of chrysanthemum were subjected to treatments with gamma rays, EMS and their combinations at different intervals. Sensitivity studies on the basis of survival percentage of plants on 45th day indicated LD_{50} value for Co1 and Co2 varieties remained between 1.0 and 20 mM in both the cultivars. There was a trend of reduction in survival of plants as the dose of gamma rays and EMS increased. Among the combined treatments 1.0 kR gamma rays plus 10 mM EMS icaused 50 percent reduction in survival in both the cultivars. Sensitivity studies revealed 1.0 to 1.5 kR of gamma rays as optimum dozes for mutagenic dozes in the above cultivars.

Introduction

Chrysanthemum (*Dendranthema grandiflora* Tzueleu) is considered as one of the best and the oldest among the commercially cultivated flower crops. In India, Chrysanthemum occupies a place of pride both as commercial flower crop and as a popular cut flower for exhibition. In Tamil Nadu, small flowered Chrysanthemum varieties viz., Co.1 and Co.2 are commercially grown. Genetic variability in Chrysanthemum can be induced either by hybridization or mutation breeding. Among the above breeding methods, mutation breeding is advantageous over hybridization.The successful application of mutation breeding in chrysanthemum is possible since this crop forms an aneuploid, hexaploid complex and heterozygous. Hence, an investigation on the induction of mutation in Chrysanthemum was conducted with the following objectives: (1). to study the sensitivity of Co.1 and Co.2 cultivars of Chrysanthemum to gamma rays, EMS and combination of both mutagens and (2). to fix LD_{50} values of gamma rays and EMS.

Materials and Method

Rooted cuttings of Co.1 and Co.2 cultivars of Chrysanthemum were subjected to mutagenic treatments. The treatment details are furnished below:

T_1 - 1.0 kR Gamma rays
T_2 - 1.5 kR Gamma rays
T_3 - 2.0 kR Gamma rays
T_4 - 2.5 kR Gamma rays
T_5 - 10 mM EMS
T_6 - 20 mM EMS
T_7 - 30 mM EMS
T_8 - 40 mM EMS
T_9 - 1.0 kR gamma rays and 10 mM EMS
T_{10} - 1.0 kR gamma rays and 20 mM EMS
T_{11} - 1.0 kR gamma rays and 30 mM EMS
T_{12} - 1.0 kR gamma rays and 40 mM EMS

T_{13} - 1.5 kR gamma rays and 10 mM EMS
T_{14} - 1.5 kR gamma rays and 20 mM EMS
T_{15} - 1.5 kR gamma rays and 30 mM EMS
T_{16} - 1.5 kR gamma rays and 40 mM EMS
T_{17} - 2.0 kR gamma rays and 10 mM EMS
T_{18} - 2.0 kR gamma rays and 20 mM EMS
T_{19} - 2.0 kR gamma rays and 30 mM EMS
T_{20} - 2.0 kR gamma rays and 40 mM EMS
T_{21} - 2.5 kR gamma rays and 10 mM EMS
T_{22} - 2.5 kR gamma rays and 20 mM EMS
T_{23} - 2.5 kR gamma rays and 30 mM EMS
T_{24} - 2.5 kR gamma rays and 40 mM EMS
T_{25} - Control

The treated rooted cuttings of Co.1 and Co.2 were planted in the tube pots filled with nursery pot mixture and raised in three replications. The treated Co.1 and Co.2 Chrysanthemum plants survived on 45th day from the date of mutagenic treatment were recorded and expressed as percentage. The LD_{50} values of gamma rays and EMS were worked out on the basis of survival percentage on 45th day.

Result and Discussion

The survival of Co.1 and Co. 2 Chrysanthemum plants on 45th day was found to be differing significantly among the treatments (Table 1). There was a distinct reduction in the survival percentage of Co.1 and Co.2 plants with an increase in the doses of gamma rays. Between the two cultivars, at the highest dose of 2.5 kR gamma rays, Co.1 recorded lower percentage of survival *ie.*, 21.4 than Co.2 which recorded 28.60 percentage of survival. However, the doses required to cause 50 per cent reduction in survival ranged between 1.0 and 1.5 kR in Co.1 and Co.2 cultivars. The LD_{50} value was found to be between 1.0 and 1.5 kR in Co.1 and Co.2 cultivars. This result was in accordance with previous findings of Kalaivani (1991).

The survival percentage was inversely proportional to the increasing concentrations of EMS in Co.1 and Co.2 cultivars. Between the two cultivars, at the highest concentration of 40 mM, Co.1 recorded the lower percentage of survival *ie.*, 22.30 than Co.2 which recorded 30.10 percentage of survival. However, the concentrations required to cause 50 per cent reduction in survival ranged between 10 and 20 mM in both Co.1 and Co.2 cultivars. Fifty per cent lethality due to EMS was observed between 10 and 20 mM in both the cultivars. In combination treatments, the dose and concentration required to cause 50 per cent reduction in survival was found at the lowest dose of gamma rays and the lowest concentration of EMS in both Co.1 and Co.2 cultivars. According to the classification of Chrysanthemum based on radio sensitivity given by Gupta (1971), the cultivars Co.1 and Co.2 were highly sensitive. The lower survival rate due to mutagenic treatments might be attributed to an inactivation of auxin levels in the plant with increasing exposures as reported by Skoog (1935). Golden and Weber (1955) showed that in vivo auxin synthesis was non-exponential with an increment in exposure but the extent of inhibition of synthesis increased with increasing doses. Moreover, mutagenic treatments caused chromosomal aberrations adversely affecting the cell division as reported by Read (1959).

Summary

Sensitivity studies revealed that 1.0 to1.5 kR of gamma rays as the optimum doses and 10 to 20 mM of EMS as optimum concentrations for mutagenic studies in Co.1 and Co.2 Chrysanthemum. The LD 50 value remained betwen1.0 and 1.5 kR. Fifty per cent lethality due to EMS was observed between 10 and 20 mM in both the cultivars.

Table 1. Survival percentage on 45th day

Treatments	Co.1 variety	Co.2 variety
T_1	69.50	70.30
T_2	47.10	45.10
T_3	35.00	32.00
T_4	21.40	28.60
FT_5	71.30	75.40
T_6	49.50	49.20
T_7	36.50	36.70
T_8	22.30	30.10
T_9	51.40	50.30
T_{10}	41.30	42.50
T_{11}	37.60	39.10
T_{12}	35.00	36.50
T_{13}	32.40	33.90
T_{14}	29.80	31.30
T_{15}	27.30	28.80
T_{16}	24.60	26.20
T_{17}	21.90	23.50
T_{18}	18.70	20.90
T_{19}	16.00	18.30
T_{20}	13.10	15.80
T_{21}	10.40	13.00
T_{22}	7.40	10.40
T_{23}	4.80	7.80
T_{24}	2.30	5.20
T_{25}	100.00	100.00
CD (P=0.05)	2.40	2.50

References

Gorden SA and Weber RP 1955. Studies on the mechanism of phytochrome damage by ionizing radiations. I. The radio sensitivity of Indole acetic acid. *Pl. Physiol.* 30: 20-210.

Gupta MN 1971. Use of isotopes and radiation in agriculture and animal husbandry research. Proc. Inter. Symp., IARI, New Delhi: 164-174.

Kalaivani T 1991. Studies on induced mutagenesis in Chrysanthemum (*Chrysanthemum morifolium* Ramat.). M.Sc. (Hort.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Read J 1959. Radiation biology of *Vicia faba* in relation to the general problem. Oxford Backwell Scientific Publications.

Skoog F 1935. The effect of X-irradiation on auxin and plant growth. *J. Cellular Comp. Physiol.* 7: 227-270.

Correlation and path analysis of yield and physiological traits in tomato (*Lycopersicon esculentum* Mill.)

Sadasakthi A and Marik Rahul
Dept. of Horticulture, Agricultural College and Research Institute, Madurai, Tamil Nadu-625104

Abstract

An investigation was carried out in tomato (Lycopersicon esculentum Mill.) at Agricultural College and Research Institute, Madurai during 2003-2005. Correlation and path analysis was computed using 36 genotypes of tomato (28 hybrids and their 8 parents). Correlation studies indicated positive associationship of plant height, number of fruits per plant, number of primary branches per plant, fruit weight and flowering duration with fruit yield. Path coefficient analysis indicated strong correlation of number of fruits per plant and single fruit weight with yield due to their high direct contribution towards yield. However single fruit yield was found as the major contributing components of fruit yield

Key words: Tomato, correlation, path coefficient analysis, yield, physiological traits.

Introduction

In India, research on tomato has moved progressively since independence. But there is no way to disagree that productivity has not taken momentum as it should have been. so the major objective of any breeding procedures are to be focused and carefully formulated in increasing the potentiality of this complex trait. Yield is considered a dependent variable on several components. In such cases, knowledge of degree of association of among such trait has great importance to the plant breeder to formulate subsequent breeding programmes. Correlation studies provide information about the impact of selection for one character on the progress of other correlate characters. Further, the study of simple correlations does not provide an exact picture of relative importance of direct and indirect influence of each of the component character towards the desired character. This will be overcome by following path coefficient analysis by further partitioning the correlation into components due to direct and indirect effects.

Materials and Method

The present investigation was carried out in the college orchard, Department of Horticulture, Agricultural College and Research Institute, Madurai, during 2003-2005. the experiment consisted of 36 genotypes of tomato (28 hybrids and their 8 parents). Each plot had a row to row distance of 60 cm and plant to plant distance of 45 cm. The experimental plots were laid out in randomized block design with two replications with twelve seedlings per cross and parent in each replication. Five plants selected randomly were tagged in each genotypes for recording the data on plant height, number of fruits per plant, number of primary branches per plant, fruit weight and flowering duration with fruit yield.

Results and Discussion

Analysis of variance of the design of the experiment showed significant difference among 36 genotypes for all the traits studied, thereby indicating the presence of variability among the genotypes (Table 1). In the present study, the phenotypic correlation coefficients obtained were identical in direction and there was not much difference between phenotypic and genotypic estimates. This indicated that environment did not play a major role on relationship among different traits. Hence, selection is based on phenotypic performance of different traits (Table 2).

Plant height registered positive association with yield (0.582). The mean yield of

indeterminate hybrids could be due to higher number of branches, number of branches per plant had a positive correlation (0.025) with fruits per plant as reported by Singh and Singh (9). In the present investigation, Positive and significant association was expressed by single fruit weight with fruit yield per plant (0.610).

Knowledge on the inter correlation among the component characters revealed the nature and extent of relationship with each other. This will help for the simultaneous improvement of different traits along with fruit yield. Plant height showed positive association with fruit yield. Root /shoot ratio had negative and significant associationship with fruit yield (0.501).). Plant height also showed negative significant correlation with chlorophyll stability index (-0.29), root length (-0.39) and dry matter accumulation (-0.28). Plant height is significantly and positively associated with flowering duration and single fruit weight (0.51). Number of fruit per plant was significantly positive relation (0.71) with flowering duration. Longer flowering duration provides chance of setting more fruits. Style elongation had significant and negative correlation (-0.41) with number of fruits per plant indicating that long style will reduce fruit setting. Root length had significant and positive correlation with number of fruits per plant (0.29). This is in agreement with the results by Natarajan (5). Number of primary branches per plant had positive and significant correlation with flowering duration (0.37). Style elongation (-0.38) and Root I shoot ratio (0.23) ratio were significantly and negatively correlated with number of primary branches per plant. Flowering duration was significant and negatively correlated with style elongation (0.39) and root/shoot ratio (0.33) and root length (0.27). Root / shoot ratio had positive and significant association with Style elongation (0.32), Root length (0.27) and Dry matter accumulation (0.51).

From the foregoing discussion, it may be concluded that intensive selection on positive side for Number of fruits per plant, Plant height, Number of primary branches per plant and Flowering duration will increase the fruit yield, since these characters showed significantly positive correlation with fruit yield and positive correlation among themselves except the associationship between Number of fruits per plant and Single fruit weight. Style elongation was negatively correlated with fruit yield which supported the selection for short styled flowers to improve the yield. Chlorophyll stability index, Root length, Root I shoot ratio and Dry matter accumulation had negative correlation with the fruit yield. Hence, intensive selection, for these characters will, however, reduce the yield and compromise towards selection is required for these characters.

Among the traits subjected to path analysis, fruit weight exerted very high direct effect of number of fruits per plant. The direct effect of number of fruits per plant was also appreciably high towards yield per plant (Table 3).

Although the indirect effect of single fruit weight through other characters was negligible, single fruit weight alone had positive and very high direct effect on fruit yield. Therefore, single fruit weight was the major contributing character on which selection pressure is to be applied for increasing the fruit yield.

The results obtained from correlation studies are also confirmed by path analysis which indicates selection should be based on more number of fruit yield and single fruit weight. The residual effect was quite low (0.196) indicating that the traits had a significant role towards the improvement of yield potential of tomato.

Table 1. Analysis of variance of RBD for different characters

						Mean squares						
Source	df	Plant Height	Number of fruits per plant	Number of primary branches per plant	Flowering duration	Single fruit weight	Fruit Yield per plant	Chlorophyll stability index	Style Elongation	Root length	Root / shoot ratio	Dry matter accumulation
Replication.	I	0.558	0.080	0.002	0.756	0.170	0.001	0.005	0.005	0.237	0.001	0.014
Treatments	35	211.408*	189.634*	6.652*	269.875*	38.312*	0.284*	40.789*	2.433*	19.344*	0.005*	51.545*
Error	35	1.798	0.352	0.267	0.673	0.580	0.002	0.114	0.014	0.169	0.001	0.148
Total	71	213.764	190.234	6.921	271.304	39.062	0.287	40.908	2.452	19.750	0.005	51.707

** Significant at* 5 *per cent level*

Table 2. Phenotypic (P) and genotypic (G) correlation coefficients between fruit yield and different characters

Characters		Plant height	No. of fruits plant	No. of primary branches per plant	Single fruit weight	Flowering duration	Chlorophyll stability index	Style elongation	Root length	Root / shoot ratio	Dry matter accumulation	Fruit Yield per plant
Plant height	P	1.00	0.07	0.11	0.50*	0.33*	-0.29*	-0.20	-0.38*	-0.55*	-0.27*	0.57*
	G	1.00	0.07	0.12	0.51 *	0.34*	-0.29*	-0.21	-0.39*	-0.57*	-0.28*	0.58*
No. of fruits per plant	P		1.00	0.30*	-0.35*	0.70*	0.20	-0.41*	0.29*	-0.15	-0.16	0.49*
	G		1.00	0.31*	-0.35*	0.71 *	0.20	-0.41*	0.29*	-0.16	-0.16	0.49*
No. of primary branches per plant	P			1.00	-0.10	0.37*	0.05	-0.36*	-0.05	-0.22*	-0.16	0.24*
	G			1.00	-0.11	0.37*	0.05	-0.38*	-0.04	-0.23*	-0.17	0.25*
Single fruit weight	P				1.00	-0.17	-0.42*	0.01	-0.23*	-0.36*	-0.27*	0.61*
	G				1.00	-0.17	-0.42*	0.01	-0.23*	-0.37*	-0.27*	0.61*
Flowering duration	P					1.00	-0.02	-0.38*	-0.16	-0.46*	-0.1 0	0.47*
	G					1.00	-0.02	-0.39*	-0.17	-0.47*	-0.10	0.49*
Chlorophyll stability index	P						1.00	-0.01	0.26*	0.32*	0.16	-0.22*
	G						1.00	-0.01	0.27*	0.33*	0.17	-0.22*
Style elongation	P							1.00	0.09	0.31 *	-0.04	-0.30*
	G							1.00	0.09	0.32*	-0.04	-0.34*
Root length	P								1.00	0.27*	-0.03	-0.01
	G								1.00	0.27*	-0.03	-0.01
Root / shoot ratio	P									1.00	0.50*	-0.49*
	G									1.00	0.51*	-0.51*
Dry matter accumulation	P										1.00	-0.36*
	G										1.00	-0.36*
Fruit yield per plant	P											1.00
	G											1.00

* *Significant at* 5 *per cent level*

Table 3. Direct and Indirect effects of different traits on fruit -yield

Characters	Plant height	No. of fruits per plant	No. of primary branches per plant	Single fruit weight	Flowering duration	Chlorophyll stability index	Style elongation	Root length	Root *I* shoot ratio	Dry matter accumulation	Correlation coefficient with fruit yield
Plant height	0.083	0.050	0.011	0.437	0.035	-0.004	-0.093	-0.011	-0.011	-0.004	0.582*
No. of fruits per plant	0.006	0.688	0.028	-0.303	0.073	0.003	-0.006	0.008	-0.003	-0.002	0.493*
No. of primary branches per plant	0.010	0.211	0.091	-0.091	0.039	0.001	-0.006	-0.001	-0.004	-0.002	0.247*
Single fruit weight	0.042	-0.242	-0.010	0.861	-0.018	-0.006	0.000	-0.006	-0.007	-0.004	0.610*
Flowering duration	0.028	0.490	0.034	-0.148	0.103	0.000	-0.006	-0.005	-0.009	-0.001	0.486*
Chlorophyll stability index	-0.024	0.135	0.005	-0.368	-0.002	0.015	0.000	0.008	0.006	0.002	-0.223*
Style elongation	-0.017	-0.281	-0.034	0.007	-0.040	0.000	0.015	0.003	0.006	-0.001	-0.344*
Root length	-0.032	0.200	-0.004	-0.195	-0.018	0.004	0.001	0.029	0.005	0.000	-0.010
Root *I* shoot ratio	-0.048	-0.108	-0.021	-0.319	-0.049	0.005	0.005	0.008	0.019	0.007	-0.501 *
Dry matter accumulation	-0.023	-0.113	-0.015	-0.228	-0.010	0.003	-0.001	-0.001	0.010	0.014	-0.364*

Residual effect = 0.196 Bold values are direct effects

* *Significant at* 5 *per cent level*

References

Anbu S 1986. Breeding for heat tolerance in tomato *(Lycopersicon esculentum* Mill.) Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamol Nadu.

Dewey DR and Lu KH 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 51: 515-518.

Indu Rani C 2002. Studies on the development of Fl hybrids in tomato *(Lycoperiscon esculentum* Mil.) for high yield and processing qualities with resistance to root knot nematode_ *(Meloidogyne incognita).* Ph.D. Hort.) Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Miller PA, Williams JC, Robinson HF and Comstock RE 1953. Estimates of genotypic and environmental variances and covariances in upland cotton and their implication in selections. *Agron J.* 50: 126-131

Natarajan S 1988. Genetics of certain quantitative traits of tomato under moisture stress. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Patil AA and Bojappa KM 1993. Studies on phenotypic and genotypic correlation on growth, yield and quality attributes in tomato *(Lycopersicon esculentum* Mil.). *Karnataka J. Agric. Sci.* 6 (2): 133-136.

Ratnamnadar C, Muthikrishnan CR, Irulappan I and Shanmugasubramanian A 1980. Variability studies in tomato *(Lycopersicon esculentum* MilL). *South Indian Horticulture* 28 (4): 123-127.

Sankari A 2000. Studies on the development of FI hybrids in tomato *(Lycopersicon esculentum* Mil.) with high yield and resistance to tomato leaf curl virus. Ph.D. (Hort.) Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Singh RR and Singh HN 1980. Correlation studies in tomato. *Indian J. Agri. Sci.*, 50: 595-598

Identification of new restorer and maintainer lines for the existing elite male sterile lines of sunflower (*Helianthus annus* L.)

Manjunatha YS, Gangappa E, Shadakshari YG and Yogeesh LN
Department of Genetics and Plfant Breeding, University of Agricultural Sciences, GKVK, Bangalore, Karnataka- 560 065.

Abstract

A study was undertaken to test 38 new inbred lines of sunflower for their behaviour as maintainers or as restorers with CMS 234A, CMS 851A and CMS 852A belonging to PET-1 source of cytoplasm at ZARS, GKVK, Bangalore during kharif 2004. Individual F_1 plants were screened for fertility and sterility based on anther dehiscence and pollen shedding. A total of 18 inbred lines behaved as common restorers by restoring fertility in all the three CMS lines and four inbreds behaved as common maintainers of sterility. Some inbreds behaved as partial restorers of fertility indicating the presence of restorer gene in heterozygous condition or the presence of modifying genes to influence fertility and appearance of partial fertility.

Key words: CMS lines, PET-1, inbred lines, maintainers, restorers, and partial restorers

Introduction

Sunflower is the major oilseed crop to join the ever growing list of cultivated species in which heterosis is being exploited. Heterosis breeding has evolved successfully since the discovery of Cytoplasmic Male Sterility (CMS), *Petiolaris* (PET-1) source by Leclercq (1969) in the progeny of the cross between *Helianthus petiolaris* Nutt and cultivated sunflower (cv. Armavirskii 9345). Simultaneously, identification of genes for fertility restoration by Kinman (1970); Enns *et al.* (1970) and Vranceanu and Stoenescu (1971) gave the added fillip that resulted in the launch of commercial hybrid seed production in sunflower using CMS source. Though 40 different CMS sources have been reported in sunflower (Serieys, 1994), the availability of effective fertility restorers for all these CMS sources is limited in the available germplasm (Reddy *et al.*2002) and the knowledge on the inheritance of fertility restoration by the newly identified restorers is also not clear.

Apart from this, CMS-F/PET1 is stable across the environments (Miller, 1987) and hence is used extensively in sunflower commercial hybrid seed production. The lack of effective restorers for new CMS sources could be compensated to certain extent through the diversification of restorers base for PET based CMS lines and thus exploiting the hybrid vigour to enhance the sunflower productivity. With this background a study was undertaken to identify new fertility restorer and maintainer lines from the new sunflower inbred lines for the CMS 234A, CMS 851A and CMS 852A, the established male sterile lines of sunflower.

Material anad Methods

Thirty eight new sunflower inbred lines were screened to establish their restorer or maintainer behaviour on three elite CMS lines *viz.,* CMS 234A, CMS 851A and CMS 852A belonging to PET-1 cytoplasm. Each of the inbred lines were crossed with all the CMS lines during *Rabi* 2003-2004 and the resulting F_1 hybrids were evaluated during *Kharif* 2004. Each hybrid was raised in a single row of 3.0 m length with a spacing of 60 cm between the rows and 30 cm between the plants within a row. Necessary package of practices and plant protection measures were followed to raise a healthy crop.

All the plants in the F_1's were visually screened for male fertility or sterility reaction to know the restorer or maintainer behaviour of inbred lines based on anther dehiscence and pollen shedding at the anthesis stage. Based on the results obtained the inbred lines used in the study were classified as maintainer, if all the F_1 plants were sterile; restorers, if all the F_1 plants were fertile and as partial restorers, where some of the plants showed normal fertility and some plants normal sterility reaction in the F_1 progenies.

Results and Discussion

The results pertaining to fertility restoration in the 114 crosses using three elite CMS cytoplasm are presented in the (Table-1). Out of 38 new inbred lines tested, 20 inbred lines *viz.,* VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7, PS-5016-1 and 128-2 were effective restorers for CMS 234A background. The inbred lines, VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7, PS-5016-1, 128-2 and LIB-2S-3 proved to be effective restorers for CMS 851A. While, VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7 and ACC-1147 behaved as effective restorers for CMS 852A (Table-2).

As many as 18 inbred lines restored the fertility in all the three CMS lines and behaved as common restorers for CMS 234A, CMS 851A and CMS 852A; while four inbred lines *viz.,* 4060, SOF-133, X-15-NB-1 and 4059 behaved as common maintainers for all the CMS lines. This indicated that, though CMS lines differed by nuclear background, the fertility restoring or sterility-maintaining gene might be same. The inbreds X-55-NB-4, 4004, 1078, 1002, 4035, SOF-133-1, 1021, 1147-4, 1079 and X-15-NB-2 restored partial fertility in all the CMS lines indicating the presence of restorer gene in heterozygous condition or a possible contamination with the unknown pollen. Hence these cross needs to be tested for additional confirmation. Further, these inbreds can also be selfed for two or more generations until they are fully homozygous and then crossing could be effected. This could develop new restorer lines developed for the existing CMS lines.

The results also revealed that the inbred lines PS-5016-1 and 128-2 behaved as fertility restorer lines for CMS 234A and 851A, but behaved as partial restorers for 852A. The inbreds ACC-1147 and 1361-1 acted as maintainers of 234A and 851A, but behaved as restorer and partial restorer for 852A, respectively. The inbred ACC-873 acted as maintainer for 234A and as partial restorer for 851A and 852A, whereas LIB-2S-3 behaved as partial restorer for 234A and 852A and as a restorer for 851A. It is evident from the present investigation that few inbreds behaved differentially with the three nuclear backgrounds in respect of maintainer and restorer behaviour. Similar results were also reported by Manivannan *et al.* (2002) and Wankhade *et al.* (2004) suggesting the influence of modifying genes for fertility restoration to exhibit partial fertility. As the complexities in the inheritance of partial restoration could be due to high dependency on environment conditions (Wankhade *et al.*, 2004), a detailed investigation with respect to partial and total fertility restoration against the same cytoplasmic background needs to be carried out.

The inbreds identified as maintainers for different nuclear backgrounds, after testing for combining ability and agronomic performance, can be converted into new cytoplasmic male sterile lines for their utilization in heterosis breeding programme or can be used in synthesizing three way cross hybrids with better heterosis and resistance to pest and diseases.

Table 1. Restorer or maintainer reaction of new inbred lines under three nuclear backgrounds of PET-1 CMS cytoplasm in sunflower

Sl. No.	Inbred Genotype	CMS 234A	CMS 851A	CMS 852A
1	VNB-NB-5	R	R	R
2	PS-5016-1	R	R	PR
3	X-55-NB-4	PR	PR	PR
4	128-2	R	R	PR
5	4004	PR	PR	PR
6	5020	R	R	R
7	1078	PR	PR	PR
8	1002	PR	PR	PR
9	4060	M	M	M
10	SOF-133-2	R	R	R
11	4035	PR	PR	PR
12	SOF-133	M	M	M
13	1361-1	M	M	PR
14	SOF-133-1	PR	PR	PR
15	1021	PR	PR	PR
16	X-15NB-10	R	R	R
17	ACC-873	M	PR	PR
18	PS-5016	R	R	R
19	X-15NB-1	M	M	M
20	SFW-1	R	R	R
21	X-15-NB-6	R	R	R
22	ACC356	R	R	R
23	1147-4	PR	PR	PR
24	NB-55-NB-13	R	R	R
25	ACC-1147	M	M	R
26	1079	PR	PR	PR
27	1538-5	R	R	R
28	NB-55-NB-5	R	R	R
29	VNB-1	R	R	R
30	X-15-NB-5	R	R	R
31	4059	M	M	M
32	1004	R	R	R
33	DS-2	R	R	R
34	PASF-110-8	R	R	R
35	PS2001	R	R	R
36	VNB-NB-7	R	R	R
37	LIB-2S-3	PR	R	PR
38	X-15NB-2	PR	PR	PR

M: Maintainer R: Restorer PR: Partial Restorer

Table 2. Frequencies of maintainers, restorers and partial restorer lines for three nuclear backgrounds of PET- 1 CMS cytoplasm.

CMS Lines	Tested Inbreds	Number of lines behaved as		
		Maintainers	Restorers	Partial Restorers
CMS 234A	38	7	20	11
CMS 851A	38	6	21	11
CMS 852A	38	4	19	15

References

Enns H, Dorrell DG, Hoes JA and Chubb WO 1970. Sunflower research– A Progress report. Proc. 4 thInter. Sunflower Conf., Memphis, U.S.A.: 162-168.

Kinman ML 1970. New developments in USDA and state experiment station sunflower breeding progarmmes. Proc. 4th Inter. Sunflower Conf., Memphis, Tennessee, U.S.A.: 181-183.

Leclercq P 1969. Une sterilite male cytoplasmique chez le tournesol. *Annales del' Ameloration des Plantes* 19: 99-106.

Manivannan N, Muralidharan V and Subbalakshmi B 2002, Fertility restoration in CMS lines in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 19: 110.

Miller JF 1987. Sunflower. *In: Principles of cultivar development* Vol. 2. Mac Millian Publ. Co., New York: 626-668.

Reddy VA, Trinadh Kumar G, Sudheer Kumar S and Sokka Reddy S 2002. Inheritance of fertility restoration for different CMS sources in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 19: 178-180.

Serieys H 1994. Identification, study and utilization in breeding progarmmes of new CMS sources for the period 1991-1993- Report on the past activities of the FAO working group. *Helia* 17: 93-102.

Vranceanu AV and Stoenescu FM 1971. Pollen fertility restorer gene from cultivated sunflower. *Euphytica* 20: 536-541.

Wankhade RR, Rajput JC, Halakude IS, Kulkarni MP, Sawarkar NW and Dalvi PA 2004. Identification of fertility restorers for CMS lines in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 21: 156-157.

Exploitation of heterosis in sesame (*Sesamum indicum* L.)

Gangappa E, Veena T, Reddy BGS, Manjunatha YS and Yogeesh LN
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, GKVK, Bangalore-560 065.

Abstract

A study was undertaken to develop sesame hybrids and to estimate standard heterosis over two standard checks, TC-25 and E-8. The material for the study consisted of 80 hybrids synthesized with 16 lines and five testers and was evaluated during summer 1999-2000. Observations were recorded on plant height, number of branches per plant, number of capsules per plant, days to 50 per cent flowering, days to maturity, 1000 seed weight, seed yield, oil content and oil yield. The results indicated that, no single cross expressed significant positive heterosis for all the traits. However, the cross combination VR-11 x TMV-3 showed higher heterosis for plant height and number of capsule per plant. The cross combination Kayamkulam x Surya and CO-1 x TMV-3 exhibited higher heterosis for seed yield and oil yield, respectively. It could be seen from the results that, TMV-3 among the testers and Kayamkulam among the lines were the parents to pass on the increasing alleles for traits like seed yield and oil yield. Further, the study also suggested that, the reproductive system in sesame is amenable for heterosis breeding.

Key words: Sesame, heterosis, seed yield, oil yield.

Introduction

Though India accounts for 27 per cent of sesame (*Sesamum indicum* L.) world's production in about 40 per cent of world's area, the average productivity of is a meager 300-400 kg/ha as against its potential of 700-800 kg/ha. Looking into the low yield levels, susceptibility to pests and diseases, the best way to enhance the sesame crop productivity could be through heterosis breeding. The utilization of heterosis as a means of maximizing the yield of agricultural crops has become one of the most important methods in plant breeding. Exploitation of heterosis, which is a quick and convenient way of combining desirable characters assumed greater significance and is often exploited to increase the yield potential of crop plants. The success of hybrid technology in self-pollinated crops like cotton and rice has given the required impetus for developing heterotic hybrids in sesame. Sesame is a very ideal crop among the self-pollinated crops to exploit heterosis on a commercial scale, as it requires low seed rate, has high seed multiplication ratio, has epipetalous floral structure enabling easy emasculation and pollination. Keeping these points in view, an attempt was made to synthesis hybrids in sesame and to estimate the heterosis over two checks, TC-25 and E-8.

Materials and Method

The material for the study comprised of 16 lines and five testers. The F_1 material was generated by effecting crosses during 1998-1999. The resulting 80 hybrids along with two standard checks, TC-25 and E-8 were sown at ZARS, UAS, GKVK, Bangalore during *summer* 1999-2000. The experiment was laid out in the Simple Randomized Block Design (RBD) with two replications. Each genotype was sown in a single row of 3.0 m length with a row-to-row spacing of 30 cm and 10 cm between plants within a row. All the recommended agronomic practices were adopted for raising a healthy crop. Data was recorded on five randomly selected plants from each entry from each replication for plant height, number of branches per plant, number of capsules per plant, days to 50 per cent flowering, days to maturity, 1000 seed weight, seed yield, oil content and oil yield. The data thus obtained was subjected for estimation of standard heterosis as per Turner (1953) and Hayes (1955).

Results and Discussion

The estimates of heterosis over two standard checks *viz.,* TC-25 and E-8 for nine quantitative traits are presented in the Table-1. It is evident from the results that majority of the cross combinations were significantly late to flower compared to standard check TC-25 and E-8 as indicated by the significant positive heterosis. However, the cross combinations, Navile x Ph- till and E-8 x Tapi showed negative heterosis over both the parents.

As par as plant height was concerned more than 50 per cent of hybrids were taller than TC-25 and 25% were taller than standard parent E-8 as indicated by positive heterosis. Tyagi and Singh (1981), Desai *et al.* (1984) and Ray and Sen (1992) reported significant positive heterosis over better parent in sesame. However, two hybrids namely, Navile x Ph-till and Kanakapura local x JMV-3 were significantly shorter than the checks.

The hybrids MT-2 x TMV-3 showed heterosis up to 168 and 157.69 per cent, respectively, over TC-25 and E-8 followed by VR-11 x TMV-3. Tyagi and Singh (1981), Dora and Kamala (1986) and Singh *et al.* (1986) reported that hybrids expressed increased mean expression. However, low or absence of heterosis for number of branches per plant was reported by Murthy (1979), Shrivas and Singh (1981) and Krishnadoss and Kadambavanasundaram (1987).

The cross VR-11 x TMV-3 manifested 232.14% heterosis over TC-25 and 86.93% heterosis over the standard check E-8, for number capsule/plant. Although significant variation was observed among the hybrids for test weight, majority of hybrids registered relatively lower heterosis over standard checks. The hybrid combination, UMA 43 x Ph-till manifested 13.28% and 24.42% heterosis, respectively, over TC-25 and E-8 for test weight. The low levels of heterosis for test weight could be attributed to low *gca* to *sca* ratio. Tyagi and Singh (1981) and Anitha and Stephan Dorairaj (1990) have also reported in sesame.

As regards to seed yield, the cross combination Kayamkulam x Surya registered 165.43% heterosis over E-8 and 66.99% over TC-25. Several workers like Tyagi and Singh (1981) and Anand kumar (1995) also reported high heterosis for seed yield.

For oil content, the cross combinations Kayamkulam x Tapi recorded 17.07% heterosis over TC-25 and 16.53% heterosis over E-8 followed by DS-1 x Surya. Low levels of heterosis for oil content were reported by Tyagi and Singh (1981) and Chauhan and Sharma (1982). However, Murthy (1974) did not observe any heterosis for oil content in sesame. Further, with respect to oil yield, the cross CO-1 x TMV-3 out yielded TC-25 by 80.87% and E-8 by 186.11%.

From the above discussion, it could be inferred that, no single cross expressed significant positive heterosis for all the traits. However, cross combination VR-11 x TMV-3 showed higher heterosis for plant height and number of capsule per plant. The cross combination Kayamkulam x Surya and CO-1 x TMV-3 exhibited higher heterosis for seed yield and oil yield, respectively. It could be seen from the results that, among the testers, TMV-3 is a common parent in all the hybrids which manifested higher heterosis for plant height, number of branches/ plant, Number capsules/ plant and oil yield. Further, among the lines, Kayamkulam appears to be a good parent by virtue of its ability to nick well to pass on the increasing alleles for traits like oil content and seed yield. This is further supported by the fact that, these two parents manifested good *gca* effect. Hence, these two lines and their derivatives could be studied further to derive the superior segregants possessing the desirable attributes.

Further, this also indicates that, the reproductive system in sesame is amenable for manual hybrid seed production.

Table1. Estimation of standard heterosis for yield and yield attributes in sesame

Crosses	X_1		X_2		X3		X4		X5	
	TC-25	E-8	TC-25	E-8	TC-25	E-8	TC-25	E-8	TC-25	E-8
TMV-6 x Tapi	20.96 *	10.55	20	15.38	78.57 *	0.5	-1.32	-2.6	-4.43 **	-2.51
TMV-6 x Ph-till	18.65 *	8.44	84 *	76.92 *	118.45	22.95	-1.32	-2.6	-1.97	0
TMV-6 x Purvi	20.31 *	9.96	52	46.15	100 **	12.56	1.32	0	-13.3 **	-11.56 **
TMV-6 x TMV-3	31.76 **	20.42 *	20	15.38	120.24 **	23.95	9.21 **	7.79 **	-7.88 **	-6.03 **
TMV-6 x Surya	21.24 *	10.80	12	7.69	16.96	-34.17	1.32	0	-13.79 **	-12.06 **
YLH-17 x Tapi	31.95 **	20.59 **	64	57.69	110.71 **	18.59	-1.32	-2.6	-6.9 **	-5.03 **
YLH-17 x Ph-till	32.78 **	21.35 **	56	50	105.95 **	15.91	-2.63	-3.9	-0.99	1.01
YLH-17 x Purvi	35.09* *	23.46 **	80*	73.08 *	77.38*	-0.17	6.58**	5.19*	-7.39**	-5.53**
YLH-17 x TMV-3	40.17 **	28.10 **	64	57.69	147.92 **	39.53 *	14.47 **	12.99 **	-0.99	1.01
YLH-17 x Surya	19.85 *	9.54	4	0	52.08	-14.41	6.58 **	5.19 *	-4.93 **	-3.02 *
TC289 x Tapi	15.33	5.40	44	38.46	65.77	-6.70	-9.21 **	-10.39 **	-0.49	1.51
TC289 x Ph-till	14.73	4.85	30	25	42.26	-19.93	5.26 *	3.9	-2.96 *	-1.01
TC289 x Purvi	24.10 **	13.42	20	15.38	41.67	-20.27	3.95	2.6	-10.84 **	-9.05 **
TC289 xTMV-3	39.43 **	27.43 **	12	7.69	115.79 **	41.17 *	10.53 **	9.09 **	-14.78 **	-13.07 **
TC289 x Surya	28.81 **	17.72 *	40	34.62	88.1 **	5.86	2.63	1.3	-7.38 **	-5.53 **
Navile x Tapi	27.61 **	16.62 *	40	34.62	54.76	-12.9	-6.58 **	-7.79 **	-3.94 **	-2.01
Navile x Ph-till	-4.25	-12.49	12	7.69	66.67	-6.2	-11.84 **	-12.99 **	-12.81 **	-11.06 **
Navile x Purvi	27.42 **	16.46 *	64	57.69	54.17	-13.23	9.21 **	7.79 **	-13.79 **	-12.06 **
Navile x TMV-3	30.56 **	19.32 *	8	3.85	60.74	-9.55	9.21 **	7.79 **	-11.82 **	-10.05 **
Navile x Surya	20.96 *	10.55	76 *	69.23 *	26.49	-28.81	9.21 **	7.79 **	-0.99	1.01
Rajeshwari x Tapi	15.60	5.65	112 **	103.85	105.95 **	15.91	-1.32	-2.6	-5.91 **	-4.02 **
Rajeshwari x Ph-till	11.54	1.94	96 **	88.46 **	128.57 **	28.64	3.95	2.6	-5.91 **	-4.02 **
Rajeshwari x Purvi	23.36 **	12.74	16	11.54	63.99	-7.7	3.95	2.6	-8.87 **	-7.04 **

Rajeshwari x TMV-3	35.36**	23.71**	12	7.69	66.69	-6.2	-6.58**	-7.79**	-3.45**	-1.51
Rajeshwari x Surya	6.93	-2.28	-24	-26.92	63.39	-8.04	-9.21**	-10.39**	-8.87**	-7.04**
E-8 x Tapi	24.47**	13.76	-12	-15.38	51.19	-14.91	-11.84**	-12.99**	-11.82**	-10.05**
E-8 x Ph-till	15.05	5.15	72*	65.38*	115.48**	21.27	-3.95	-5.19*	-13.3**	-11.56**
E-8 x Purvi	10.80	1.27	16	11.54	19.05	-33.00	1.32	0	-10.3**	-8.54**
E-8 x TMV-3	31.58**	20.25*	4	0	56.25	-12.06	-1.32	-2.6	-12.81**	-11.06**
E-8 x Surya	25.48**	14.68	48	42.31	72.32*	-3.02	-3.95	-5.19*	-13.3**	-11.56**
ATPT 856 x Tapi	2.68	-6.16	40	34.62	84.52*	3.85	-5.26*	-6.49**	-14.29**	-12.56**
ATPT 856 x Ph-till	35.92**	24.22**	76*	69.23*	170.24**	52.09**	-6.58**	-7.79**	-9.36**	-7.54**
ATPT 856 x Purvi	9.14	-0.25	4	0	24.11	-30.15	2.63	1.3	-14.78**	-13.07**
ATPT 856 x TMV-3	37.4**	25.57**	24	19.23	64.29	-7.54	-3.95	-5.19*	-10.84**	-9.05**
ATPT 856 x Surya	21.98*	11.4	-20	-23.08	33.63	-24.79	-1.32	-2.6	-5.91**	-4.02**
VR-11 x Tapi	3.97	-4.98	60	53.85	92.56**	8.38	-1.32	-2.6	-12.32**	-10.55**
VR-11 x Ph-till	13.3	3.54	52	46.15	25.89	-29.15	-6.58**	-7.79**	-13.79**	-12.06**
VR-11 x Purvi	1.94	-6.84	12	-15.38	9.23	-38.53*	1.32	0	-6.9**	-5.03**
VR-11 x TMV-3	55.63**	42.24**	128**	119.23**	232.14**	86.93**	2.63	1.3	-9.85**	-8.04**
VR-11 x Surya	17.82*	7.68	60	53.85	55.06	12.73	1.32	0	-3.45**	-1.51
DS-1 x Tapi	25.3**	14.51	24	19.23	71.43*	-3.52	-6.58**	-7.79**	-14.78**	-13.07**
DS-1 x Ph-till	7.2	-2.03	36	30.77	100.89**	13.07	-6.58**	-7.79**	-12.81**	-11.06**
DS-1 x Purvi	23.64**	13.00	68*	61.54	91.07**	7.54	5.26*	3.9	-4.43**	-2.51
DS-1 x TMV-3	41.92**	29.70**	96**	86.46**	150**	40.7*	7.89**	6.49**	-5.42**	-3.52**
DS-1 x Surya	34.16**	22.62**	76*	69.23*	89.58**	6.7	3.95	2.60	-15.27**	-13.57**
TC-25 x Tapi	4.2	-4.77	24	19.23	42.26	-19.93	10.53**	9.9**	-7.39**	-5.53**
TC-25 x Ph-till	5.63	-3.46	24	19.23	85.71*	4.52	-9.21**	-10.39**	-15.27**	-13.57**
TC-25 x Purvi	20.31	9.96	8	3.85	73.51*	-2.35	1.32	0	-13.79**	-12.06**
TC-25 x	35.55*	23.88	24	19.23	38.1	-22.28	-9.21	-10.39	-6.90	-5.03

TMV-3	*	**					**	**	**	**
TC-25 x Surya	14.16	4.81	20	15.38	50	-15.58	-1.32	-2.6	-12.81 **	-11.06 **
Kanaka pura local x Tapi	7.48	-1.77	60	11.54	88.99 **	6.37	-1.32	-2.6	-4.43 **	-2.51
Kanaka pura local x Ph-till	4.16	-4.81	-28	-30.77	75 *	-1.51	-1.32	-2.6	-0.99	1.01
Kanaka pura local x Purvi	29.36 **	18.23 *	68 *	61.54	146.43 **	38.69 *	-1.32	-2.6	-13.79 **	-12.06 **
Kanaka pura local x TMV-3	-10.99	-18.65 *	4	0	32.74	-25.29	-1.32	-2.6	-5.91 **	-4.02 **
Kanaka pura local x Surya	16.25	6.24	44	38.46	55.36	-12.56	-1.32	-2.6	-13.30 **	-11.06 **
CO-1 x Tapi	4.06	-4.89 *	-12	-15.38	45.54	-18.09	-1.32	-2.6	-1.48	0.50
CO-1 x Ph-till	18.93 *	8.69	16	11.54	48.81	-16.25	-1.32	-2.6	-10.84 **	-9.05 **
CO-1 x Purvi	10.43	0.93	12	7.69	92.26 **	8.21	-6.58 **	-7.79 **	-0.49	1.51
CO-1 x TMV-3	18.19 *	8.02	48	42.31	79.17 *	0.84	0.00	-1.3	-0.99	1.01
CO-1 x Surya	8.86	-0.51	104 **	96.15 **	149.7 **	40.54 *	-1.32	-2.6	-12.81 **	-11.06 **
Uma-43 x Tapi	21.51 *	11.05	32	26.92	150.89 **	41.21 *	-1.32	-2.6	-5.91 **	-4.02 **
Uma-43 x Ph-till	1.57	-7.17	-8	-11.54	42.86	-19.6	-6.58 **	-7.79**	-10.34 **	-8.54 **
Uma-43 x Purvi	14.68	4.81	32	26.92	131.85 **	30.49	-6.58 **	-7.79 **	-13.79 **	-12.06 **
Uma-43 x TMV-3	22.9 **	12.32	52	46.15	168.45 **	51.09 **	-1.32	-2.6	-9.85 **	-8.04 **
Uma-43 x Surya	4.06	-4.89	-12.00	-15.38	44.05	-18.93	3.95	2.6	-5.91 **	-4.02 **
RT-264 x Tapi	21.14*	10.72	32.00	26.92	129.76 **	29.31	1.32	0.00	-9.36 **	-7.54 **
RT-264 x Ph-till	12.37	2.70	100.00 **	92.31 **	87.80*	5.7	1.32	0.00	-9.36 **	-7.54 **
RT-264 x Purvi	14.50	4.64	-12.00	-15.38	43.60	-19.18	9.21 **	7.79 **	-2.96 *	-1.01
RT-264 x TMV-3	7.11	-2.11	0.00	-3.85	69.34 *	-4.69	1.32	0.00	-6.90 **	-5.03 **
RT-264 x Surya	20.87 *	10.46 **	4.00	0.00	68.15 *	-5.36	3.95	2.60	-2.96 *	-1.01
MT-2 x Tapi	39.52* *	27.51	100.00 **	92.31 **	152.08 **	41.88 *	3.95	2.60	-9.85 **	-8.04 **
MT-2 x	25.21	14.42	48.00	42.31	47.92	-16.75	3.95	2.60	-9.36	-7.54

Ph-till	**								**	**
MT-2 x Purvi	11.08	1.52	108.00 **	100.00 **	66.07	-6.53	6.58 **	5.19 *	-9.85 **	-8.04 **
MT-2 x TMV-3	12.65	2.95	168.00 **	157.69 **	197.62 **	67.50 **	-1.32	-2.60	-2.46	-0.5
MT-2 x Surya	15.7	5.74	8.00	3.85	97.32 **	11.06	3.95	2.60	-1.48	0.5
Kayamkulam x Tapi	23.55 **	12.91	58.00	51.92	98.51 **	11.73	-9.21 **	-10.39 **	-12.81 **	-11.06 **
Kayamkulam x Ph-till	11.27	1.69	52.00	46.15	126.19 **	27.30	-2.63	-3.9	-12.32 **	-10.55 **
Kayamkulam x Purvi	17.73 *	7.59	88.00 *	80.77 *	64.58	-7.37	9.21 **	7.79 **	-13.30 **	-11.56 **
Kayamkulam x TMV-3	15.42	5.49	64.00	57.69	85.12 *	4.19	9.21 **	7.79 **	-3.94 **	-2.01
Kayamkulam x Surya	22.99 **	12.32	40.00	34.62	164.88 **	49.08 *	6.5 **	5.19*	-13.79 *	-12.06 **

	X6		X7		X8		X9	
Crosses	TC-25	E-8	TC-25	E-8	TC-25	E-8	TC-25	E-8
TMV-6 x Tapi	-31.34 **	-24.59 **	-3.46	-3.90	-68.35 **	-49.69 **	-69.37 **	-51.54 **
TMV-6 x Ph-till	-20.9**	-13.11 **	-3.11	-3.56	-28.93 **	12.96	-31.18 **	8.87
TMV-6 x Purvi	-22.39 **	-14.75 **	7.61 *	7.21 *	-67.57 **	-48.46 **	-65.17 **	-44.91 **
TMV-6 x TMV-3	-8.96 **	0.00	3.23	2.76	-59.42 **	-35.49 **	-58.08 **	-33.68 **
TMV-6 x Surya	-29.85 **	-22.95 **	9.11 *	8.61 *	-65.92 **	-45.83 **	-62.73 **	-41.04 **
YLH-17 x Tapi	-34.33 **	-27.87 **	-5.88	-6.31	-65.83 **	-45.68 **	-67.83 **	-49.12 **
YLH-17 x Ph-till	-29.85 **	-22.95 **	-3.92	-4.36	-59.42 **	-35.49 **	-60.95 **	-38.22 **
YLH-17 x Purvi	-37.31 **	-31.15 **	-3.23	-3.67	-69.32**	-51.23 **	-70.47 **	-53.29 **
YLH-17 x TMV-3	-29.85 **	-22.95 **	-1.61	-2.07	14.56 **	82.10 **	12.76 *	78.37 **
YLH-17 x Surya	-26.87 **	-19.67 **	2.77	2.30	-69.13 **	-50.93 **	-68.59 **	-50.31 **
TC289 x Tapi	-5.97	3.8	-1.15	-1.61	-1.94	55.86 **	-3.70	52.33 **
TC289 x Ph-till	-38.81 **	-32.79 **	1.15	0.69	-59.22 **	-35.19 **	-58.53 **	-34.40 **
TC289 x Purvi	-37.31 **	-31.15 **	2.19	1.72	-37.67 **	-0.93	-36.27 **	0.81
TC289 xTMV-3	-8.96 *	0.00	4.15	3.67	-72.82 **	-56.79 **	-71.69 **	-55.21 **
TC289	-26.87	-19.67	-4.15	-4.59	-33.98	4.94	-37.02	-0.38

x Surya	**	**			**		**	
Navile x Tapi	0.00	9.84 *	3.34	2.87	-29.63 **	11.85	-27.25 **	15.01
Navile x Ph-till	-29.85 **	-22.95 **	4.73	4.25	-73.98 **	-58.64 **	-72.67 **	-56.77 **
Navile x Purvi	-26.87 **	-19.67 **	4.5	4.02	-46.41 **	-14.81	-44.07 **	-11.52
Navile x TMV-3	-26.87 **	-19.67 **	7.5*	7.00	-76.50 **	-62.65 **	-74.76 **	-60.08 **
Navile x Surya	-26.87 **	-19.67 **	-2.42	-2.87	-37.28 **	-0.31	-38.73 **	-3.08
Rajeshwari x Tapi	-2.99	6.56	11.42 **	10.91 **	-40.00 **	-4.63	-33.12 **	5.80
Rajeshwari x Ph-till	2.99	13.11 **	4.61	4.13	2.33	62.65 **	7.07	69.37 **
Rajeshwari x Purvi	-29.85 **	-22.95 **	9.8 **	9.30 **	-53.79 **	-26.54 **	-49.17 **	-19.59 *
Rajeshwari x TMV-3	-1.49	8.2 *	3.81	3.33	-0.97	57.41 **	2.56	62.24 **
Rajeshwari x Surya	-2.99	6.56	12.00 **	11.48 **	-74.17 **	-58.95 **	-71.04 **	-54.18 **
E-8 x Tapi	-11.94 **	-3.28	10.50 **	9.99 **	-46.99 **	-15.74 *	-41.39 **	-7.28
E-8 x Ph-till	-4.48	4.92	7.84*	7.35 *	-66.60 **	-46.91 **	-63.97 **	-43.01 **
E-8 x Purvi	-28.36 **	-21.31 **	1.96	1.49	-61.94 **	-39.51 **	-61.22 **	-38.65 **
E-8 x TMV-3	-14.93 **	-6.56	2.77	2.3	-73.79 **	-58.33 **	-73.04 **	-57.35 **
E-8 x Surya	-17.91 **	-9.84 *	5.65	5.17	-73.20 **	-57.41 **	-71.68 **	-55.20 **
ATPT 856 x Tapi	-11.94 **	-3.28	5.54	5.05	10.68 *	75.93 **	16.80 **	84.77 **
ATPT 856 x Ph-till	-32.84 **	-26.23 **	-1.73	-2.18	-49.42 **	-19.6 *	-50.32 **	-21.42 *
ATPT 856 x Purvi	-41.79 **	-36.07 **	-1.38	-1.84	-66.14 **	-46.17 **	-66.56 **	-47.11 **
ATPT 856 x TMV-3	-26.89 **	-19.67 **	-1.61	-2.07	-76.12 **	-62.04 **	-76.54 **	-62.73 **
ATPT 856 x Surya	-32.84 **	-26.23 **	-2.77	-3.21	-71.65 **	-54.94 **	-72.46 **	-56.43 **
VR-11 x Tapi	-25.37 **	-18.03 **	3.11	2.64	-39.03 **	-3.09	-37.22 **	-0.69
VR-11 x Ph-till	-28.36 **	-21.31 **	-1.96	-2.41	-69.71 **	-51.85 **	-70.47 **	-53.28 **
VR-11 x Purvi	-34.33**	-27.87 *	0.23	-0.23	-71.46 **	-54.63 **	-71.47 **	-54.86 **
VR-11 x	-35.85	-29.51	2.08	1.61	-73.79	-58.33	-73.29	-57.75

TMV-3	**	**			**	**	**	**
VR-11 x Surya	-31.34 **	-24.59 **	4.15	3.67	-69.13 **	-50.93 **	-69.87 **	-49.18 **
DS-1 x Tapi	-20.90 **	-13.11 **	-1.15	-1.61	-78.83 **	-66.36 **	-79.13 **	-66.98 **
DS-1 x Ph-till	-34.63 **	-28.20 **	7.61 *	7.12 *	-53.59 **	-26.23 **	-50.07 **	-21.01 *
DS-1 x Purvi	-50.75 **	-45.90 **	8.01 *	7.58 *	67.18 **	-47.84 **	-64.72 **	-44.20 **
DS-1 x TMV-3	-51.04 **	-46.23 **	4.04	3.56	-67.07 **	-47.65 **	-65.82 **	-45.93 **
DS-1 x Surya	-13.43 **	-4.92	12.69 **	12.17 **	-48.74 **	-18.52 *	-42.82 **	-8.70 **
TC-25 x Tapi	-34.33 **	-27.87 **	10.61 **	10.10 **	-59.42 **	-35.49 **	-55.10 **	-28.97 **
TC-25 x Ph-till	-23.88 **	-16.39 **	9.69 **	9.18 *	-20.97 **	-25.62 **	-13.41 *	-36.97 **
TC-25 x Purvi	-16.42 **	-8.20 *	2.77	2.30	-66.60 **	-46.91 **	-65.57 **	-45.85 **
TC-25 x TMV-3	-41.79 **	-36.07 **	-0.81	-1.26	-73.59 **	-58.02 **	-73.75 **	-58.48 **
TC-25 x Surya	-35.82 **	-29.51 **	8.42 *	7.92 *	-65.44 **	-45.06 **	-62.51 **	-40.69 **
Kanaka pura local x Tapi	-8.96 *	0.00	3.11	2.64	-5.44	50..31 **	-2.59	54.10 **
Kanaka pura local x Ph-till	-23.88 **	-16.39 **	8.07 *	7.54 *	-38.25 **	-1.85	-33.30 **	5.50
Kanaka pura local x Purvi	-32.84 **	-26.33 **	-0.58	-1.03	-58.25 **	-33.64 **	-58.59 **	-34.49 **
Kanaka pura local x TMV-3	-16.42 **	-8.20 **	9.23 *	8.73 *	-20.19 **	91.05 **	-31.26 **	107.63 **
Kanaka pura local x Surya	-23.88 **	-16.39 **	-1.04	-1.49	-12.23 *	78.40 **	-10.94 *	74.49 **
CO-1 x Tapi	-28.36 **	-21.31 **	1.50	1.03	-76.31 **	-62.35 **	-75.99 **	-62.02 **
CO-1 x Ph-till	-11.94 **	-3.28	2.42	1.95	-19.42 **	28.0 **	-17.41 **	30.64 **
CO-1 x Purvi	-7.46 *	1.64	4.96	4.48	-29.90 **	11.42	-26.27 **	16.63 **
CO-1 x TMV-3	-17.91 **	-9.84 *	8.42 *	7.92 *	-66.99 **	165..43 **	80.87 **	186.11 **
CO-1 x Surya	-8.96 *	0.00	3.58	3.10	-21.94 **	93.83 **	26.20 **	99.63 **
Uma-43 x Tapi	0.00	9.84 *	8.77 *	8.27 *	-7.38	47.22 **	0.78	59.42 **
Uma-43 x Ph-till	13.28 **	24.43 **	-5.42	-5.86	-66.41 **	-46.60 **	-68.18 **	-49.66 **

Uma-43 x Purvi	-17.76 **	-9.67 *	-2.08	-2.53	-72.82 **	-56.79 **	-73.43 **	-57.96 **
Uma-43 x TMV-3	-17.01 **	-8.85 *	-1.73	-2.18	-13.01 **	38.27 **	-14.43 **	35.36 **
Uma-43 x Surya	-35.82 **	-29.51 **	-3.81	-4.25	-76.50 **	-62.65 **	-77.44 **	-64.31 **
RT-264 x Tapi	-10.45 **	-1.64	-2.77	-3.21	-4.58	51.67 **	-7.24	46.74 **
RT-264 x Ph-till	-25.37 **	-18.03 **	-4.27	-4.71	-70.87 **	-53.70 **	-72.00 **	-55.71 **
RT-264 x Purvi	-35.82 **	-29.51 **	-3.69	-4.13	-67.9 6**	-49.07 **	69.40 **	-51.59 **
RT-264 x TMV-3	-28.36 **	-21.31 **	-1.96	-2.41	-65.98 **	-45.90 **	-66.76 **	-47.42 **
RT-264 x Surya	-38.81 **	-32.79 **	0.12	-0.34	-77.86 **	-64.81 **	-77.79 **	-64.86 **
MT-2 x Tapi	-8.96 *	0.00	-1.27	-1.72	-85.73 **	-77.31 **	-85.50 **	-77.06 **
MT-2 x Ph-till	-20.90 **	-13.11 **	-0.58	-1.03	-75.34 **	-60.80 **	-75.56 **	-61.34 **
MT-2 x Purvi	-38.81 **	-32.79 **	-3.92	-4.56	-67.38 **	-48.15 **	-68.56 **	-50.27 **
MT-2 x TMV-3	-2.69 **	6.89	-5.19	-5.63	32.04 **	109.88 **	25.12 **	97.92 **
MT-2 x Surya	-31.34 **	-24.59 **	-3.23	-3.67	-51.46 **	-22.84 **	-53.12 **	-25.84 **
Kayamkulam x Tapi	-1.49 **	8.20 *	17.07 **	16.53	8.82	72.96 **	27.45 **	101.62 **
Kayamkulam x Ph-till	-17.91 **	-9.84 *	-3.58	-4.02	11.46	77.16 **	7.62	70.23 **
Kayamkulam x Purvi	-17.91 **	-9.84 *	-4.15	-4.56	-44.66 **	-12.04	-46.64 **	-15.60
Kayamkulam x TMV-3	-35.82 **	-29.51 **	-2.31	-2.79	-69.13 **	-50.93 **	-69.93 **	-52.43 **
Kayamkulam x Surya	-2.99	6.56	-2.88	-3.33	66.99 **	165.45 **	61.66 **	155.72 **

X_1= Plant height X_2=No. of Branches X_3 =No. of capsules per plant X_4= Days to 50% flowering X_5= Days to maturity X_6= Test weight (g) X_7 = Oil content (%) X_8= Seed yield (kg/ha) X_9= Oil yield (kg/ha)

References

Anand Kumar CR 1995. Heterosis and inbreeding depression in sesame. *J. Oilseeds Res.* 12: 100-120.

Anitha and Stephan Dorairaj M 1990. *Per se* performance of parents and hybrids in sesame. *Madras Agric. J.* 79: 401-405.

Chauhan BPS and Sharma RL 1983. Heterosis and inbreeding depression in sesamum. *Madras Agric. J. 70*: 561-566.

Desai NM, Shah RM and Kukadia MU 1984. Hybrid vigour in sesame. *Gujarat Agril. Univ. Res. J.* 9: 69-71.
Dora KB and Kamala T 1987. Heterosis and gene action in Sesame. *Indian J. Agric, Sci.* 56: 690-696.

Hayes HK, Immer FR and Smith DC 1955. Methods of Plant Breeding. Mc Graw Book company Inc., New York, 551pp.

Krishnadoss D and Kadambavanasundaram M 1987. Study on heterosis or yield in sesame. *The Andra. Agric. J.* 32: 151-154.

Murthy DS 1974. Heterosis, combining ability and reciprocal effects for agronomic and chemical characters in sesame. *Theor. Appl. Genet.* 45: 294-299.
Ray SD and Sen S 1992. Heterosis in sesame (*Sesamum indicum* L.). *Trop. Agric.* 69: 276-278.

Singh VK, Singh HG and Chauvan YS 1986. Heterosis in sesame. *Farm Sci. J.* 1: 65.

Shrivas SR and Singh SP 1981. Heterosis and combining ability in Sesamum. *Indian J. Genet.* 41: 1-4.

Tyagi BP and Singh HG 1981. Heterosis in sesamum. *Indian J. Agric. Sci.* 51**:** 849-852.

Multilocational testing of certain elite genotypes of cardamom (*Elettaria cardamomum* Maton)

Radhakrishnan VV, Priya P Menon, Vadivel V, Madhusoodanan KJ, Kuruvilla KM and Thomas J
Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala– 685553.

Abstract

Three promising hybrids and one selection of cardamom viz., MHC-10, MHC-13, MHC-18 and MCC-21 evolved by the Indian Cardamom Research Institute were evaluated for three consecutive crop seasons at three locations of the cardamom tract such as Myladumpara (Kerala), Anakkara (Kerala) and Gudalur (Tamil Nadu) for their adaptability. Performance assessment of these elite genotypes with regard to growth and yield characters was made and compared with the released clone ICRI-2 and local varieties. The combined analysis of variance was done and the results indicated very high significant difference between the clones and also the interaction of the clones with the locations for the characters such as yield per clump, racemes per panicle and panicles per clump. The hybrid MHC-18 was found to be superior in all the locations. Large- scale cultivation of this clone is recommended in these locations for augmenting production and productivity of cardamom.

Key words*:* Cardamom, *Elettaria cardamomum*, multilocational testing.

Introduction

Small cardamom (*Elettaria cardamomum* Maton) known as the "Queen of Spices" is one of the most important spice crops endemic to the tropical wet evergreen forests of the Western Ghats. The cardamom production in India is 11,415 MT during 2004-2005 and it is obtained from an area of 73,725 ha covering the southern states of Kerala, Karnataka and Tamil Nadu (Spices Board, 2005). Though India accounts for the largest area under cardamom, productivity is only 208 kg/ha, which is very low compared to that of other producing countries. To augment production and productivity, large scale planting of genetically superior elite lines suited to different agro-climatic situations is imperative.

Crop improvement studies carried out at the Indian Cardamom Research Institute (ICRI), Myladumpara during the last decade has resulted in the evolution of large number of hybrids and selections of cardamom (Madhusoodanan *et al.*, 1993). On preliminary evaluation of these hybrids and selections, four of them such as MHC-10, MHC-13, MHC-18 (hybrids) and MCC-21 (selection) have been found to be promising with regard to yield and yield contributing attributes. These four elite genotypes have been subjected to performance evaluation along with the released clone ICRI-2 (Madhusoodanan and Radhakrishnan, 1996) and local check for three crop seasons at three locations of the cardamom tract for multilocational adaptability testing.

Materials and Methods

The study was carried out at three locations of the cardamom tract such as Myladumpara (Kerala), Anakkara (Kerala) and Gudalur (Tamil Nadu) during 1999-2005. The experiment was laid out in randomized block design with four replications and sixteen plants per plot adopting 3m x 3m spacing in all the three locations. Three hybrids of cardamom viz., MHC-10, MHC-13 and MHC-18 and one selection viz., MCC-21 that were found to be promising on preliminary evaluation and one released clone ICRI-2 and local check were planted. In all the cases vegetatively propagated suckers were used as planting materials. Package

of practices recommendations of the Spices Board was followed for cultivation (Spices Board, 1999). Growth parameters like total tillers, height of the tallest tiller, number of leaves on the tallest tiller, number of bearing tillers per clump, number of panicles per clump, number of racemes per panicle and number of capsules per raceme were recorded. Yield obtained after two years of planting was also recorded for three consecutive seasons and the cumulative yield was analyzed.

The combined analysis of variance was done for the three locations to estimate the average response to treatments and also to test the consistency of the responses from place to place i.e., the interaction of the treatment effects with the places. The meaningfulness of the average estimates of treatment responses would therefore depend largely upon the absence or presence of this interaction (Gomez and Gomez, 1983).

Results and Discussion

The performance of the elite clones varied with regard to growth and yield attributes in all the three locations (Tables 1 to 7). To work out the combined analysis of variance, the error mean squares for the different locations should be homogenous (Panse and Sukhatme, 1967). As the error mean squares in the case of total tillers, bearing tillers per clump and yield per clump were heterogenous for the three locations; weighted analysis of variance was performed. The characters such as total tillers per clump, bearing tillers per clump, panicles per clump, racemes per panicle and yield per clump showed significant difference for the average treatment effect as well as the interaction of the treatment effects with the locations. Cardamom being a commercial crop, more attention was paid for yield evaluation by earlier workers (Goerge *et al.*, 1981). High variability with regard to yield parameters in cardamom has been reported earlier (Korikanthimath *et al.*, 1997).

In the case of number of leaves per tiller there is no significant difference between the average performance of the clones and the interaction of the clones with the locations, where as for capsules per raceme the average performance of the clones differed significantly. Cumulative yield differed significantly among the genotypes and the hybrid MHC-18 performed the best in all the three locations with a yield of 1524 to 2400 kg/ha. Since cardamom is highly heterozygous, vegetative propagation is suggested to produce 'true to type' planting materials (Nadgauda *et al.*, 1983). Large-scale cultivation of MHC-18 is recommended in these locations for augmenting production and productivity of cardamom.

Table 1. Genotype x Environment interaction for total tillers

Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	56.68	97.05	81.16	36.09
MHC-13	60.32	96.99	80.75	42.40
MHC-18	50.00	110.25	101.66	41.71
MCC-21	67.41	92.51	63.97	33.00
ICRI-2	62.32	101.61	102.82	34.56
Local Check	58.14	93.14	89.36	35.61
CD(5%)	NS			
G at E . CD(5%)		13.84		
E at G . CD(5%)		14.64		

Table 2. Genotype x Environment interaction for bearing tillers				
Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	35.07	37.24	46.00	18.06
MHC-13	33.71	35.10	45.70	19.60
MHC-18	41.61	43.94	56.75	21.17
MCC-21	34.42	38.94	31.82	15.10
ICRI-2	35.96	38.29	55.01	13.05
Local Check	39.62	42.16	58.04	16.11
CD(5%)	NS			
G at E . CD(5%)		5.83		
E at G . CD(5%)		9.38		

Table 3. Genotype x Environment interaction for number of leaves				
Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	16.08	17.16	15.69	15.38
MHC-13	16.20	15.90	17.11	15.60
MHC-18	16.82	16.78	17.75	15.95
MCC-21	16.51	18.11	16.57	14.85
ICRI-2	16.63	17.85	17.08	14.97
Local Check	16.41	17.10	17.02	15.11
CD(5%)	NS			
G at E . CD(5%)		NS		
E at G . CD(5%)		NS		

Table 4. Genotype x Environment interaction for panicles/clump				
Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	54.05	72.80	63.78	25.57
MHC-13	62.63	67.52	90.92	29.46
MHC-18	76.75	90.13	109.82	30.29
MCC-21	52.27	79.26	54.95	22.61
ICRI-2	69.51	79.58	108.19	20.76
Local Check	69.60	73.64	110.56	24.60
CD(5%)	7.76			
G at E . CD(5%)		13.23		
E at G . CD(5%)		13.13		

Table 6. Genotype x Environment interaction for capsules/racemes				
Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	18.05	20.14	16.71	17.31
MHC-13	19.97	18.21	23.07	18.62
MHC-18	19.71	21.70	17.82	19.62
MCC-21	19.30	23.08	17.76	17.07
ICRI-2	17.19	21.80	15.83	13.95
Local Check	17.97	19.22	16.33	18.36
CD(5%)	1.66			
G at E CD (5%)		2.28		
E at G . CD(5%)		1.92		

Table 7. Genotype x Environment interaction for yield/plot				
Genotypes	Means	G x E interaction		
		Anakkara	Gudalur	Myladumpara
MHC-10	6.15	6.20	6.44	5.81
MHC-13	7.09	7.46	7.62	6.22
MHC-18	7.74	8.13	8.72	6.38
MCC-21	6.46	6.81	7.49	5.10
ICRI-2	6.55	7.69	6.43	5.55
Local Check	6.48	6.72	7.23	5.52
CD(5%)	0.54			
G at E CD (5%)		NS		
E at G . CD(5%)		NS		

References

George KV., Dandin SB, Madhusoodanan KJ and Koshy John, 1981. Natural variations in the yield parameters of cardamom (*Elettaria cardamomum* Maton). In: Proc. PLACROSYM- IV. (Ed. S. Visveshwara), ISPC, Kasaragod, India: 216-223.

Gomez AK and Gomez AA, 1983. Statistical procedures for agricultural research. John Wiley and sons, New York, p. 680.

Korikanthimath V.S., Ravindra Mulge and Hosmane MM, 1997. Preliminary evaluation of elite clones of cardamom (*Elettaria cardamomum* Maton) for yield and yield parameters in clonal nursery. *J. Plantation Crops* 6(1): 57-61.

Madhusoodanan KJ and Radhakrishnan VV, 1996. Cardamom breeding in Kerala. In: *Breeding of Crop Plants in Kerala:* 73-81.

Nadgauda R, Mascarenhas AF and Madhusoodanan KJ, 1983. Clonal multiplicatiopn of cardamom (*Elettaria cardamomum* Maton) by tissue culture. *J. Plantation Crops* 11: 60-64.

Panse VG and Sukhatme PV, 1967. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi, p. 381.

Spices Board, 1999. Package of practices for cardamom. Spices Board, Cochin, Kerala, India.

Spices Board, 2005. Spices statistics. Spices Board, Cochin, Kerala, India.

Acknowledgement

The authors are thankful to Dr. S.N. Potty, former Director, ICRI for facilities and encouragement.

Fixation of hybrid vigour in interspecific crosses of *Gossypium spp.*

Veeresh Gowda RP[1], Katageri IS[1], Salimath PM[2], Khadi BM[3], Kalmeshwer Gouda Patil[4] and Ganapathy KN[4]
[1] Agricultural Research Station, Dharwad Farm, Dharwad, Karnataka.
[2] Dept. of Genetics and Plant Breeding, UAS, Dharwad, Karnataka.
[3] CICR, Nagpur, Maharashtra.
[4] Dept. of Genetics and Plant Breeding, UAS, Bangalore, Karnataka.

Abstract

Cotton is an inevitable source of natural fibre in the textile industry throughout the world. The present research was aimed at deriving recombinant lines from interspecific cross. DCH –32 (Gossypium hirsutum var DS 28 x Gossypium barbadense var SB (YF)-425) released in 1998 for commercial cultivation in India. Off later, this hybrid has been found to be vulnerable to sucking pests and pink bollworms and resulting in huge losses. Pedigree method of selection was applied to create balanced recombinant lines possessing hirsutum character of economic importance with high fibre strength (24 – 25g/tex) and longer fibre (>30mm). Data on seed cotton yield and yield contributing characters of recombinant plants of the cross DS 28 x SB (YF) –425 were showed the possibility of fixation of hybrid vigour for seed cotton yield and yield contributing charcters.

Keywords: Hybrid vigour, recombinant plants, *Gossypium hirsutum, Gossypium barbadense*, seed cotton yield

Introduction

Cotton known as "white gold", is one of the premier cash crop of India. The role that cotton plays in the Indian economy is second to no other crop. Distant hybridization has played a significant role in transferring fibre quality, disease and insect resistance, drought resistance and male sterility in cotton besides improvement in yield by releasing hybrids. The exceptional fibre length, strength and fineness of Sea Island cotton (*G. barbadense*) gives 30% to 50% price advantage over the more widely grown upland cotton (*G. hirsutum*). Due to their higher susceptibility to sucking pests, poor boll opening, low yielding ability, varieties belonging to *G. barbadense* did not spread and they covered only of 0.1 per cent of total cotton cultivating area in India (Swaminathan, 1999). Due to this they were used as male parents in developing interspecific hybrids (*G. hirsutum* x *G. barbadense*) and today their contribution to extra long staple cotton production is visible. Varalaxmi and DCH-32 were two cultivars, which helped India to attain self-sufficiency in extra long staple cotton production (Katarki, 1972). Since then some more hybrids were released for commercial production. Interspecific hybridization followed by pedigree method of selection has been followed at Agricultural Research Station, Dharwad farm, Dharwad to develop *G. hirsutum* lines with superior fibre quality, seed cotton yield and yield contributing characters.

Material and Method

Derivatives of DCH-32 (*G. hirsutum* var DS-28 x *G. barbadense* var SB (YF) – 435) were tested at F_6 generation. Female parent of DCH-32 possessed big boll, good boll opening and higher yielding besides its earliness. The progenies studied in the present study were from the plants of F_5 generation. The pedigree method of selection commenced in 1999-2000 with initial population of 1000 plants in F_2. The selection criteria were mainly on hirsutum type of plants. Individual selected plants were tested according to the progeny method and care was taken to have minimum of 100 plants per plant in F_3, F_4 and F_5 generations. By the end of F_5 generation Katageri *et al.* (2003) phenotyped the 66 plants as

they showed more than 33mm fibre length. The fibre properties like 2.5 per cent span length (fibre length), fibre strength and fibre fineness were analyzed. Seed cotton yield, ling yield, seed index, lint index and ginning out turn (GOT) were also determined.

Results and Discussion

Before estimation of fibre properties of all the plants under HVI (High Volume Instrument), halo length of 1848 plants was measured. The enormous variation (16.00 mm to 40.60 mm) was seen for halo length among recombinants, only 13 plants have been finally chosen based on halo length (> 34 mm) and availability of sufficient lint for HVI test. The results of HVI test are presented in Table 1. Out of 13 plants, 4 plants (7-2, 16-4, 48-10 and 64-19b) showed fibre length of more than 30.00 mm with fibre strength on 27.00g/tex, 26.70 g/tex, 23.10 g/tex and 24.90 g/tex respectively. These four plants recorded seed cotton yield of 61.00 g/plant, 53.00 g/plant, 52.00 g/plant and 44.00 g/plant respectively with the GOT of 34.43, 35.85, 36.54 and 38.64. The seed cotton yield and yield contributing characters of selected plants is presented in Table 1. This data indicated the possibility in enhancing not only fibre properties but also yield and yield contributing characters from such interspecific crosses.

Seed cotton yield: Seed cotton yield per plant ranged between 44.00 g to 65.00 g as against 38.00 g (DS-28). The per cent increase over DS-28 was observed for seed cotton yield in all the selected plants, which are having elevated fibre properties (Table 2). Plant numbers 2-18 had recorded highest per cent increase (105.26) over DS-28 for seed cotton yield, whereas plant number 7-2, which was superior in fibre length (30.80 mm) and fibre strength (27.00 g/tex) all so recorded 60.50 per cent increase over DS-28 for seed cotton yield. It indicates that, there is a possibility of fixation of hybrid vigour for seed cotton yield in the recombinant plants of cross between DS-28 x SB (YF) – 425.

Lint weight: All the recombinant plants recorded the per cent increase of lint weight over DS-28 (Table 2). There were three plants (2-18, 7-2 and 9-16) which showed higher per cent of increase (more than 60.00) over DS-28. Among these, one plant (7-2) was also superior in fibre length (30.80 mm) and fibre strength (27.00 g/tex).

Seed index: The per cent increase over DS-28 for 100 seed weight was observed in all the recombinant plants where as, one plant (16-4) recorded higher per cent increase (46.20) over DS-28 along with superior fibre length (32.30 mm) and fibre strength (26.70g/tex).

Lint index: Three plants (16-4, 20-13 and 64-19b) recorded highest per cent increase (more than 50.00) over DS-28 for lint index. Among them, two plants (16-4 and 64-19b) also recorded superior fibre length of more than 32.00 mm and fibre strength of more than 24.00 g/tex.

Ginning out turn (GOT): Per cent increase of GOT over DS-28 was found in all the recombinant plants, except 2-18 and 19-10a whereas two plants *ie.,* 13-1 and 64-19b recorded highest per cent increase (more than 12.00) over DS-28 and among them, one plant (64-19b) also showed higher fibre length (32.50 mm) and fibre strength (24.00 g/tex).

This indicates that, there is a possibility of fixation of hybrid vigour for seed cotton yield, lint weight, seed index lint index and ginning out turn in the recombinant plants of cross between DS-28 (*G. hirsutum*) x SB (YF) – 425 (*G. barbadense*).

Table 1. Fibre properties, seed cotton yield and yield contributing characters of recombinant plants from cross between DS-28 x SB (YF)-425

Pedigree	Fibre length (mm)	Fibre strength (g/tex)	Seed cotton (g/plant)	Lint weight (g/plant)	Seed index (g)	Lint index (g)	GOT (%)
2--18	28.6	23.2	78.0	25.0	9.6	4.5	32.0
7--2	30.8	27.0	61.1	21.0	9.5	4.9	34.4
9--16	29.8	25.3	65.0	23.0	10.0	5.4	35.3
13--1	29.6	22.4	48.0	19.0	8.8	5.7	39.5
16--4	32.3	26.7	53.0	19.0	11.7	6.5	35.8
21--2	29.4	27.2	58.0	20.0	8.8	4.6	34.4
19--10a	27.9	22.8	62.0	21.0	8.8	4.5	33.8
20--13	28.9	24.7	49.0	18.0	10.8	6.2	36.7
32--22	9.3	24.3	46.0	17.0	10.1	5.9	36.9
47--28a	29.9	23.3	47.0	17.0	9.8	5.5	36.1
48--10	32.5	23.1	52.0	19.0	9.5	5.4	36.5
57--2	28.2	21.0	48.0	18.0	9.9	5.9	37.5
64--19b	32.5	24.9	44.0	17.0	10.2	6.4	38.6
DS-28	29.5	20.3	38.0	13.0	8.0	4.1	34.2

Table 2. Per cent increase over DS-28 for seed cotton yield and yield contributing characters in cross DS-28 x SB (YF)-425

	Per cent increase over DS-28				
Pedigree	Seed cotton (g/plant)	Lint weight (g/plant)	Seed index (g)	Lint index (g)	GOT (%)
2--18	105.2	92.3	20.0	8.9	6.3
7--2	60.5	61.5	18.8	20.0	6.0
9--16	71.1	76.9	25.0	31.7	3.4
13--1	26.3	46.2	10.0	38.7	15.7
16--4	39.5	46.2	46.3	57.2	4.8
21--2	52.6	53.8	10.0	11.3	0.8
19--10a	63.2	61.5	10.0	8.4	1.0
20--13	28.9	38.5	35.0	50.7	7.4
32--22	21.1	30.8	26.3	42.3	8.0
47--28a	23.7	30.8	22.5	33.4	5.7
48--10	36.8	46.2	18.8	31.5	6.8
57--2	26.3	38.5	23.8	42.8	9.6
64--19b	15.8	30.8	27.5	54.3	12.9

References

Katageri IS, Khadi BM, Manohar K, Soregaon CD, Vamadevaiah HM, Manjula S and Badigannavar AM 2003. Recombinant lines in cotton (*Gossypium spp*). Proc. World cotton conference, Cape Town, South Africa: 9-13.

Katarki BH 1972. Annual report on DCH-32 high yielding interspecific hybrids. University of Agricultural Sciences, Bangalore.

Swaminathan MS 1999. Cotton and rural livelihoods. Silver jubilee lecture series of Indian Society for Cotton Improvement, Mumbai:, 1999: 1-3.

Acknowledgement

We sincerely thank the cotton corporation of India, Mumbai for initial funding and the Director CICR, Nagpur and member secretary for TMC for providing funds for continuation of the project.

Variability and performance of interspecific hybrids of *Coffea canephora* Sln. 3R (CxR) x *Coffea bengalensis*

Sureshkumar VB[1], Suhala[2], Mohanan KV[2] and Santharam A[3]
1 Regional Coffee Research Station, Chundale, Wayanad, Kerala.
2 Centre for Plantation Development Studies, University of Calicut, Kerala- 673 635.
3.Central Coffee Research Institute, Coffee Research Station (P.O.), Chickmagalor, Karnataka.

Abstract

Hybrids of Sln.3R (CxR) coffee and Coffea bengalensis were evolved with an objective of developing coffee varieties with improved quality and less caffeine content. The relationship of some vegetative characters, viz. stem girth, number of primary branches, girth of primary branch, length of primary branch, number of secondaries per primary, bush spread, inter nodal length and leaf area and yield characters such as number of fruiting nodes per plant and number of berries per node were studied presently in the above hybrids. Totally 14 hybrid populations were observed and a hybrid that performed better could be located. Phenotypes of this hybrid resembled that of the female parent aand it may be due to the recessive nature of these genes in the male parent.

Introduction

In tropical countries all over the world coffee is cultivated as a stimulating beverage. Due to the lower elevation of the cultivated areas, robusta coffee is planted in many coffee areas of South India. Consumers, especially those of western countries are much concerned of the high caffeine content of robusta coffee. Due to inferior quality and high quantity of caffeine, robusta fetches comparatively lower price in the market. Hence breeding for varieties with lower caffeine content is one of the prime objectives in robusta coffee breeding. The wide geographical range of natural population of robusta coffee, *Coffea canephora* var. *robusta* gives scope for widening its genetic base by crossing it with other types of coffee so as to bring out favourable changes such as lesser caffeine content, high drought tolerance, good cup quality and reduced ripening duration.

The present study is an evaluation of 14 populations of inter specific hybrids produced from a cross between Sln. 3R variety of CxR coffee (a derivative of robusta coffee) and C*offea bengalensis,* a wild species of coffee with low coffein content so that further improvement and exploitation of desirable plants from these progenies will be possible (Table 1).

Materials and Method

The progeny of 14 CxR x Bengalensis crosses planted at Regional Coffee Research Station (RCRS), Chundale, Wayand, Kerala, were used for the present study. 14 sibmated progenies of CxR (Sln. 3R) plants established at RCRS in 1983 were used for the cross conducted at RCRS in 1990. Out of the 14 croesses, a total of 105 plants were obtained and planted at RCRS at a spacing of 7' x 7' and out of this 82 survived.

The progenies of the crosses made in 1990 maintained in the experimental field of RCRS, Chundale, Wayanad and their parents were observed in 2004 for 8 growth characters and two yield characters (Table 1). The progenies were ranked based on performance points attributed to them. After identifying the superior plants in each cross, the selected superior plants were assessed based on an index prepared and the plants were again ranked so as to select the superior performer from the fourteen progeny classes.

Results and Discussion

Comparative analysis of the best hybrids selected from the fourteen crosses lead to the selection of one hybrid plant. The plant showed phenotypic characters similar to the female parent, Sln. 3R. This may be due to the dominant genes present in Sln.3R. However, *Coffea bengalensis* is a diploid species with certain useful characters like low caffeine content (Sreenath 1997). Oservations on agronomical characters showed high degree of variation in characters. Reddy (1986) has done similar studies on phenotypic characters in diploid interspecific hybrids of coffee. Relatively high degree of variation of different morphological characters was observed in the F1 of *Coffea exselsa x Coffea eugenoides* by him.

According to a study conducted by Walyaro (1983) growth and yield characters of coffee are controlled by additive, dominant and epistatic genes. Genetic variability of growth and yield characters of coffee was studied by Dharmarj and Gopal (1989).They have observed highly significant differences between selections in respect of all growth and yield characters. Phenotypic and genotypic coefficients indicated substantial variability in most of the growth and yield characters. Studies were conducted by Jamsheed Ahamed and Sreenivasan (1988) with regard to some morphological characters.

In the present study phenotypes of these hybrid plants resembled the female parent viz; Sln.3r (CxR). This may be due to the recessive nature of genes representing the characters in *Coffea bengalensis*. However further studies on molecular and phytochemical aspects are to be conducted to confirm the hybrid nature of these plants. Phytochemial studies must also be carried out to assess the caffeine content in these plants as it is the prime objective of this hybridization and to confirm the results of the present study and to know the hybrid nature of the plants. The desirable plants can be included in future breeding progames.

Table 1. Details of interspecific hybrids and the parents involved in each cross.

Sl. No.	Details of parents involved	Number of plants established	Plants established in the farm as marked in the field graph maintained in RCRS.
1	Sln.3R(CxR), Sib 6 15/6 x *C. bengalensis* 4/1	6	A1, A2, A3, A4, A5, A6
2	Sln.3R(CxR), Sib6 11/6 x *C.bengalensis* 4/1	13	B1, B2, B3, B4, B5, B6,B7 C1, C3, C4, C5, C6, C7
3	Sln.3R(CxR), Sib6 4/1 x C.*bengalensis* 1/1	7	D1, D2, D3, D4, D5, D6,D7
4	Sln.3R(CxR), Sib6 8/5 x C.*bengalensis* 1/1	6	E1, E2, E4, E5, E6, E7
5	Sln.3R(CxR), Sib6 4/1 x C.*bengalensis* 2/1	12	F1, F2, F3, F4, F5, F6,F7 G1,G2, G3, G4, G5
6	Sln.3R(CxR), Sib6 6/5 x C.*bengalensis* 3/5	5	H2, H3, H4, H5, H6
7	Sln.3R(CxR), Sib5 9/5 x C.*bengalensis* 2/1	4	I2, I3, I4, I6
8	Sln.3R(CxR), Sib5 9/5 x C.*bengalensis* 1/1	10	J1, J2, J3, J4, J5 K1, K2, K3, K4, K5
9	Sln.3R(CxR), Sib6 11/6 x C.*bengalensis* 1/1	3	L1, L2, L3
	Sln.3R(CxR), Sib6 8/5 x	3	M1, M2, M3

10	C.*bengalensis* 2/1		
11	Sln.3R(CxR), Sib6 11/3 x C.*bengalensis* 3/3	4	N1, N2, N3, N4
12	Sln.3R(CxR), Sib5 4/5 x C.*bengalensis* 2/1	3	O1, O2, O3
13	Sln.3R(CxR), Sib6 11/6 x C.*bengalensis* 2/1	3	P1, P2, P4
14	Sln.3R(CxR), Sib5 4/5 x C.*bengalensis* 1/1	3	Q1, Q2, Q3

Table 2. Performance of elite plants selected from 14 different crosses.

Sl. No.	Elite plants identified from different crosses	Parents involved in each cross	Rank of plants based on performance index.
1	N2	Sln.3R(CxR), Sib6 11/3 x C.*bengalensis* 3/3	1
2	Q2	Sln.3R(CxR), Sib5 4/5 x C.*bengalensis* 1/1	2
3	P1	Sln.3R(CxR), Sib6 11/6 x C.*bengalensis* 2/1	3
4	M2	Sln.3R(CxR), Sib6 8/5 x C.*bengalensis* 2/1	4
5	I4	Sln.3R(CxR), Sib5 9/5 x C.*bengalensis* 2/1	5
6	F5	Sln.3R(CxR), Sib6 4/1 x C.*bengalensis* 2/1	5
7	D5	Sln.3R(CxR), Sib6 4/1 x C.*bengalensis* 1/1	6
8	L1	Sln.3R(CxR), Sib6 11/6 x C.*bengalensis* 1/1	7
9	C1	Sln.3R(CxR), Sib6 11/6 x *C.bengalensis* 4/1	8
10	A5	Sln.3R(CxR), Sib6 15/6 x *C.bengalensis* 4/1	9
11	J4	Sln.3R(CxR), Sib5 9/5 x C.*bengalensis* 1/1	10
12	O2	Sln.3R(CxR), Sib5 4/5 x C.*bengalensis* 2/1	10
13	H2	Sln.3R(CxR), Sib6 6/5 x C.*bengalensis* 3/5	11
14	E6	Sln.3R(CxR), Sib6 8/5 x C.*bengalensis* 1/1	12

References

Dharamaraj PS and Gopal NH 1989. Genetic variability of growth and yield characters in some selections of coffee. PLACROSYMVII: 351-356.

Jamsheed Ahameed and Srinivasan MS 1988. Evaluation of some morphological characters: Yield, seed size ratio, out turn and liquor quality in congensis x robusta hybrids. *Indian Coffee*: 25-28.

Reddy AGS 1986. A quantitative study of phenotypic characters in the diploid interspecific hybrids of *Coffea* L . *Journal of Coffee Research* 16 (3&4): 94-101.

Sreenath HL 1997. Development of caffeine free varieties. *Indian coffee* 61(10): 13-14.

Walyaro DJA 1983. Considerations in breeding for improved yield and quality in arabica coffee (C*offea arabica*). Doctoral Thesis, Wageningen, The Netherlands, p. 121.

Performance of some popular clones of rubber (*Hevea braziliensis*) and their hybrid progenies

Ajithkumar E, Bitha N*, Annamma Varghese Y and Kavitha K Mydin
Rubber Research Institute of India, Kottayam-686 009, Kerala.
*Centre for Plantation Development Studies, University of Calicut, Kerala- 673 635.

Abstract

Fourteen popular clones of rubber (Hevea brasiliensis Muell. Arg.) of varying origin and their hybrid progenies in eleven cross combinations were evaluated for girth, annual mean dry rubber yield and summer yield drop in the main field in a statistically laid out trial. The mean dry rubber yield in the first, second and third year of tapping, yield in the summer period of third year and girth at opening were analysed to identify superior parents and progenies. Significant variation was evident among the parents and hybrid progenies with respect to yield and girth. The mean yield of the parent clones over three years of tapping ranged from 15.01 to 67.33 g/tree/tap, while the mean yield of their hybrid progenies ranged from 15.05 to 45.87 g/tree/tap. The study revealed the high yield potential of clone PB 235 and the high vigour of RRII 118 and RRII 203.The drought tolerance potential of clones RRII 118 and PB 217 was also indicated from the present results. The cross combination RRII 105 x RRII 118 was superior for yield and girth with highest recovery of high yielding hybrids among the progeny.

Introduction

The para rubber tree (*Hevea brasiliensis* Willd.ex Adr.de Juss. Muell. Arg.), a native of Central America is the major source of natural rubber and it was domesticated after the invention of vulcanization by Charles Good Year. This perennial tree was introduced into South East Asia in 1876. The original rubber seedlings were reported to have an average yield of 200 to 300 kg per hectare per year (Panikker *et al.*, 1980). Now there are clones with a production potential of 3500 kg per hectare per year (Licy *et al.*, 1998). Conventional breeding techniques have played a major role in this productivity improvement. In India, rubber is cultivated in an area of 5.78 lakh hectares with a total annual production of 7.50 lakh tonnes. The productivity of rubber is 1705 kg per hectare per year. *Hevea brasiliensis* is a predominantly outbred species, which is amenable to vegetative propagation. Widespread use of clones as planting material has resulted in monoculture of the best clones and rubber plantations are thus rendered vulnerable to various maladies. To guard against the catastrophes, monoclonal plantation of rubber is now discouraged. Present day crop improvement programmes lay emphasis on evolving clones with a wider genetic base i.e. of varied parentage, and identification of the most potential parent which bears good characters to transfer to its progenies.

Materials and Method

A population of 700 mature trees consisting of 14 popular clones of *Hevea brasiliensis* of varying origin (Table 1) and their hybrid progenies in 11 cross combinations were planted in a simple lattice design with four replications and seven trees per plot at Central Experiment Station of Rubber Research Institute of India, situated at Chethackal, Ranni, Pathanamthitta dist, in Kerala. Each progeny constituted 28 individuals.

Tapping was initiated seven years after planting and the yield data of three consecutive years were recorded and statistically analysed. The yield of dry rubber per tree was recorded once a month on a normal tapping day by coagulating the latex in the collection cup and drying cup lumps in a smoke

house. The weight of the dried cup lumps were recorded in grams per tree per tap, after discounting 10 percent of the weight to account for the residual moisture trapped in the cup lumps. The mean dry rubber yield of each parent and the progeny of each cross were worked out for each month. From the monthly mean yields, the mean yield over the year and the mean yield over three consecutive years were computed. The mean annual yield and the mean yield during the summer period (Feb-May) were computed separately for the third year of tapping when the yield in the first panel had stabilized. The extent of drop in yield in the summer months was computed as percentage over the annual mean yield. The girth of trees was recorded at a height of 150 cm from the bud union in the year of initiation of tapping.

Data on yield in the first, second, and the third year of tapping, yield in the summer period and girth at opening were subjected to the analysis of variance to identify the superior parents and progenies.

Results and Discussion

Tables 2 and 3 present the dry rubber yield of the parents and progenies respectively, for the first three years of tapping. There was highly significant variation among the parents and hybrid progenies with respect to yield.

Among the parent clones, PB 235 recorded the highest yield in the first year (76.95g/tree/tap), second year (49.94g/tree/tap) and third year(75.09g/tree/tap)of tapping. This clone was consistently superior to the high yielding check clone RRII 105, which gave a mean yield of 38.99 g/tree/tap over the first three years.

Among the 11 hybrid progenies evaluated, the progeny of the cross RRII 105 x RRII 118 was superior to the rest with a mean yield of 43.31, 36.87and 57.43 g/tree/tap in the first, second and third year of tapping respectively. This progeny showed a mean yield of 45.87g/tree/tap over the first three years, followed by the progeny of the cross RRII 105 x PB 86 (41.46 g/tree/tap), RRII 105 x PB 217 (36.96g/tree/tap)and PB 5/51 x RRII 208 (36.81 g/tree/tap). As shown in Figure 1, a high mean annual yield coupled with a high percentage recovery of high yielding clones within the progeny was recorded by the cross RRII 105x RRII 118.

The 14 popular *Hevea* clones included in the parentage of the hybrid progenies were studied with respect to the monthly variation in yield in the third year of tapping (Figure 2). All the clones in general showed a low yield during the summer period from February to May. There are ample reports that this drop in yield is due to the compounded effect of the dry summer period coupled with the stress on the rubber tree due to the process of refoliation taking place during the period. Clone PB 235 showed high yield throughout the year, with yield drop only in the February to May period. As evident from the graphs, clones PB 217, RRII 203 and RRII 118 maintained a higher level of yield compared to the rest of the clones in the summer period (February to May), indicating their tolerance to summer stress. In terms of absolute yield in the summer months, there was significant variation among the parent clones and progenies (Table 4) with the parent clones PB 235, RRII 203,PB 217 and RRII 118 maintaining comparatively high yields of 25.54, 24.31, 23.66 and 23.17 g/tree/tap respectively. In terms of extent of drop in yield in summer, among these clones, PB 217 and RRII 118 were found to be more tolerant to the summer stress with only 41.12 and 46.89 percent reduction respectively in yield from the annual mean yield level. Clone PB 86 also recorded a low yield drop of 42.14 percent in summer. These three clones, when crossed to RRII 105 produced progeny with a high mean yield in the summer months (Table 5). Among the three promising progenies (RRII 105 x RRII 118, RRII 105 x PB 217 and RRII 105 x PB 86), RRII 105 x RRII 118 established

superiority in performance in summer, the progeny having recorded more than 22.79 g of dry rubber/tree/tap. The lowest mean yield drop in summer was recorded from the progeny of the cross RRII 105 x PB 217(40.69 percent), suggesting its tolerance to summer stress.

Clonal variation for girth at opening was also significant with the parent clones in general having recorded a mean girth of 47.82 cm(Table 6) and their hybrid progenies, 50.97 cm(Table 7).. Among the parent clones RRII 118 (59.41 cm), followed by RRII 203(57.72 cm) and PB 235 (56.82 cm) were the most vigourous, while RRII 105 recorded a girth of 49.98 cm in the year of opening. The progeny of the cross RRII 105 x RRII 118 recorded the highest girth at opening (56.31 cm), with 53.85 percent recovery of vigorous clones in the progeny. This was followed by the cross PB 5/51 x RRII 208 (53.75cm) and RRII 105 x PR 107(52.53cm) the latter showing a high recovery of 59.26 percent of vigourous hybrid clones.

Hevea brasiliensis being a perennial tree species, sustained high yield of rubber is of utmost importance, for which good tree growth is vital. Clone PB 235, in the present study has maintained high yield from the first to the third years of tapping as also reported earlier (Mydin, 1992). Clones RRII 118 and RRII 203 are reported to be very vigorous (Saraswathyamma *et al.,* 2000) and the present results corroborate the same. Clone RRII 105 is reported to possess high yield but average vigour while clone RRII 118 is a medium yielder with good vigor in terms of girth. The present study has revealed the superiority of the cross combination RRII 105 x RRII 118 in terms of annual mean yield, summer yield and girth. The prepotency of clone RRII 105 (Mydin *et al.*, 1996) may have contributed to the high recovery of high yielding clones within the progeny of this cross. The present results highlight the drought tolerance potential of clones PB 217 and RRII 118. This needs to be explored further since the progeny obtained on crossing these clones with RRII 105 also showed an inherent potential to maintain high yield in summer. Further evaluation of the high yielding hybrids and drought tolerant clones with in the progenies can help in developing superior clones with a wider genetic base.

Conclusion

The present study on 14 popular *Hevea* clones and 11 hybrid progenies with 28 clones per progeny has helped to establish the superior yielding ability of clone PB 235 and the high vigour of clones RRII 118 and RRII 203. The cross combination RRII 105 x RRII 118 was proved to be superior for yield and girth with a high recovery of high yielding hybrid clones within the progeny. The drought tolerance potential of clones PB 217 and RRII 118 and the scope for utilizing these clones in crosses with RRII 105 for evolving drought tolerant hybrids is also indicated from the present results.

Table 1: Parent clones used for hybridization

Clones	Country of origin
RRII 105	India
RRII 118	India
RRII 33	India
RRII 203	India
RRII 208	India
RRIM 600	Malaysia
PB 5/51	Malaysia
PB 28/59	Malaysia
PB 217	Malaysia
PB 235	Malaysia
PB 242	Malaysia
PB 86	Malaysia

Gl 1	Malaysia
PR 107	Indonesia

Table 2: Mean yield of parent clones over three years

Parent	Annual mean dry rubber yield (g/tree/tap)		Mean yield over three years	
	First year	Second year	Third year	(g/tree/tap)
RRII 105	44.92	31.72	40.33	38.99
RRII 118	36.21	33.23	42.60	37.35
RRII 33	17.83	14.51	18.40	16.91
RRII 203	44.08	44.90	57.45	48.81
RRII 208	28.66	25.73	32.37	28.92
RRIM 600	33.61	29.53	39.55	34.23
PB 5/5I	32.68	23.42	25.36	27.15
PB 28/59	46.60	35.36	46.62	42.86
PB 217	39.40	33.91	41.42	38.24
PB 235	76.95	49.94	75.09	67.33
PB 242	43.34	37.02	42.39	40.92
PB 86	33.12	24.85	25.22	27.73
Gl 1	17.79	17.97	26.34	20.70
PR 107	11.10	15.39	18.54	15.01
General mean	36.16	29.82	37.98	34.65
V.R	5.27**	6.51**	9.59**	11.66**
C.D.(0.05)	13.87	9.49	12.15	9.17

Table 3: Mean yield of progenies over three years

Progeny	Annual mean dry rubber yield (g/tree/tap)			Mean yield over three years (g/tree/tap)
	Firstyear	Second year	Third year	
RRII 105 x PB 5/51	37.49	25.84	35.99	33.11
RRII 105 x PR 107	41.40	26.79	33.21	33.80
RRII 105 x RRII 118	43.31	36.87	57.43	45.87
RRII 105 x PB 217	42.13	30.39	38.35	36.96
RRII 105 x PB 86	41.05	35.22	48.12	41.46
RRIM 600 x RRII 203	38.61	31.02	37.16	35.60
RRIM 600 x RRII 33	13.43	13.68	18.04	15.05
RRIM 600 x Gl 1	22.84	24.20	31.73	26.26
RRIM 600 x PB 235	33.41	25.97	37.65	32.34
PB 242 x RRII 105	36.55	24.86	33.36	31.59
PB 5/51 x RRII 208	35.87	31.29	43.26	36.81
General mean	33.10	29.82	37.66	33.53
V.R	5.27**	6.51**	9.59**	11.66**
C.D.(0.05)	13.87	9.49	12.15	9.17

Table 4: Yield performance of parent clones in summer (third year of tapping)

Clones	Dry rubber yield (g/tree/tap)	Summer yield drop (%)
RRII 105	13.93	65.00
RRII 118	23.17	46.89
RRII 33	5.78	58.39
RRII 203	24.31	58.78
RRII 208	16.75	48.29
RRIM 600	16.72	58.09
PB 5/51	9.39	63.61
PB 28/59	17.36	63.14
PB 217	23.66	41.12
PB 235	25.54	65.70
PB 242	19.76	54.26
PB 86	14.61	42.14
Gl 1	9.62	65.82
PR 107	6.97	59.91
General mean	16.26	56.51
V.R	5.22**	1.91*
C.D.(0.05)	7.15	18.28

Table 5: Yield performance of progenies in summer (third year of tapping)

Progenies	Dry rubber yield(g/tree/tap)		Summer yield drop (%)
	Mean	% above mean	
RRII 105 x PB 5/51	11.03	40.91	68.26
RRII 105 x PR 107	14.90	43.48	52.34
RRII 105 x RRII 118	22.79	60.87	58.95
RRII 105 x PB 217	22.93	43.48	40.69
RRII 105 x PB 86	22.81	45.00	51.73
RRIM 600 x RRII 203	19.07	42.11	41.97
RRIM 600 x RRII 33	10.05	57.14	43.35
RRIM 600 x Gl 1	16.96	68.42	47.21
RRIM 600 x PB 235	14.18	40.00	61.06
PB 242 x RRII 105	16.58	28.57	51.18
PB 5/51 x RRII 208	21.16	47.83	49.01
General mean	17.50	40.07	51.43
V.R	5.22**		1.91*
C.D.(0.05)	7.15		18.28

Table 6: Girth of parent clones at opening

Clones	Girth at opening (cm)
RRII 105	49.98
RRII 118	59.41
RRII 33	37.76
RRII 203	57.72
RRII 208	50.46
RRIM 600	45.66
PB 5/51	45.84

PB 28/59	45.82
PB 217	47.77
PB 235	56.82
PB 242	44.44
PB 86	43.03
Gl 1	42.38
PR 107	42.41
General mean	47.82
V.R	4.09*
C.D.(0.05)	7.46

Table 7: Girth of progenies at opening

Progenies	Girth at opening(cm)	
	Mean girth(cm)	% above mean
RRII 105 x PB 5/51	49.98	50.00
RRII 105 x PR 107	52.53	59.26
RRII 105 x RRII 118	56.31	53.85
RRII 105 x PB 217	51.02	58.83
RRII 105 x PB 86	51.54	55.09
RRIM 600 x RRII 203	51.17	52.17
RRIM 600 x RRII 33	49.15	47.83
RRIM 600 x Gl 1	47.07	44.00
RRIM 600 x PB 235	47.83	60.87
PB 242 x RRII 105	50.28	40.90
PB 5/51 x RRII 208	53.75	45.83
General mean	50.97	51.69
V.R	4.09**	
C.D.(0.05)	7.46	

References

Dijkman MJ 1951. *Hevea*: *Thirty years of research in the Far East*. University of Miami Press, Florida, p. 329.

Licy J 1998. *Variability Correlations and Heterosis for Yield and Yield Components in Certain Hhybrid Clones of the Para Rubber Tree Hevea brasiliensis. (Willd.ex.Adr.de Juss) Muell.Arg.*, Ph.D. Thesis, University of Kerala, Thiruvananthapuram, India, p. 158.

Mydin KK 1992. *Genetic Divergence Prepotency and Inbreeding Depressions in Para Rubber (Hevea brasiliensis) Muell.Arg*. Ph.D. Thesis, Kerala Agricultural University, Thrissur, India, p. 321.

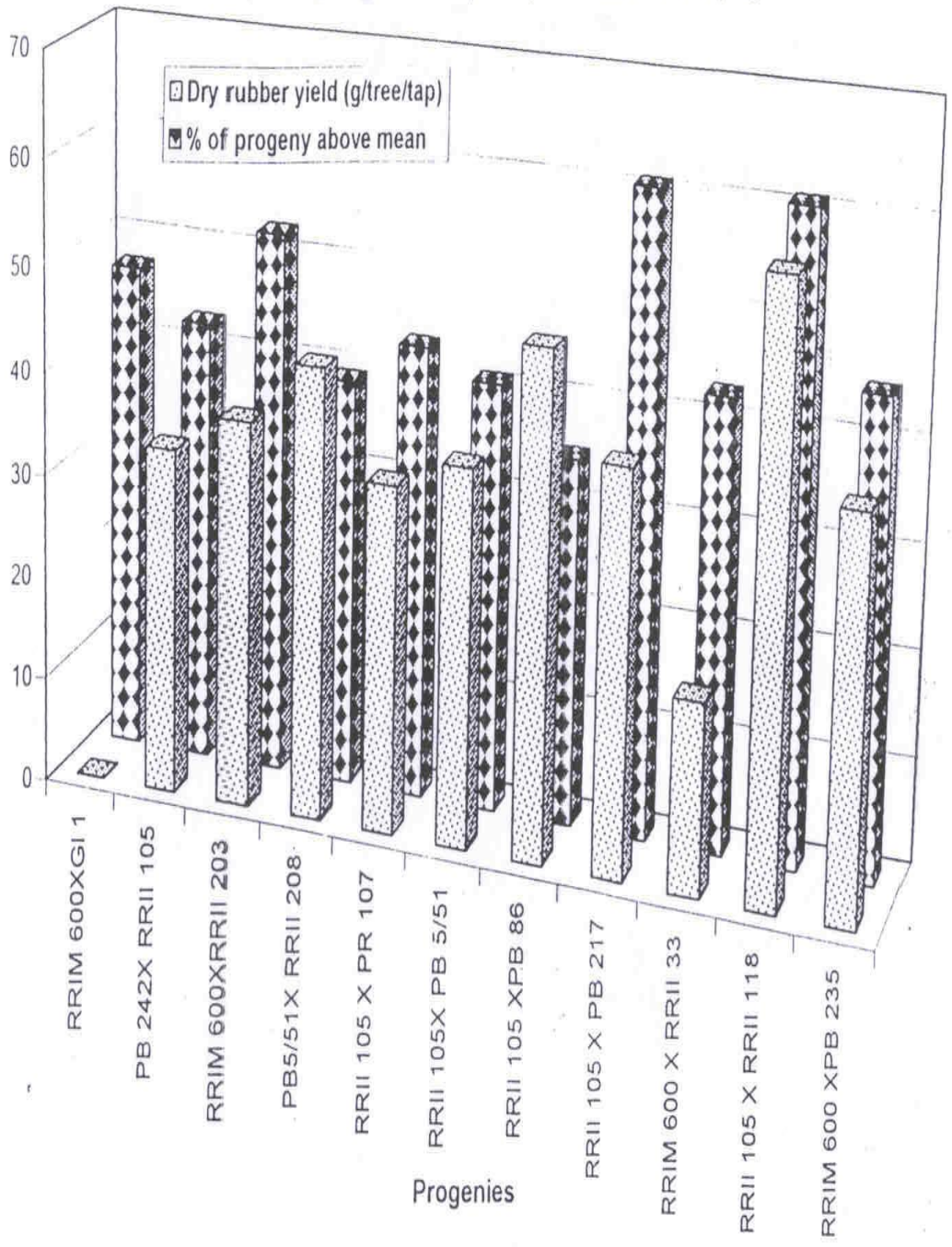
Mydin KK, Gopinathan Nair V, Sethuraj MR, Panikkar AON, Nazeer MA and Saraswathy P 1996. Prepotency in rubber: 2. Seedling progeny analysis for yield and certain yield attributes. *Indian Journal of Natural Rubber Research* 9(1): 63-66.

Panikkar AON, Nair VKB and Markose VC 1980. Breeding and tree improvement. In: 'Handbook of Natural Rubber production in India, (Ed.P.N.Radakrishna Pillai)', Rubber Research Institute of India, Kottayam, India: 35-43.

Saraswathyamma CK, Joseph G Marattukalam, Chandrasekhar TR, Licy J, Vinoth Thomas, Premakumari D., Kavitha K Mydin, Mercykutty VC, Rajaswari Meenattor J, Alice John, GireeshT, Meenakumari T, Sankari Ammal L 2000.

Rubber clones approved for planting in India - a catalogue. Rubber Research Institute of India, Kottayam- 686 009, India, p. 66.

Figure 1 : Recovery of superior clones with in progenies



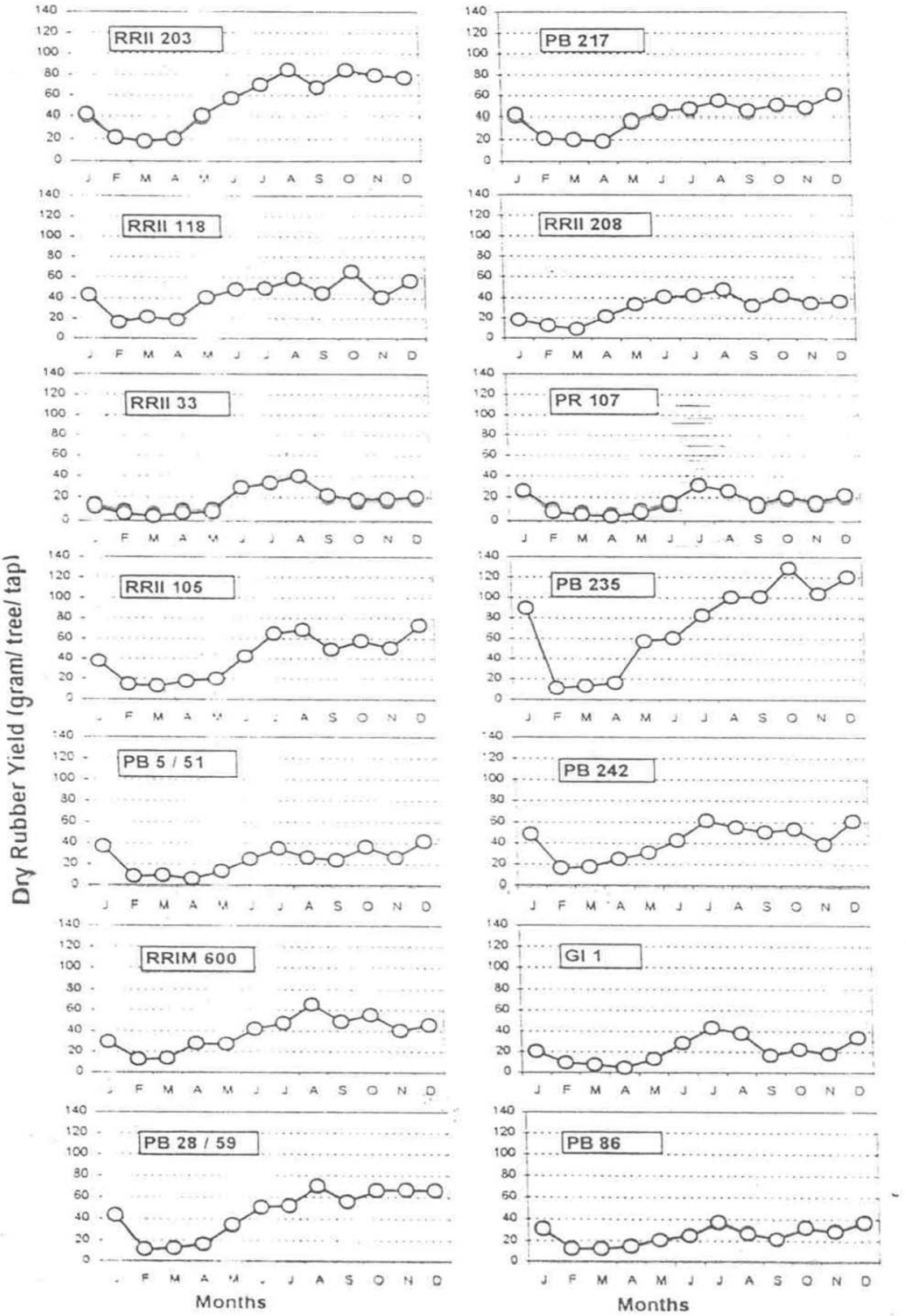


Figure 2 : Monthly variation in yield of parent clones

Acknowledgements

The authors are grateful to the Director, Rubber Research Institute of India for facilities provided to undertake this study. The encouragement and guidance given by Dr.C.K Saraswathyamma, Deputy Director (Botany) is gratefully acknowledged.

The first author places on record acknowledgement to the CSIR, Govt of India for providing Junior Research Fellowship to pursue research in the RRII. The second author is grateful to Dr.K.V Mohanan, Course Coordinater (Plantation Development) University of Calicut for facilities provided

Genetics of powdery mildew in four crosses of chilly

Krishna TV, Mohan Rao A, Kulkarni RS, Manjunatha YS and Saritha J Kundukulum.
Department of Genetics and Plant Breeding, GKVK, UAS, Bangalore, Karnataka-560065.

Abstract

Powdery mildew caused by Leveillula taurica leads to severe damages in chilli. Present cultivating varieties are not resistant to powdery mildew disease. Hybridization was under taken with resistant parent PMR39 crossed to four susceptible parents (Arka Abhir, Arka Lohith, Punjab Surkh and PBC972) to generate six generation viz. P_1, P_2, F_1, F_2, B_1 and B_2. Six generation mean analysis was carried out to know the genetics of gene action of powdery mildew resistance and related yield traits. Of four crosses, PBC972 x PMR39 had the highest estimates of mean performance for powdery mildew resistance, dry fruit yield and other yield related traits. Inheritance studies indicated the dominance gene action for powdery mildew resistance in PMR39. Both additive and non-addititve types of gene action were predominant with complementary type of epistasis in all four crosses studied. High heritability and genetic advance were observed for powdery mildew resistance in all the four crosses.

Introduction

Chilli (*Capsicum annuum* L.) is most important spice crop. India is major producer and exporter of chilli in the world. It has larger area and production. But the productivity is very less compare to other competitive countries. This is mainly because of non-availability of good varieties and more incidences of pests and diseases. Among diseases powdery mildew caused by *Leveillula taurica* is severe and causes heavy losses during the crop maturity. In chilli both open pollinated varieties and hybrids are commercially viable. A proper assessment of genetic system controlling the powdery mildew disease resistance and other traits is very essential for plant breeders. Genetic variation may arise from additive, dominant and epistatic gene effects. Generation mean analysis is efficient test to understand the nature and magnitude of gene effects involved in the expression of characters (Mather and Jinks, 1983). Thus, the present investigation was conducted to understand the genetics of powdery mildew disease resistance in chilli.

Material and Method

The genotype PMR-39 was selected as resistance parent, because it was found to have little or no incidence of powdery mildew (with disease score of zero) under field conditions. PMR-39 is a powdery mildew resistant line collected from IIHR, Bangalore. The four genotypes viz., Arka Abhir, Arka Lohith, Punjab Surkh and PBC-972 were susceptible lines with disease scores of four under field conditions were used as susceptible parents.

The crossing programme was started during *summer* 2003 by using the selected parents. The parents viz., PMR-39, Arka Abhir, Arka Lohith, Punjab Surkh and PBC-972 were crossed to get seeds of the following F_1s; Arka Abhir x PMR-39, Arka Lohith x PMR-39, Punjab Surkh x PMR-39 and PBC-972 x PMR-39. Part of the F_1 seeds along with their parents were immediately sown during *kharif* 2003 and transplanted subsequently in a well-prepared crossing block. All the parental lines were multiplied through selfing. B_1 and B_2 generation seeds were obtained by crossing the F_1 with their respective parents. Through selfing of

buds in the F_1s, their respective F_2 seeds were obtained. Thus seeds of six generation of all the four sets were obtained as outlined below:

Set 1: Arka Abhir, PMR-39, Their F_1, B_1, B_2 and F_2.

Set 2: Arka Lohith, PMR-39, Their F_1, B_1, B_2 and F_2.

Set 3: Punjab Surkh, PMR-39, Their F_1, B_1, B_2 and F_2.

Set 4: PBC-972, PMR-39, Their F_1, B_1, B_2 and F_2.

All the six generations viz., P_1, P_2, F_1, F_2, B1 and B_2 of the four crosses were planted during January 2004. A powdery mildew susceptible line Punjab Surkh was planted as spreader row after every seventh row and all around the experimental plot to ensure spread of powdery mildew in the main field.

RCBD was adopted in the experiment with two replications. Observations on total weight of dry fruits and powdery mildew disease were recorded replication wise on ten plants in parents and F_1, on 50 plants in Backcrosses and 150 plants in F_2. For each character, the average of respective number of plants was considered as the phenotypic value of the concerned treatment. Total weight of dry fruits from all the pickings were recorded and expressed as grams per plant.

Powdery mildew disease symptoms appeared as yellowish spots on the upper surface and a white powdery growth on the lower surface of the leaves. In severe case shedding of foliage was noticed. All plants in each of the replication were scored for powdery mildew using the scorecard given below. Five leaves were randomly selected from bottom, middle and top portion of each of the plant for the purpose. Disease scoring was done twice, once at full ripe stage, when the disease was rampant in the spreader rows and again twenty days later and their mean was calculated.

Score Card

Description	Score
Leaf completely free from powdery growth.	0
Up to 10 per cent of the leaf affected	1
11 to 20 per cent of the leaf infected	2
21 to 30 per cent of the leaf infected	3
31 to 40 per cent of the leaf infected	4
More than 40 per cent of the leaf infected	5

The per cent powdery mildew disease index (PMDI) was calculated for per cent infection on the leaves using the following formula (Wheelar, 1983)

$$PMDI = \frac{\text{Sum of individual ratings}}{\text{Maximum disease score} \times \text{Number of leaves sampled}} \times 100$$

Genetic analysis was performed in case of all the crosses separately for characters on which the observations were taken. Genetic analysis included six-generation mean analysis and test of epistasis were calculated. The notation for the various gene effects (Hayman, 1958) used here are mean (m), additive (d), dominance (h), additive X additive (i), additive X dominance (j) and dominance X dominance (l). Parameters such as (m), (d), (h) were estimated by using Cavalli's joint scaling test (1952) to know the adequacy of additive and dominant model. The method proposed by Hayman (1958) for the analysis of six-generation means was followed to obtain information on the nature of gene effects governing the traits under study.

Results and Discussion

Means and variances: The F_1 generation of all the four crosses exhibited higher fruit yield per plant in comparison to all other five generation. Among the four crosses, the F_1 of cross PBC-972 x PMR-39 (C_4) registered the highest dry fruit yield per plant than other crosses. Variances in the segregating generations were higher than those of non-segregating generations. F_2 variance was higher than back crosses in all the four crosses studied. In all the four crosses studied, the mean dry fruit yield per plant of F_1 surpassed both the parents, indicating the over dominance in the desirable direction. High mean accomplished by high variance in F_2 of cross Punjab Surkh x PMR-39 (C_3) and PBC-972 x PMR-39 (C_4) suggested presence of transgressive segregants and selection could result in a genotype with higher yield. Similarly, B_2 generation of the cross C_4 (PBC-972 x PMR-39) exhibited maximum variance, indicating that more number of transgressive segregants could be speculated in B_2 generation of this cross (Table 1).

For powdery mildew disease Index (PMDI) the maximum disease incidence was noticed in P_1 of all the crosses studied as compared to other generations. PMR-39, the common parent of all the crosses, and F_1 of all the crosses studied registered very low disease incidence. Whereas, B_2 of all the crosses registered moderate disease incidence. The F_2s mean performances of all the crosses were intermediate between both the parents studied. The variance of F_2s in Arka Abhir x PMR-39 (C_1), Arka Lohith x PMR-39 (C_2) and Arka PBC-972 x PMR-39 (C_4) was higher than those of backcrosses. In Punjab Surkh x PMR-39 (C_3), the variance was found to be the highest for B_1 generation.

The mean values of F_1 in the crosses C_2, C_3 and C_4 were intermediate to their parents, suggesting an incomplete dominance for the trait. Whereas cross C_1 registered lesser mean value (lesser than least parent). Higher mean and variance in segregating population was observed in all the crosses. This clearly shows that one could select for lesser values of powdery mildew disease index in segregating population and forward to advanced generations. But there was an increasing trend in segregating generation indicating that making selection for lesser PMDI would be difficult. Among the four crosses studied, the cross PBC-972 x PMR-39 (C_4) had highest estimates of mean performance and variance for both the traits viz., dry fruit yield per plant and powdery mildew resistance. Higher fruit yield accompanied with lesser incidence of powdery mildew is desirable. This suggests that the cross C_4 could be used for the further improvement.

Generation mean analysis: Inadequacy of additive-dominance model was observed for both the characters. Hence, the additive-dominance model was extended to include other parameters (Table 2).

Various gene effects Viz., additive [d], dominance [h], additive X additive [i], additive X dominance [j] and dominance X dominance [l] estimated from the observed means of six generations of four crosses are presented in Table 3. Under each character, only the significant effects are considered for comparing their magnitudes. Similarly, even to compare the magnitudes of different effects, the one's that were significant were considered. Therefore, it means that the particular effects, which are left out, were not significant. However, in knowing the type of epistasis, the crosses wherein, the signs of dominance [h] and dominance x dominance [l] were not significant were also considered at least to get an indication of the type of epistasis. It is complementary type of gene action if both [h] and [l] have same sign or it is duplicate type if the signs are different.

Predominance of dominance gene effect for dry fruit yield per plant was evident though additive, additive x additive and dominance x dominance gene effects were also highly significant in all the crosses, except for additive effect which was non significant in C_2. And also the duplicate type interaction was noticed in all the four crosses studied.

As far as the most important character dry fruit yield is concerned dominance x dominance type of genetic effect was predominant over additive, dominance, additive x additive and additive x dominance effects in all the crosses. The additive genetic effects were also important for dry fruit yield in the crosses Arka Abhir x PMR-39 (C_1), Arka Lohith x PMR-39 (C_2) and PBC-972 x PMR-39 (C_4) with higher magnitude of dominance x dominance suggesting the complex inheritance nature for dry fruit yield per plant in these crosses. Duplicate type of epistasis was found to be operative in all the four crosses.

Additive, dominance and all the three types of epistatic gene effects were highly significant for Powdery mildew disease index in all the crosses. However, magnitude of dominance genetic effect was highest in all the crosses. All the four crosses exhibited complementary type of interaction.

Additive genetic effect was evident in the inheritance of PMDI in all the crosses as envisaged by the significant and the highest magnitude of additive genetic effects, although dominance, additive x dominance and dominance x dominance genetic effects were found to be significant in all crosses. These indicate contribution of both additive non-additive gene action for the expression of PMDI. The present findings were in conformity with Daubeze *et al.* (1989) and Krishnamurthy *et al.* (1997). The complementary gene effects were found to be operative in all the four crosses.

Table 1. Mean, standard error and variances in four crosses of chilli.

Generations		Dry fruit yield per plant (g)			Powdery mildew disease index (%)		
		Range	Mean ± SE	Variance	Range	Mean ± SE	Variance
P_1	C_1	86.71 - 110.00	96.36 ± 1.50	22.50	34.71-51.31	42.01 ± 0.88	7.77
	C_2	79.89 - 99.87	91.01 ± 1.23	15.13	16.98-59.12	43.87 ± 0.52	2.70
	C_3	74.52 - 98.54	84.39 ± 1.45	21.02	36.78-65.12	51.84 ± 0.64	4.09
	C_4	49.58 - 64.25	55.50 ± 1.04	10.82	36.25-60.30	46.88 ± 1.84	7.05
P_2	C_1	80.21 - 100	89.86 ± 1.34	18.02	4.25 – 9.32	6.88 ± .03	1.09
	C_2	80.21 - 100	89.86 ± 1.34	18.02	4.25 – 9.32	6.88 ± .03	1.09
	C_3	80.21 - 100	89.86 ± 1.34	18.02	4.25 – 9.32	6.88 ± .03	1.09
	C_4	80.21 – 100	89.86 ± 1.34	18.02	4.25 – 9.32	6.88 ± .03	1.09
F_1	C_1	70.13 - 98.36	104.97 ± 1.64	26.89	4.01 – 7.19	5.28 ± 0.21	0.44
	C_2	79.89 - 127.20	95.50 ± 0.98	9.60	5.61 – 21.02	10.72 ± 0.42	1.76
	C_3	69.14 - 98.54	98.25 ± 1.51	32.76	4.69 – 9.88	7.33 ±0.34	1.16
	C_4	89.65 - 118.30	111.62 ± 1.78	31.68	4.95 – 9.36	6.66 ± 0.31	0.96
F_2	C_1	109.0 - 151.3	92.42 ± 0.63	59.53	06.12 – 49.21	20.86 ± 0.75	84.37
	C_2	99.87 - 145.20	81.65 ± 0.55	45.37	19.21 – 48.21	30.58 ± 0.47	33.13
	C_3	98.54 - 152.50	84.81 ± 0.83	103.33	24.56 – 51.07	33.81 ± 0.39	22.81
	C_4	125.6 - 193.20	99.27 ± 0.77	88.93	11.02 – 50.2	32.30 ± 0.55	45.37
B_1	C_1	80.12 - 105.00	92.72 ± 0.56	15.68	08.78 – 41.02	26.97 ± 0.98	48.07
	C_2	70.13 - 95.54	82.51 ± 0.75	28.12	15.02 – 43.12	30.58 ± 0.47	23.12
	C_3	68.50 - 98.54	82.39 ± 0.89	39.60	16.48 – 48.66	33.15 ± 0.86	36.98
	C_4	87.25 - 132.40	106.29 ± 1.01	51.01	21.02 – 40.36	30.31 ± 0.45	10.12
B_2	C_1	79.35 - 127.20	103.46 ± 1.48	0.044	07.99 – 28.45	16.08 ± 0.57	16.24
	C_2	70.13 - 95.34	84.35 ± 0.54	14.58	13.54 – 30.11	22.17 ± 0.5	12.50
	C_3	79.89 - 127.30	93.28 ± 1.13	63.84	15.03 – 35.09	24.85 ± 0.53	14.04
	C_4	91-54 -129.40	108.54± 1.14	64.98	15.03 – 30.11	23.78 ± 0.43	9.24

Table 2. Joint scaling test in four crosses of Chilli

Characters	Cross	[m]	[d]	[h]	Chi-square value
Dry fruit yield per Plant (g)	C_1	101.82**	-9.63**	12.92**	41.01**
	C_2	88.47**	5.69**	20.32**	63.72**
	C_3	00.93**	-5.94**	10.76**	14.85**
	C_4	88.74**	-16.88**	80.11**	53.91**
Powdery Mildew Disease Index (%)	C_1	26.81**	18.43**	-20.75**	3.93
	C_2	31.05**	21.51**	-11.55**	20.14**
	C_3	40.44**	28.85**	-28.28**	67.24**
	C_4	33.02**	21.69**	-22.05**	36.02**

Table 3. Estimates of additive, dominance and interaction effects in four crosses of Chilli.

Characters	Cross	[m]	[d]	[h]	[i]	[j]	[l]	Epistasis
Dry Fruit Yield/plant (g)	C_1	13.20**	-10.73**	-144.46**	-135.71**	-13.39**	100.72**	D
	C_2	121.65**	-1.84	-144.62**	-152.89**	-5.61**	184.65**	D
	C_3	124.80**	-10.89**	-157.08**	-147.87**	-7.81**	127.96**	D
	C_4	169.27**	7.749**	-200.75**	-227.46**	27.20**	130.90**	D
Powdery mildew disease index (%)	C_1	20.85**	10.89**	-16.39**	2.67**	-6.95**	-29.31**	C
	C_2	30.58**	9.81**	-28.86**	-14.02**	-8.50**	-21.74**	C
	C_3	33.81**	8.29**	-41.44**	-19.27**	-14.06**	-23.06**	C
	C_4	32.29**	6.53**	-41.11**	-21.02**	-13.59**	-21.32**	C

C_1=Arka Abhir x PMR-39, C_2= Arka Lohith x PMR-39, C_3= Punjab Surkh x PMR-39 and C_4= PBC-972 x PMR-39.

* = Significant at 5% level ** = Significant at 1% level

References

Cavalli LL 1952. An analysis of linkage in quantitative inheritance E.C.R.Reeve and Waddington (Eds), HMSO, London.

Daubeze AM, Pochard E and Pallox A 1989. Inheritance of resistance to *Leveillula taurica* and relation to other phenotypic characters in the haplodiploid progeny issued from an African line. *Palanka*: 65-73.

Hayman BJ 1958. Seperation of epistasis from additive and dominance variation in generation means. *Heridity* 12: 371-391.

Krishnamurthy HM and Deshponde AA 1997. Studies on genetics of powdery mildew resistance in chilli (*Capsicum annuum* L). *Veg. Sci.,* 24: 127-131.

Mather K and Jinks JL 1983. Biometrical Genetics. Chapman and Hall, London.

Wheeler K 1983. An Introduction to plant disease. John Wiley and Sons, London.

Comparison of Mahalanobis D^2 and principal component method in the study of genetic divergence in upland cotton (*Gossypium hirsutum* L.)

Ganapathy KN and Gunasekharan M
Dept. of Plant Breeding and Genetics, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu- 625 104.

Abstract

Forty three genotypes of upland cotton (Gossypium hirsutum L.) collected from different geographical sources were subjected to D^2 and Principle component analysis, wherein, the 43 genotypes formed as many as eight and 16 clusters respectively. The large number of clusters formed indicted that cotton genotypes are marked by considerable genetic diversity. The clustering patterns also revealed that distribution of genotypes into different clusters were at random with regard to their geographical origin. The results obtained from D^2 analysis showed no similarity with those obtained from Principle component analysis. This may be due to the fact that the clusters obtained from I^{st} two main axis of differentiation by PCA accounted for only 40.26 per cent of total genetic divergence. For getting a clear two dimensional graphic representation, the contribution by I^{st} two canonical vectors should be more than 80 per cent.

Key words: *Gossypium hirsutum*, Mahalanobis D^2, PCA, Genetic divergence

Introduction

The breeder has tremendous responsibility to ensure that adequate genetic variability remain available in the crop for use by future generations and proper management of plant germplasm resources is necessary to ensure future improved cultivars. According to quantitative genetic theory the probability of producing unique genotypes increases in proportions to the number of genes for which parents differ (genetic distance). However, past success in developing high yielding cultivars from the mating of closely related parents has led some to question the importance of genetically diverse parents to crop improvement. Although the choice of parents is often the most important decision in a breeding program, little is known about the importance of parents genetic distance to successful cotton cultivar development. The Mahalanobis D^2 statistic has been the acknowledged tool for estimation of the genetic distance for use in plant breeding and it was found to be successful in selection of parents (Chandra,1977). The canonical root method or principle component analysis reflects the importance of the largest contributor to the total variation at each axis of differentiation and are used to represent the genetic divergence of genotypes in graphical form (Rao,1952). The present study reports the findings from an evaluation of 43 upland cotton genotypes of diverse origin.

Materials and method

The material for the present investigation consisted of 43 genotypes of upland cotton (*G. hirsutum*) of diverse geographical origin. They were grown in randomized block design with three replications during 2003 – 04 summer season. Each genotype consisted of 20 plants raised in two rows, each row of 3M length with a spacing of 75 cm between rows and 30 cm between plants. Observations were recorded on10 competitive plants for days to 50 percent flowering, plant height, sympodial branches per plant, bolls per plant, boll weight, seed cotton yield, ginning per cent, lint index, seed index, 2.5 per cent span length, uniformity ratio, micronaire value, tenacity 3.2 mm and elongation per cent. Analysis of variance for various characters was done as per standard procedure. Genetic divergence was worked out by using Mahalanobis D^2 statistic

as described by Rao (1952). On the basis of D^2 values the varieties were grouped into different clusters by employing Tocher's method as outlined by Rao (1952). Canonical analysis is complementary to D^2 analysis. Assembly of data, Wilk's test, common dispersion matrix, transformation of correlated variables into uncorrelated ones, plotting of the various populations in the graph are sequentially the steps followed in analysis. Finally the clusters are formed on the basis of graph.

Results and discussion

The variance due to the genotypes for all the traits was observed to be highly significant indicating significant differences among the genotypes for all the traits studied. The highly variability among the genotypes was also ascertained by D^2 analysis and canonical analysis wherein, the 43 genotypes formed as many as eight and 16 clusters respectively. This large number of clusters formed indicated that cotton is marked by considerable genetic diversity. The clustering pattern revealed that the distribution of genotypes into different clusters were at random with regard to their geographical origin. Among the eight clusters obtained by D^2 analysis, it was observed that cluster III was the largest with 18 genotypes followed by cluster I with 11 genotypes. The cluster II possessed five genotypes whereas, the cluster IV, V, VI, and VII has two genotypes and the cluster VIII possessed one genotype. Among the 16 clusters obtained by canonical root analysis, it was observed that cluster VII was the largest with six genotypes followed by cluster III (five genotypes). The clusters namely IV, IX, X, XII possessed four genotypes each. The cluster VI and VIII possessed 3 genotypes each whereas the cluster XI and XIII possessed two genotypes each while the cluster I, II, V, XIV, XV, XVI possessed one genotype each. The pattern of group constellations revealed the absence of any parallelism between genetic diversity and geographical diversity. This was in conformity with earlier findings (Rajarathinam and Nadarajan, 1993 and Sambamurthy *et al.* 1995). Murthy and Arunachalam (1966) also suggested genetic drift and natural selection forces and diverse environmental conditions within a country cause more diversity than geographical isolation. Therefore, the choice of genotypes for hybridization should be based on genetic diversity rather than on geographical diversity. The intra and inter cluster D^2 and D values among the eight clusters are presented in the Table 1. The intra cluster generalized distance was maximum for cluster II (25.33) and minimum for cluster IV (12.66). The low intra cluster distance might be attributed to the coherent polygenic and pleiotrophic genetic mechanism as reported by Singh and Gupta (1968) in cotton. The inter cluster distance was found to be maximum between clusters V and VIII (50.31). Hybridization among the genotypes with maximum cluster distance would produce successful hybrids and desirable segregants in future generations. Maximum mean values for plant height (119.50), sympodial branches per plant (19.00), bolls per plant (40.80), boll weight (3.75g), 2.5 per cent span length (19.00), tenacity 3.2mm(23.80) and seed cotton yield (101.09) were obtained in cluster VIII. Cluster V registered maximum mean values for ginning per cent (36.66) and elongation per cent (5.20) whereas, cluster VI recorded highest mean value for lint index (4.65) and seed index (8.93g) and uniformity ratio (51.50). The cluster IV and VIII were found to have superior mean values for days to 50 per cent flowering (49.0), and micronaire value (3.65). The genotypes from the above mentioned clusters may be tested in a series of diallel analysis to select the best genotypes for their combining ability so as to fix the parents in the hybridization programme. From the clusters obtained by D^2 it was observed that two genotypes from Coimbatore and one genotype each from New Delhi, Nanded, Guntur, Adilabad, Srivilliputhur, Sirugappa, Dharwad, Khandwas and Hisar were found to aggregate in cluster I. Similarly one genotype each from Coimbatore, Sirsa, Faridcot, Arabhavi, and Dharwad constituted cluster II. Likewise from canonical root analysis it was observed that one genotype each from Nanded, Dharwad, Guntur, Sirugappa and Arabhavi were included in cluster IV. Similarly one

genotype each from Ludhiana, Arabhavi and Dharwad were included in cluster VI. Clustering of genotypes from different ecogeographic locations into one cluster was attributed to the free exchange of breeding materials from one place to another (Verma and Mehta, 1976).

From D^2 analysis two genotypes from Arabhavi were found to be aggregated in cluster III. However, rest of the genotypes from Arabhavi scattered in cluster II and VI. Similarly three genotypes from Srivilliputhur were scattered into three different clusters I, III and VI. From canonical root analysis three genotypes from Coimbatore were found to be aggregated in three different clusters (cluster XIV, XV and XVI). This kind of genetic diversity among varieties belonging to the same ecogeographic region may perhaps due to the differential adaptation of genotypes. Such wide adaptabilty would be possible due to the factors like heterogenity, genetic architecture of the population, past history of selection, developmental traits and degree of general combining ability (Murthy and Arunachalam, 1966).

In the present investigation, the results obtained from D^2 analysis showed no similarity with those obtained from canonical vector method. These are in accordance with results obtained by Kowsalya and Raveendran (1996). This may be due to the fact that the group constellations obtained from I st two main axis of differentiation (Z1 and Z2) obtained from canonical root method accounted for only 40.26 per cent of the total genetic divergence. For getting a clear two dimensional graphic representation, the contribution by Ist canonical roots should be more than 80 per cent Patel *et al*. (1989). Dani (1985) encountered similar situation while studying the seed and lint characteristics in upland cotton.

Table 1. Composition of clusters and their origin by D^2 analysis

Cluster	Number of genotypes	Names of genotypes	Origin
I.	11	PUSA 9217	IARI, New Delhi
		NH 1020	MAU, Nanded
		LAM 787	APAU, Guntur
		ADB 320	APAU, Adilabad
		TSH 9725	Srivilliputhur
		SCS 51	UAS, Sirugappa
		CCH 526612	CICR, Coimbatore
		CPD 787	UAS, Dharwad
		KH 140	JNKVV, Khandwa
		H 1246	HAU, Hisar
		CCH 342	TNAU, Coimbatore
II.	5	GMR 5	CICR, Coimbatore
		CSH 35	CICR, Sirsa
		F 2036	PAU, Faridcot
		ARB 760	UAS, Arabhavi
		CPD 745	UAS, Dharwad
III.	18	RAH 3	UAS, Raichur
		SVPR 2	Srivilliputhur
		CNH 3003	CICR, Nagpur
		GSHV 99/307	GAU, Surat
		AKH 9618	PKV, Akola
		LH 1995	PAU, Ludhiana
		HS 267	HAU, Sirsa
		HAG 785	UAS, Hageri
		GSHV 99/291	GAU, Surat

		CCH 510-4	CICR, Coimbatore
		RHC 1594	MPKV, Rahuri
		NDLA 761	APAU, Nandyal
		ARB 784	UAS, Arabhavi
		ARB2001	UAS, Arabhavi
		MCU 12	TNAU,Coimbatore
		GSHV 97/6/2	GAU, Surat
		GJHV 392	GAU, Junadadh
IV	2	ADB 250	ANGRAU, Adilabad
		MCU 7	TNAU, Coimbatore
V	2	CCH 4	CICR, Coimbatore
		H 1250	HAU, Hisar
VI	2	TSH 9704	Srivilliputhur
		ARB 2005	UAS, Arabhavi
VII	2	SCS 15	UAS, Sirugappa
		RAH 101	UAS, Raichur
VIII	1	SURABHI	CICR, Coimbatore

Table 2. Composition of clusters and their origin by canonical vector analysis

Cluster	Number of Genotypes	Name of Genotypes	Origin
I	1	RAH 3	UAS, Raichur
II	1	KH 140	JNKVV, Khandwa
III	5	NH 1020	MAU, Nanded
		HS 267	HAU, Sirsa
		CNH 3003	CICR, Nagpur
		CSH 35	CICR, Sirsa
		GSHV 97/6/2	GAU, Surat
IV	4	CPD 787	UAS, Dharwad
		LAM787	APAU, Guntur
		SCS 15	UAS, Sirugappa
		ARB2001	UAS, Arabhavi
V	1	NDLA 761	APAU, Nandyal
VI	3	LH 1995	PAU, Ludhiana
		ARB 2005	UAS, Arabhavi
		CPD755	UAS, Dharwad
VII	6	SVPR 2	Srivilliputhur
		PUSA 9217	IARI,New Delhi
		SCS 51	UAS, Sirugappa
		MCU 12	TNAU,Coimbatore
		ARB 760	UAS, Arabhavi
		CPD 745	UAS, Dharwad
VIII	3	ADB 250	ANGRAU, Adilabad
		RHC 1594	MPKV, Rahuri
		CCH 342	TNAU, Coimbatore
IX	4	TSH 9725	Srivilliputhur
		TSH 9704	Srivilliputhur
		RAH 101	UAS, Raichur
		MCU 7	TNAU, Coimbatore
X	4	ADB 320	APAU,Adilabad
		GSHV 99/291	GAU, Surat
		CCH 4	CICR, Coimbatore

		H 1250	HAU, Hisar
XI	2	CCH 526612	CICR, Coimbatore
		GSHV 99/307	GAU, Surat
XII	4	F 2036	PAU, Faridcot
		AKH 9618	PKV, Akola
		H 1246	HAU, Hisar
		GJHV 392	GAU, Junadadh
XIII	2	HAG 785	UAS, Hageri
		ARB 784	UAS, Arabhavi
XIV	1	CCH 510-4	CICR, Coimbatore
XV	1	GMR 5	CICR, Coimbatore
XVI	1	SURABHI	CICR, Coimbatore

Table 3. Intra and inter cluster D and D^2 values

Cluster	I	II	III	IV	V	VI	VII	VIII
I	**611.25 (24.72)**	687.16 (26.21)	589.28 (24.28)	522.46 (22.86)	758.05 (27.53)	478.21 (21.87)	608.40 (24.67)	1732.65 (41.63)
II		**641.23 (25.33)**	673.10 (25.94)	443.09 (21.05)	1088.52 (32.99)	527.69 (22.97)	712.81 (26.70)	1068.10 (32.68)
III			**611.82 (24.74)**	488.58 (22.10)	733.59 (27.09	429.23 (20.72)	672.51 (25.93)	1676.05 (40.94)
IV				**160.31 (12.66)**	956.94 (30.94)	314.43 (17.73)	821.51 (28.66)	1261.91 (35.52)
V					**185.67 (13.63)**	460.47 (21.46)	692.66 (26.32)	2530.61 (50.31)
VI						**226.43 (15.05)**	638.24 (25.26)	1757.51 (41.92)
VII							**480.17 (21.91)**	1413.1 (37.59)
VII								**0.00 (0.00)**

Diagonal values indicate intra cluster values
Values in parenthesis indicate D values

Table 4. Cluster mean values for different characters

Clusters	DFF	PHT	NSB	BP	BW	GP	LI	SI	2.5% SL	UR	MV	T 3.2mm	ER	Seed cotton yield
I	50.46	91.12	15.227	25.93	3.52	32.74	4.25	8.38	26.48	50.14	4.51	20.46	4.56	66.75
II	50.10	98.04	17.28	31.98	3.62	32.77	4.35	8.68	27.63	50.10	4.40	20.51	4.36	86.96
III	49.50	87.49	15.45	26.03	3.58	34.18	4.20	8.16	26.73	50.22	4.48	20.88	4.52	72.06
IV	48.25	80.08	15.60	26.65	3.50	31.44	4.38	8.70	28.03	49.00	4.20	22.23	4.93	76.33
V	49.00	85.40	15.30	28.13	3.42	36.66	3.43	5.93	23.45	50.00	4.38	20.75	5.20	81.82
VI	48.50	83.35	17.15	31.68	3.73	34.73	4.65	8.93	24.90	51.50	4.48	19.95	4.60	90.59
VII	49.50	110.08	16.30	28.80	3.36	35.77	4.50	8.38	25.78	49.00	4.50	19.65	4.70	75.38
VII	50.50	119.50	19.00	40.80	3.75	33.74	3.55	7.65	32.45	50.50	3.85	23.80	4.80	101.09

DFF - Days to 50 per cent flowering
PHT - Plant height
NSB - Number of sympodial branches
BP - Bolls per plant
BW - Boll weight
GP - Ginning per cent
SI - Seed index
2.5% SL - 2.5% span length
UR - Uniformity ratio
MV - Micronaire value
T 3.2mm - Tenacity 3.2 mm
ER - Elongation ratio
LI - Lint index

References

Chandra S 1977. Comparison of Mahalanobis method and metroglyph technique in the study of genetic divergence in *Linum usitattisimum* germplasm collection *Euphytica,* 26:141 – 149.

Dani RG 1985. Genetic divergence for seed and lint characteristics among some varieties of *Gossypium hirsutum* L. *J. Indian. Soc. Cotton Improv.*10 (2): 90 - 99.

Kowsalya R and Raveendran TS 1996. Genetic variability and D^2 analysis in upland cotton. *Crop Res.* 12(1): 36-42.

Murthy BR and Arunachalam V 1966. The nature of genetic divergence in relation to breeding system in crop plants. *Indian J. Genet.* 26:188 – 198.

Patel M Z, Reddy MV, Rana BS and Reddy BJ 1989. Genetic divergence in safflower (*Carthamus tinctorius* L.). *Indian J. Genet.* 49 (1):113 -118.

Rajarathinam S, Nadarajan N and Sukanya Subramanian 1993. Genetic variability and association analysis in cotton (*Gosssypium hirsutum* L.). *J. Indian Soc. Cotton Improv.* 18: 54-59.

Rao CR 1952. Advanced statistical Methods in Biometrical Research. John Wiley and Sons Inc., New York.

Sambamurthy JVS, Reddy DM and Reddy EHG 1995. Studies on the nature of genetic divergence in upland cotton (*Gossypium hirsutum* L.). *Ann. Agri. Res.* 16: 307-310.

Singh RB and Gupta MP 1968. Multivariate analysis of divergence in upland cotton (*Gossypium hirsutum* L.). *Indian J. Genet.* 28:151 – 157.

Verma VS and Mehta RK 1976. Genetic divergence in Lucerne. *J. Maharastra Agric. Univ.,* 1: 23 -28.

In vitro studies and micropropagation of *Hedychium flavescens* Carey *ex* Roscoe

Dollymol M.A., Sailas Benjamin and Madhusoodanan P.V.
Biotechnology Division, Department of Botany, University of Calicut, Kerala - 673635

Abstract

Hedychium flavescens, an aromatic, ornamental and medicinal plant of Zingiberaceae has antioxidant property and is being used for curing stomachache. Linalool, 1,8-cineole and β-pinene are the major active principles in it. *In vitro* studies were conducted employing leaf lamina, leaf sheath and rhizome bud. MS fortified with 2,4-D (1.0 mgl^{-1}) and BA (0.2 mgl^{-1}), 2,4-D (2.0 mgl^{-1}) and NAA (1.0 mgl^{-1}) and 2,4-D (2.0 mgl^{-1}) was optimum for callogenesis from leaf lamina, leaf sheath and rhizome buds, respectively. Short photoperiod (4 h) had induced profuse callus proliferation from leaf sheath and rhizome bud on half-strength MS medium. Generally, 70% plants survived in the field conditions, and of different explants tested, rhizome buds were more effective in the micropropagation of *H. flavescens*.

Key words: *Hedychium flavescens, micropropagation, callogenesis.*

Introduction

Hedychium flavescens Carey *ex* Roscoe (Zingiberaceae) is a medicinal, aromatic, ornamental, perennial herb with yellow fragrant flowers; commonly known as *yellow* or *cream ginger* (Sabu, 2006) Possession of linalool (35%), 1,8-cineole (eucalyptol) (15.3%) β-pinene (14.7%), α-terpeniol (14.5%) and α-pinene (5.3%) in the rhizhome has led to its increased demand in modern as well as traditional medicines like Ayurveda (Chirangini *et al.*, 2004). Thus, the prime objective of this work is to establish an *in vitro* protocol for callogenesis and micropropagation of *H. flavescens* as an alternative for rapid multiplication with a focus on exploring secondary metabolites.

Materials and Method

Explants at different stages of growth were collected from the field grown plants in the Calicut University Botanical Garden, and washed in mild detergent (teepol, 0.5%) for five minutes and then washed thoroughly with distilled water. Leaf lamina and leaf sheath segments were sterilized with 0.05% $HgCl_2$ for seven minutes and ten minutes, respectively. Rhizome segments were surface-sterilized with 0.1% $HgCl_2$ for 12-14 minutes. The sterilant was drained off and the explant was rinsed 4-5 times with sterile double distilled water. The surface-sterilized explants were cultured on MS (Murashige and Skoog, 1962) medium containing varying concentrations and combinations of auxins and cytokinins. Sucrose (3%) was used as the carbon source, and agar (0.8%) as the gelling agent. The pH of the medium was adjusted to 5.8 before autoclaving at 15ψ. The cultures were maintained under fluorescent light (1600 lx) and exposed to a normal 16:8 h light and dark periods at 25 ± 2° C.

Contamination-free *in vitro* stock cultures were raised from leaf lamina, leaf sheath and rhizome bud for further studies. The percentage of responsive explants was calculated four weeks after culture. The hardened plants were transferred to plastic pots containing sand and soil (1:1) maintained under high humidity condition for 15 days and under greenhouse condition for five weeks. After acclimatization the plants were transferred to soil.

Results and Discussion

A. Callus induction on leaf lamina

During the induction of callus, it was observed that only middle and proximal region of leaf yielded better results. In most of the given combinations (Table 1), leaf grew up to 1cm within 10 days. But it did not dedifferentiate into callus. The leaf cut surfaces curved into the medium, turned brown and no further development was noted. Various concentrations of 2,4-D alone or in combination with cytokinin were tried for callogenesis. Auxin (1.7 mgl^{-1}) alone could induce callus after 2 months of cultivation. Among various combinations, synergistic action of 2,4-D (1.0 mgl^{-1}) and BA (0.2 mgl^{-1}) has resulted in maximum callus induction in 40-45 days (Fig. 1). BA (3.5 mgl^{-1}) in combination with NAA **(**1.5 mgl-1) and Kn (0.5 mgl^{-1}) was better for fast luxuriant induction roots and root hairs in 1 week (Fig. 2).

Table 1. Response of leaf lamina on MS medium with varying concentrations of growth regulators (mgL^{-1}). Formations of degenerative callus in 40-45 days (+++); friable callus in 60 days (++), and very small callus in 60 days (+).

Sl. No:	Growth regulators				Types of response
	NAA	2,4-D	BA	Kn	
1	1.0	-	-	-	-
2	2.0	-	-		-
3	1.0	-	1.0	-	-
4	1.0	-	2.0	-	-
5	1.0	-	0.5	-	++
6	1.5	-	0.5	-	++
7	1.5	-	1.0	-	-
8	1.5	-	-	0.5	-
9	2.0	-	-	1.0	-
10	1.0	2.0	-	-	-
11	-	0.5	-	-	-
12	-	1.0	-	-	-
13	-	1.7	-	-	+
14	-	2.0	-	-	-
15	-	1.5	0.5	-	-
16	-	1.5	1.0	-	-
17	-	1.0	0.2	-	+++
18	-	1.0	2.0	-	-
19	-	1.5	-	1.0	+

B. Callus induction on leaf sheath

Generally, young glabrous leaf sheath yielded better results (Table 2). Synergistic action of auxins *ie*; combination of 2,4-D (2. 0 mgl^{-1}) and NAA (1.0 mgl^{-1}) had promoted better callus formation (Figs 3 and 4). High concentrations of 2,4-D (2.0 mgl^{-1} or more) alone or in combination with low cytokinin (BA, 0.2 mgl^{-1}) also could induce mild callogenesis. These calli were subjected to further studies for organogenesis on full or half-strength MS medium, of which the latter was found superior.

C. Callus induction on rhizome bud

Rhizome bud explants were inoculated on MS medium fortified various hormones (Table 3), of which a combination of 2,4-D and BA or Kn was inferior to 2,4-D alone (2.0 mgl^{-1}). Combination of 2,4-D (1.5 mgl^{-1}) and BA (0.5 mgl^{-1}) showed better callus induction than other combinations. Upon transfer to higher concentrations of cytokinin, it produced greenish-white callus appearance with root (Fig 5).

Table 2. Response of leaf sheath on MS medium with different concentrations of growth regulators (mgl^{-1}). Formations of regenerative callus in 30 days (+++), friable callus in 60 days (++), and small callus in 60 days.

Sl No:	Growth regulators				Types of response
	NAA	2,4-D	BA	Kn	
1	1.0	-	-	-	-
2	0.5	1.0	-	-	-
3	1.0	2.0	-	-	+++
4	-	0.5	-	-	-
5	-	1.0	-	-	-
6	-	1.5	-	-	-
7	-	2.0	-	-	++
8	-	1.0	0.2	-	+
9	-	2.0	-	1.0	-

MS medium fortified with NAA (1.5 mgl^{-1}) was better for simultaneous callusing and rooting. Upon its cubculture to a cytokinin-rich (BA 3.0 mgl^{-1}) medium, fast shoot development also occurred (Fig 6). Interestingly, inhibitory effect of long photperiod (over 12 h) on callus induction (½MS + 2.0 mgl^{-1} BA) was noticed (Fig 7) in 1-2 weeks of induction. However, short photoperiod (4 h) on rhizome explants (MS + 2.0 mgl^{-1} BA) had induced profuse callusing (Fig 8). Healthy plantlets were hardened and established in the field successfully (Fig 9).

Table 3. Response of rhizome buds on MS medium with different concentrations of growth regulators (mgl^{-1}). Formations of calli within one month and have high regeneration capacity (++++), calli within two months and have high regeneration capacity (+++), calli within two months (++), very small calli within two months (+), and roots (R).

Sl. No:	Growth regulators				Types of response
	NAA	2,4-D	BA	Kn	
1	-	0.5	-	-	-
2	-	1.0	-	-	++
3	-	1.3	-	-	+
4	-	2.0	-	-	+++
5	-	1.0	-	-	+
6	-	1.5	0.2	-	+++
7	-	1.5	0.5	-	++++
8	-	4.0	1.0	-	+
9	-	1.0	1.0	0.5	-
10	-	1.5	-	0.5	-
11	-	2.0	-	1.0	+
12	0.5	-	-	-	***R***
13	1.0	-	-	-	+++
14	1.5	-	-	-	R
15	1.5	-	1.0	-	R
16	1.5	-	-	0.5	R
17	1.0	-	0.5	-	-
18	1.0	-	1.0	-	-
19	2.0	-	1.0	-	-
20	-	-	2.0	1.0	-

Present studies on *H. flavescens* proved that an auxin alone or its combinations or in combination with BA/Kn augmented the formation of callus. Callus was initiated from the cut ends of all the explants. Young pale green leaves were efficient in inducing callus. Among Zingiberacean members, callogenesis using leaf explants have been achieved on ginger and turmeric (Salvi *et al.,* 2001), *H. coronarium* (Lung *et al.,* 2002). and *Keampferia galanga* (Chitra, 2002).

Leaf explants from distal portion did not induce callus formation. As explained by Welander (1988), efficiency of the proximal end may be due to difference in the maturity between proximal and distal ends of the leaf which relies on the fact that leaves reach maturity first at distal and subsequently in the basipetal progression and also the physiological and biochemical condition of the cell. Babu *et al.* (1992) have noticed development of callus from leaf on various concentrations of 2, 4-D in *Z. officinale*. When the callus was subcultured to a high cytokinin-auxin medium, organogenesis and plantlet formation were noticed, but NAA was necessary for root development. Spontaneous root development may be due to the presence of high amount of indigenous auxin in the explant. In contrast to the reports of Chitra (2002) a combination of 2,4-D and Kn did not give better result.

Callogenesis from leaf sheath coincides with the reports of Anand *et al.* (1997), wherein 2, 4-D and NAA combination provided high percentage of callus induction in *Alpinia calcarata.* In contrast to the observations of Lung *et al.*, (2002), the leaf sheath did not give shoot and root in the presence of BA and NAA. Chitra (2002) had reported the development of somatic embryogenesis in *K. galanga* on half-strenght MS. More callus development was noticed in this work on half-MS with root initiation. It may be due to the combined action of low concentration of NO_3^- and the effect of auxin. Most of the reports of callus induction on members of Zingiberaceae have been from rhizome bud explants. They include *Curcuma* sp., *C. longa* (Sunitibala *et al.,* 2001), and ginger (Rout and Das, 1997). Callus induction has been documented from ovary of ginger (Babu *et al.,* 1996), protoplasts of ginger and cardamom (Geetha *et al.*, 2000), and roots of *C. zedoaria* (Miachir, 2004).

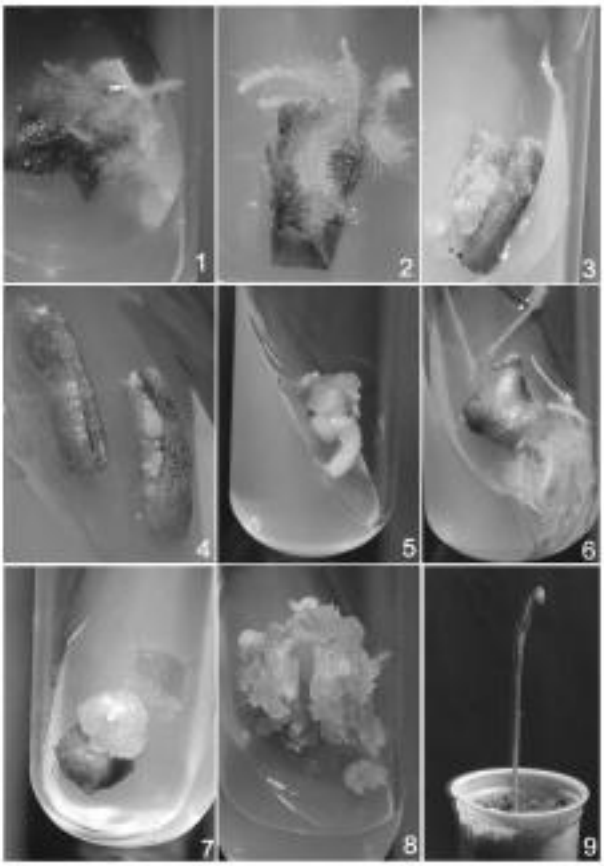


Fig.1- 9: Different aspects of *in vitro* morphogenesis of *H. flavescens* on MS medium fortified with growth hormones (mgl^{-1}). Fig 1. callogenesis on leaf lamina explant (2, 4-D 1.0, BA 0.2); Fig. 2.rhizogenesis on callus derived from leaf lamina (BA 3.5, NAA 1.5, Kn 0.5); Fig 3 & 4 callogenesis on leaf sheath explant (2, 4-D 2.0, NAA 1.0); Fig 5. callogenesis on rhizome bud (2,4-D 1.5, BA 0.5); Fig.6. luxurient rhizogenesis on callus derived from rhizome bud (BA 3.0); Fig 7. low callus induction under long photoperiod (12h) on rhizome bud (1/2MS, BA 0.2); Fig 8. profuse callus under short photoperiod (4h) on rhizome bud (1/2MS, BA 2.0); and Fig.9 hardened plantlet.

In contrast to the reports of Anand and Hariharan (1997), callus induction was maximum on MS medium with 2, 4-D or NAA alone than in auxin and cytokinin combination. Induction of callus upon the treatment with NAA showed similarity with the result of Miachir *et al.,* (2004) in *C. zedoaria.* Root (but no shoot) formation was observed in the callus even after 2 months. Malamug *et al.,* (1991) reported a similar type of callus formation in ginger where the callus was capable of only rhizogenesis. The auxin 2, 4-D has been particularly found to be an inducer of somatic embryogenesis in more than 50% of plant taxa reported (Miachir *et al.,*2004) was not effective in inducing embryogenic callus in *H.flavescens.* Simultaneous development of root coincides with the reports in which the cytokinin-auxin combination produces shoot and more roots simultaneously (Geetha *et al.,* 1997).

In contrast to this work, low concentration of NAA had enhanced root formation in *H. roxburghii* and *Z. officinale (*Arimura *et al.,*2000).Occasionally it was observed that long dark period induces callus multiplication both on leaf sheath and rhizome bud when incubated in dark on half-strength MS medium. Similar observation was made by Miachir, (2004) in *C. zedoaria.* It is due to the fact that activity of auxin increases in dark condition. Of different explants tested,

rhizome buds were more effective in the micropropagation of *H. flavescens, and a*s per the literature, this is the first ever *in vitro* attempt on *H. flavescens.*

References

Anand PHM and Hariharan M 1997. *In vitro* multiplication of Greater Galangal, (*Alpinia galanga* (Linn.) Willd.) a medicinal plant. *Phytomorphology* 47: 45 - 50.

Arimura CT, Finger FL. and Casali VWD 2000. Effect of NAA and BAP on Ginger (*Zingiber officinale* Roscoe.) sprouting in solid and liquid medium. *Revista Brasileira de Plantas Medicinais* 2: 23-26.

Babu KN, Samsudeen K and Ratnambal MJC 1992. *In vitro* plant regeneration from leaf-derived callus in Ginger (*Zingiber officinale* Roscoe.) *Plant Cell, Tissue Org. culture* 29: 71-74.

Chiranjini P, Sharma GJ and Sinha SK 2004. Sulfur free radical with curcumin as reference for evaluating antioxidant properties of medicinal zingiberales. *J. Environ. Pathol. Toxicol. Oncol.* 23: 227-236.

Chitra M. 2002. *In vitro* morphogenesis studies on medicinally important *Rotula aquatica* Lour. and *Kaempferia galanga* Linn. M.Sc. Dissertation, University of Calicut, Kerala.

Geetha SP 2005. Induction of *in vitro* micropropagation in *Kaempferia rotunda* Linn. – An endangered medicinal plant. *Technical programme, Extended summaries of papers and abstracts of Papers, 17th Kerala Science Congress*, KFRI, Peechi.

Lung HP and Chichu T 2002. Micropropagation of *Hedychium coronarium* Koenig via somatic embryogenesis. *JChinese Soc. Hort. Sci.* 48: 239-245.

Kackar A, Bhat SR, Chandel KPS and Malik 1998. Plant regeneration via somatic embryogenesis in ginger. *Plant Cell Tissue Org. Culture* 32:289-292.

Malamug JJF, Inden H and Asahira T 1991. Plantlet regeneration and propagation from ginger callus. *Scientia Horticulturae* 48: 89-97.

Miachir JI, Romani VLM, de Amaral C, Mello MO, Crocomo OJ, and Melo M 2004. Micropropagation and callogenesis of *Curcuma zedoaria* Roscoe. *Scientia Agricola.* 61: 427-432.

Murashige T and Scoog F 1962. A revised medium for rapid growth and bioassay with tobacco tissue cultures. *Physiologia Plantarum* 15: 473-497.

Rout GR and Das P 1997. *In vitro* organogenesis in Ginger (*Zingiber officinale* Roscoe). *J. Herb. Spice Med. Plants* 4: 41-51.

Sabu M 2006. Zingiberaceae and Costaceae of South India. Indian Association fro Angiosperm Taxonomy, Calicut University, Kerala pp: 199.

Salvi ND, George L and Eapen S 2002. Direct regeneration of shoot from immature inflorescence cultures of turmeric. *Plant Cell, Tissue Org. Culture* 52: 235-138.

Sunitibala H, Damayanthi M and Sharma GJ 2001. *In vitro* propagation and rhizome formation in *Curcuma longa* Linn. *Cytobios*. 105: 71-82.

Welander M 1988. Plant regeneration from leaf and stem segments of shoots raised *in vitro* from mature apple trees. *J. Plant physiol.* 132: 738 - 744.

Acknowledgements

Live specimens maintained in the Calicut University Botanic Gardens were kindly provided by Dr. M. Sabu, Department of Botany. Mr. M.C. Shameer and Ms. V.P. Saeeda had efficiently contributed to the preparation of this manuscript.

Adaptability of S.274 coffee to Wayanad and Coorg conditions

Nikhila KR[1], Sureshkumar VB[2], and Mohanan KV[1]
1 Genetics and Plant Breeding Division, Department of Botany, University of Calicut, Kerala- 673 635.
2 Regional Coffee Research Station, Chundale, Wayanad, Kerala.

Abstract

S.274 is an improved variety of the diploid species of cultivated coffee, Coffea canephora var. robusta. The performance of the variety under Wayanad and Coorg conditions was comparatively analysed, so as to assess the adaptability of it to the agro climatic conditions of the two coffee growing districts of the western ghat region of South India. The study reveals no significant difference in the case of growth and yield characters of S.274 coffee under the two agro climatic conditions. An average yield per plant of 10.67 Kg was observed in Coorg and 13.39 Kg/plant in Wayanad, which amounts to about 10500 kg/ha and 13000Kg/ha respectively.

Introduction

The diploid species of cultivated coffee, *Coffea canephora* var. robusta is widely cultivated in the coffee tracts of Kerala and Karnataka. Wayanad of Kerala and Coorg of Karnataka are two major coffee growing districts with different agro climatic conditions. The adaptability of S.274, an improved variety of robusta coffee released by Central Coffee Research Institute, India, to the conditions of these two districts has been analysed presently based on data collected from six estates each of these two districts. The experiment was conducted during 2003-2004.

Materials and Method

Six estates each growing stabilized plants of S.274 coffee, selected at random from the two coffee growing districts were used as the study area. All the estates were moderate to large sized and maintaining standard manurial and plant protection protocols. Six plants were selected at random from each estate and data recorded on 23 characters as shown in Table 1. Range and mean values were calculated to study the adaptability of the variety in the two districts based on their comparative performance. Incidence of leaf rust was scored with the help of a six-point scale-nil/ very low/ low/ medium/ high/ severe.

Results and Discussion

Mean stem girth, girth of primary branches, number of secondaries per primary, length of primary branches, internodal length, bush spread, fruits per node, yield per plant, fresh fruit weight, fruit thickness and seed breadth were found to be higher in Wayanad estates, and number of primary branches, leaf length, leaf breadth, leaf area, seed weight, fruit length, fruit breadth, fruit volume, seed length, seed thickness and seed volume were found to be higher in Coorg estates. However these variations have been found to be statistically nonsignificant.

The above analysis shows that the variation in performance shown by S.274 variety of robusta coffee under Wayanad and Coorg conditions is insignificant. The variety performed very well under Coorg and Wayanad conditions as evidenced by the above observation. Average yield per plant was 13.39 kg in Wayanad and 10.67 kg in Coorg, which amounts to around13000 kg/ha of green coffee per ha. in Wayanad and 10500 kg green coffee/ha in Coorg conditions, thus showing that S.274 can be recommended for cultivation both in Wayanad and Coorg. Some efforts have been carried out by earlier workers also to analyse the performance of different varieties of coffee in different agro climatic

regions (Sreenivasan and Jamsheed Ahmed, 1998). Sreenivasan (1984), Jamsheed Ahmed (1985), Dharmaraj (1985), Reddy (1985) and Gopal (1985) have conducted investigation on the adaptation of different coffee cultivars to traditional and non traditional areas.

Table 1. Performance of S 274 coffee under Wayanaad and Coorg conditions.

Characters	Wayanad estates		Coorg estates	
	Mean	Range	Mean	Range
Stem girth (mm)	108.74	73.3-150	103.47	68.23-134
Girth of primary(mm)	73.11	30.7-111.9	66.71	31.5-123.32
No. of primary	2.03	1-4	2.45	1-5
No. of sec. per pri.	5.76	4-7	5.64	3.5-8.5
Length of pri. (cm)	204.89	124.5-290	191.34	122-294
Internodal length (cm)	7.09	5-11	6.41	3.75-9.2
Bush spread (cm)	322.78	183-480	317.97	204-475
Fruits/node	17.02	8-36.67	16.83	3.8-32.5
Leaf length (cm)	21.78	17-27.3	22.49	17.75-29
Leaf breadth (cm)	9.48	6-12	9.67	4.25-14.5
Leaf area (cm2)	132.69	96.39-196.56	135.77	55.91-219.24
Yield /plant (Kg)	13.39	2-35	10.67	2.5-28
Leaf rust		Nil-severe		Nil-high
Fresh fruit wt. (100 fruits)	143.32	101.5-191.9	141.79	97.6-209.3
Dry fruit wt. (100 fruits)	61.05	35.7-78.6	79.12	36.3-130
Seed wt. (100 seeds)	17.14	9.8-20.8	17.3	11-28.5
Fruit length(mm)	14.65	12.82-17.35	14.92	13.03-18.22
Fruit breadth (mm)	13.53	11.98-14.7	13.57	11.97-15.92
Fruit thickness(mm)	11.6	10.52-12.9	11.57	9.92-13.38
Fruit volume(mm3)	1211.24	867.57-1543.99	1218.19	804.55-1803.89
Seed length(mm)	8.29	7.11-9.64	8.74	6.18-12.19
Seed breadth(mm)	6.94	6-7.82	6.87	6.04-8.3
Seed thickness(mm)	4.48	4.18-4.94	4.55	3.74-5.3
Seed volume(mm3)	139.3	95.19-194.98	150.04	102.3-245.74

(the difference was found to be statistically non significant in all cases)

Reference

Dharmaraj PS 1985. Adaptation of coffee selections in Andhra Pradesh. *Journal of Coffee Research* 15: 32.

Gopal NH 1685. Performance of coffee cultvars of Andhra pradesh region with reference to drought. *Journal of Coffee Research* 15: 58.

Jamsheed Ahmad 1985. Adaptation of selections in traditional areas. *Journal of Coffee Research* 15 . 30-31.

Reddy AGS 1985. Adaptation of selections in nontraditional areas. *Journal of Coffee Research* 15. 32-33.

Srinivasan CS 1984. Performance of *arabica* varities at three locations in Coorg. *Indian Coffee* 48(4): 11-13.

Srinivasan CS and Jamsheed Ahmad 1998. Performance of coffee varities in Coorg- an assessment. Souvenir, Golden Jubilee Celebrations, CRSS, Chettalli, Karnataka:.45-47.

Evaluation of tamarind accessions and variety for growth, fruit yield and quality under rainfed vertisol condition

Balakrishnan S.
Agricultural College and Research Institute, Madurai, Tamil Nadu- 625 104.

Abstract

Tamarind is grown predominantly in the southern districts of Tamil Nadu. It is mostly growh under rainfed conditions. Tamarind accessions/ varieties suitable for rainfed vertisol condition have not been evaluated so far. A study to evaluate 26 tamarind accessions and a variety (PKM 1) for growth, fruit yield and quality under rainfed vertisol condition was conducted in Tamil Nadu. The different genotypes exhibited significant variations in tree height, tree girth, number of branches, fruit yield, pulp weight, pulp percentage, TSS and acidity. PKM 1 recorded the the highest mean values for tree height, tree girth, number of branches, fruit yield, fruit weight, pulpm percentage, TSS and acidity. Next to PKM 1, Ettayapuram accession performed well in respect of the above characters. Hence, PKM 1 and Ettapuram can be selected for cultivation under rainfed vertisol condition in Tamil Nadu.

Introduction

Tamarind (*Tamarindus indica*) is grown in 18,600 hectares in Tamil Nadu with an annual production of 58,340 tonnes of fruits. In southern districts of Tamil Nadu, tamarind is mostly grown under rainfed condition in vertisol. The tamarind accessions / variety suitable for rainfed vertisol condition have not been evaluated so far. Hence, there is a need to identify the suitable variety/ type of tamarind for rainfed vertisol. With this objective, a study on evaluation of tamarind accessions and variety for growth, fruit yield and quality under rainfed vertisol condition was conducted.

Materials and Method

This experiment was conducted with 26 diverse genotypes of tamarind comprising 25 accessions and a variety viz., PKM 1 in a Randomized Block Design with two replications at Regional Research Station, Kovilangulam. Tamarind trees of uniform age were used for recording data during the year 2002. The cultural practicees were followed as per the standard recommendations for Tamil Nadu (Anonymous, 1999)) under rainfed condition.

Results and Discussion

The mean data collected during the year 2002 are presented in Table 1. The different genotypes exhibited significant variations in tree height, tree girth, number of branches, fruit yield / tree, fruit weight, pulp weight, pulp percentage, TSS and acidity.

Among them, PKM 1 recorded the highest mean values in respect of tree height (475 cm), tree girth (72 cm), number of branches (6), fruit yield (32.5 kg / tree), fruit weight (15.6 g), pulp weight (5.4 g), pulp percentage (34.6),TSS (24^{o} Brix), and acidity (11..9%). The superiority of PKM 1 over the other types is due to its regular bearing habit and the inherent high yield potential of the variety with good quality has been reported by Arumugam (1990). The fruit quality of PKM 1 was god with respect to total soluble solids and acidity.Next to PKM 1, Ettayapuram (TI 5) accession performed well in respect of the above growth and yield characters.

Summary

Twenty six diverse genotype of Tamarind comprising 25 accessions and a variety PKM 1 were evaluated to identify suitable type / variety for cultivation under rainfed vertisol condition. The results of the experiment have indicated that PKM 1 was the best with the highest fruit yield (32.5 kg/tree) followed by Ettayapuram accession (IT.5) with a fruit yield of 28.7 kg / tree. Hence, PKM 1 and Ettayapuram accession(TI. 5) can be selected for cultivation under rainfed vertisol condition due to their regular bearing habit and their superior performance under rainfed vertisol condition.

Table 1. Evaluation of tamarind germplasm during April- May (2002)

Accession No.	Name of accession / variety with source	Tree height (cm)	Tree Girth (cm)	No. of branches	Fruit Yield (kg)/ tree	Fruit Weight (g)	Pulp Weight (g)	Pulp Percentage	TSS °Brix	Acidity %
TI_1	Aruppukottai	450	45	6	10.9	15.3	5.1	23.3	22	10.8
TI_2	PKM 1	475	72	6	32.5	15.6	5.4	34.6	24	11.9
TI_3	Anchity	434	43	5	12.7	13.8	4.5	32.6	19.	9.0
TI_4	Madurai	462	54	4	12.1	11.3	3.8	33.6	24	11.0
TI_5	Ettayapuram	465	61	5	28.7	15.2	5.2	34.2	24	11.5
TI_6	Kovilangulam	457	54	5	11.4	9.6	3.1	32.3	20	10.4
TI_7	Palayampatti	445	52	4	12.8	10.8	3.4	31.5	24	9.0
TI_8	Mettupalayam	413	51	4	13.1	10.3	3.4	33.0	22	9.1
TI_9	Poovani	450	50	5	11.7	9.7	3.3	34.0	23	9.3
TI_{10}	Kallar	442	49	5	10.8	9.3	3.0	32.2	22	9.0
TI_{11}	Faizabad	430	46	4	10.2	9.0	3.0	33.3	22	9.4
TI_{12}	Senduraikottaipatti	425	33	4	8.8	9.5	3.2	33.6	21	9.0
TI_{13}	Sendurai	360	34	4	6.0	9.2	3.1	33.7	20	9.1
TI_{14}	Ayyalur	393	37	4	5.4	9.0	3.0	33.3	20	9.2
TI_{15}	Rajapalayam	376	36	5	8.2	9.4	3.1	32.9	21	8.8
TI_{16}	Uluppakudi-1	337	27	3	7.8	8.8	2.9	32.9	21	9.0
TI_{17}	Kokilapuram	410	39	3	4.6	9.2	3.1	33.6	20	8.9
TI_{18}	Uluppakudi-2	342	27	3	5.2	8.9	2.8	31.4	21	8.8
TI_{19}	Karaikundu-1	376	32	3	7.9	9.1	3.0	32.9	20	9.0
TI_{20}	Punnapatti	350	30	4	8.2	9.0	3.1	34.4	19	9.1
TI_{21}	Vemparpatti	352	31	3	6.4	8.8	2.8	31.8	19	8.8
TI_{22}	Karanthamalai	282	26	3	5.2	8.6	2.8	32.5	20	8.7
TI_{23}	Karaikundu-2	327	29	4	7.0	9.0	3.0	33.3	18	8.9
TI_{I4}	Uluppakudi-3	262	28	4	8.4	9.2	3.1	33.6	18	9.1
TI_{25}	Odddukkam	250	25	3	6.2	9.5	3.2	33.7	19	9.0
TI_{26}	Kovilangulam-2	196	23	2	4.0	8.4	2.7	32.1	18	8.9

References

Anonymous, 1999. Crop production techniques of Horticultural Crops. Directorate of Horticulture and Plantation Crops, Chennai, p.127.

Arumugam R, 1990. Variety release proposal of PKM 1 tamarind submitted to Tamil Nadu Agricultural University, p.14.

Gregor Mendel Foundation Proceedings 2006

Line X tester analysis for seed yield and yield attributes in sunflower *(Helianthus annuus* L*).*

Yogeesh LN, Gangappa E, Manjunatha YS and Shadakshari YG

Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore-560 065.

Abstract

A Line x tester analysis involving three CMS lines, six male lines and the resulting 18 hybrids were carried out to study the combining ability for seed yield, oil content and its components at GKVK, Bangalore during 2005. The estimated components of gca and sca variances established the predominance of non additive gene action for all the characters except for days to 50 per cent flowering which appeared to be under the control of additive gene action. Among the lines, CMS 234A proved to be the good general combiner for early flowering, volume weight, test weight, oil content and oil yield. Among the testers, the tester I-79 for earliness, volume weight, test weight and seed yield and the tester I-98, for oil content and oil yield were good general combiners as evident from their high gca effects. The cross CMS 234A x I- 77 for seed yield, CMS 234A x I-79 for oil content and CMS 852A x I-98 for oil yield were found to be best specific combiners.

Key words: Combining ability.

Introduction

At present, sunflower cultivation is rising due to its day neutrality, wide adaptability, short duration, potential to give higher seed and oil yields coupled with remunerative prices. From the past experience, it has been observed that *per se* performance of parents is not always a true indicator of its potential in hybrid combination. The information on the combining ability status of the genotypes will give an indication as to how well they combine with a given genotype to produce potential and productive hybrid. In this direction the concept of *gca* and *sca* helps the breeders to decide upon the choice of parents for hybridization and to isolate promising genotypes from the segregating population. Keeping this in view, the present study was under taken to estimate combining ability in sunflower.

Material and Method

The material for the present study consisted of six newly developed inbred lines viz., I-77, I-79, I-92, I-98, I-114 and I-116 and three elite cytoplasmic male sterile lines *viz.,* CMS 234A, CMS 851A and CMS 852A. During *rabi/summer* of 2004-05, all the three CMS lines and six inbred lines were sown in the field to develop crosses. The capitula of CMS lines were covered with cloth bags a day prior to opening of ray florets in order to prevent undesirable pollination. Similarly, the capitula of testers were also covered and the pollen from the new inbreds (testers) was collected in petri plates and applied onto the CMS lines using camel hairbrush during morning hours. The pollination was repeated for 8-10 days to ensure sufficient number of seeds in each of the combinations. In all, the material consisting of 27 genotypes (18 single crosses, three lines and six testers) was sown in the fields of Zonal Agricultural Research Station UAS, GKVK, Bangalore during *kharif* 2005 (For evaluating the lines, the respective CMS B lines were used for sowing). The experiment was laid out following Simple Randomized Block Design (RBD) with of three replications. Each genotype was sown in a single row of 3.0 m length with a row-to-row spacing of 60 cm and 30 cm between the plants within a row. All the recommended agronomic practices

were adopted for raising a healthy crop. Observations were recorded on nine quantitative characters *viz.* Days to 50 per cent flowering, plant height, head diameter, stem diameter, seed yield, volume weight, test weight, oil content and oil yield in both hybrids and parents. Five random competitive plants were selected for recording the observations and the mean of five plant observations were used for further analysis. Combining ability was estimated following the method of Kempthorne (1957).

Results and Discussion

Analysis of variance for nine characters revealed a significant variation among the sources (Table-1). Among the lines variance was found to be significant for the days to 50 per cent flowering, plant height, head diameter, volume weight and oil yield. For the testers, variance was found significant for days to 50 per cent, plant height and volume weight. Crosses derived from them significantly different from each other, which could be due to the fact that, line x tester was significant for all the characters indicating the ability of the parents to produce variability. Significance of variance due to interaction between lines and testers also suggested the involvement of non-allelic interactions in the inheritance of all the traits. Significance of variance due to lines, testers, and line x testers interactions was also reported by Giriraj *et al.,* (1987), Wali (1987) and Gangappa *et al.,* (1997a).

The estimation of combining ability indicated (Table-2) that lines CMS 234B and CMS 851B were good general combiner for earliness and tend to produce progenies with early flowering. Among the testers, I-79 (-2.29) was having high breeding value for earliness suggesting its utility to synthesize early maturing hybrids. Earlier workers like Bajaj *et al.,* (1997), Gangappa *et al.,* (1997a), Singh *et al.,* (1999) and Vishwanath (2003) have also identified CMS 234A as good a general combiner for early flower. The lines CMS 852B (267.07) and CMS 234B (53.29) and the testers I-79 (165.24), I-77 (165.24) and I-92 (151.01) appeared to transmit increasing alleles with additive effects to their progeny as evident from their significant positive *gca* effects for seed yield. These findings are in agreement with the earlier reports of Bajaj *et al.,* (1997), Gangappa *et al.,* (1997a), Singh *et al.,* (1999) and Vishwanath (2003). Among the lines, CMS 234B (2.89) exhibited significant *gca* effects; while, the tester I-98 (6.21), manifested significant positive *gca* effects and appeared to transmit additive gene to their progenies for oil content. Giriraj *et al.* (1987), Singh *et al.,* (1999) and Vishwanath (2003) also reported good general combiners for oil content. The line CMS 234B (90.55) and the testers I-98 (133.93) and I-79 (82.02) were good general combiners for oil yield as evident from their high *gca* effects. This is obvious as oil yield is the function of seed yield and oil content. Earlier workers like Bajaj *et al.,* (1997), Shekar *et al.,* (1998) and Radhika *et al.,* (2001) have reported high *gca* effects for seed yield and oil content.

The estimation of specific combining ability indicated (Table-3) that, five out of 18 cross combinations recorded negative *sca* effects in the desirable direction for days to 50% flowering. The cross combination CMS 234 A x I-114 (-1.40) was the best specific combination followed by CMS 851A x I-79 (-1.26), CMS 851A x I-116 (-1.0) and CMS 234A x I-77 (-0.98). The reporters by Gangappa *et al.* (1997a) and Ashok *et al.,* (2000) have indicated these lines good specific combiners for earliness. In respect of seed yield, five cross combinations manifested significant positive sca effects. The hybrid CMS 234A x I-77 (468.14) topped the list followed by the crosses, CMS 851A x I-114 (364.59) and CMS 234A x I-114 (259.96). Earlier workers like Gangappa *et al.* (1997a), Sharma *et al.*, (2003) have reported high *sca* effects for seed yield. The crosses CMS 234A x I-79 (3.58), CMS 852A x I-114 (3.51) and CMS 234A x I-92 (2.27) were the best specific combinations for oil content. Gangappa *et al.,* (1997a), Ashok *et al.,* (2000) and Sharma *et al.,* (2003) reported good specific combiners for oil content.

The cross, CMS 852A x I-98 (170.5) was found to be best specific combiner followed by the crosses CMS 851 A x I-114 (123.16) and CMS 234 A x I-79 (112.35). Ashok *et al.,* (2000), Sharma *et al.,* (2003) and Vishwanath (2003) also reported good specific combiners for oil yield.

The lines CMS 234B, CMS 851B and the tester I-79 were found to be good general combiner for earliness and tend to produce progenies with early flowering. Therefore, these lines and tester could be used in the synthesis of early maturing hybrids. Among the lines CMS 852B and CMS 234B and the testers I-98 and I-77 exhibited high *gca* effects for seed yield. Therefore, these lines and tester could be used in the production of high yielding hybrids. The hybrids CMS 234A x I- 77 for early flowering and seed yield, CMS 234A x I - 98 for oil content and CMS 852A x I-98 for oil yield is suggested for testing on a large scale trials to confirm its superiority over different seasons and locations.

References

Ashok S, Mohammed Sheriff N and Lakshminarayanan S 2000. Combining ability studies in sunflower. *Crop Res*. 20: 457-460.

Bajaj RK, Kamaljit, Anjula K and Chahal GS 1997. Combining ability studies in sunflower (*Helianthus annuus* L.). *Crop Improve*. 24: 50-54.

Gangappa E, Channakrishnaiah KM, Harini MS and Ramesh S 1997. Studies on combining ability in sunflower (*Helianthus annuus* L.). *Helia* 20: 73-84.

Giriraj K, Shantha R. Hiremath and Seenappa K 1987. Combining ability of converted male sterile lines of sunflower (*Helianthus annuus* L.). *Indian J. Genet.* 47: 315-317.

Kempthorne O 1957. An Introduction to Genetic Statistics. John Willey and Sons, Inc., New York. 545p.

Radhika P, Jagadeshwar K and Sharma PS 2001. Genetic analysis of seed yield and certain physiological parameters in sunflower. *J. Res.* ANGRAU 27: 5-17.

Singh DP, Singh SB and Raheja RK 1999. Combining ability analysis for seed yield and oil quality in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 16: 38-42.

Sharma, Bajaj RK, Narinder Kaur, Sehgal SK, Sharma S and Kaur N 2003. Combining ability studies in sunflower (*Helianthus annuus* L.). *Crop Improve.* 30: 69-73.

Shekar GC, Jayaramaiah H, Virupakshappa K and Jagadeesh BN 1998. Combining ability of high oleic acid in sunflower. *Helia* 21: 7-14.

Vishwanath KS 2003. Evaluation of hybrids synthesized from elite CMS lines and restorer for their value in crop improvement in sunflower (*Helianthus annuus* L.). M.Sc. (Agri). Thesis, UAS, Bangalore, p. 95.

Wali MC, 1987. Line x Tester analysis of estimating combining ability in sunflower. *M.Sc (Agri). Thesis*, UAS, Bangalore, p. 96.

Table 1: Analysis of variance for seed yield and yield attributing traits in sunflower

Source	d.f	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	Test weight (g)	Volume weight (g/100cc)	Seed yield (Kg/ha)	Oil content (%)	Oil yield (Kg/ha)
Replications	2	2.25	361.12	0.38	0.032	0.005	2.75	3360	0.527	48
Treatments	26	14.61**	5936.58**	6.45**	0.23**	1.393**	76.24**	2553783.5**	10127**	332663.8**
Parents	8	6.08**	1284.54**	4.93**	0.33**	1.26**	75.60**	1223836.2**	75.93**	198033.18**
Crosses	17	19.30**	276.47	7.01**	0.088**	1.52**	24.26**	573466.37**	60.34**	83416.97**
Parent Vs Crosses	1	2.69*	139374.9**	9.00**	1.77**	0.28**	964.87**	4685791**	289.89**	5646894.8**
Lines (L)	2	77.71**	695.6**	20.77*	0.189	0.95	5.23*	81656.18	114.57	263126*
Testers (T)	5	25.15*	473.9**	7.98	0.037	2.23	50.06**	373241.59	96.84	90262.41
L x T	10	4.6**	93.92	3.78**	0.9**	1.28**	15.17**	470019.19**	31.26**	44052.39**
Error	52	0.55	297.25	0.351	0.031	0.007	1.16	24119.385	2.86	4259.308

** Significant at P= 0.01 level
* Significant at P= 0.05 level

Table 2: Estimates of general combining ability effects of lines and testers for yield and yield attributes in sunflower

Parents	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm))	Test weight (g)	Volume weight (g/100cc)	Seed yield (Kg/ha)	Oil content (%)	Oil yie (Kg/h
MS 234B	-1.39**	5.76	-0.53**	0.04	0.03	0.62*	53.296**	2.89**	90.55
MS 851B	-1.00**	0.83	1.24**	0.08	-0.24**	-0.25	-320.37**	-1.77**	-137.3
MS 852B	2.39**	-6.59	-0.70**	-0.12**	0.21**	-0.37	267.07**	-1.12*	46.75
	0.18	4.06	0.14	0.04	0.02	0.25	36.6	0.40	15.38
RS									
I-77	-0.50*	4.92	0.76**	0.07	-0.02	-1.44**	165.24*	-1.68*	33.92
I-79	-2.29**	1.36	0.16	0.03	0.72**	2.47**	172.68*	0.63	82.02
I-92	2.28**	3.68	0.52*	0.06	-0.70**	-1.37**	151.01*	-2.93**	-47.62
I-98	0.07	6.97	0.25	-0.06	-0.17**	3.35**	-85.06	6.21**	133.93
I-114	-1.06**	-12.45*	-1.86**	-0.07	-0.22**	-0.50	-340.87**	-0.44	-129.4
I-116	1.50**	-4.48**	0.18	-0.05	0.39**	-2.51**	-62.42	-1.79*	-72.7
SE±	0.25	5.74	0.20	0.06	0.03	0.36	51.7	0.56	21.76

****** Significant at P= 0.01 level ***** Significant at P= 0.05 level

Table 3: Estimates of specific combining ability effects of hybrids for yield and yield attributes in sunflower

ds	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	Test weight (g)	Volume weight (g/100 cc)	Seed yield (Kg/ha)	Oil content (%)	C (
I-77	-0.98**	-3.84	0.67	-0.18	0.72**	-1.82*	468.14**	-2.66*	
I-79	2.17**	-2.11	1.23**	0.00	0.35**	-1.66*	-5.6299	3.58**	1
I-92	-0.08	8.27	-0.10	0.02	-0.48**	1.34*	-343.29**	2.27**	
I-98	0.50	-0.28	-0.09	0.15	-0.10*	-0.68	-452.62**	0.10	-1
I-114	-1.40**	-3.20	-1. 58**	-0.04	0.14*	-0.70	259.59*	-3.94**	
I-116	-0.30	1.16	-0.13	0.06	-0.63**	3.51**	-73.81	0.64	
I-77	1.00*	5.53	-0.94*	0.06	0.11*	2.18**	-308.18*	0.71	
I-79	-1.26*	4.30	-0.43	0.05	-0.71**	-1.42*	-156.29	-2.91**	-1
I-92	0.56	-1.25	0.05	0.13	-0.12*	-1.74*	111.37	1.91	
I-98	-0.22	-3.18	-1.03*	-0.18	-0.01	0.87	233.70*	-1.93	
I-114	0.89**	-4.66	1.15**	-0.20*	0.62**	1.44*	364.59**	0.42	1
I-116	-1.00**	-0.74	1.20**	0.14	0.11*	-1.33	-245.18*	1.80	
I-77	-0.06	-1.69	0.27	0.12	-0.83**	-0.36	-159.9	1.95	
I-79	-0.97**	-2.19	-0.80*	-0.05	0.36**	3.08**	161.9	-0.67	
I-92	-0.59	-7.02	0.04	-0.15	0.60**	0.40	231.92*	-4.19**	
I-98	-0.03	3.47	1.11*	0.04	0.12*	-0.19	-218.92*	1.83	1
I-114	0.50	7.85	0.43	0.24*	-0.76**	-0.74	-624.18**	3.51**	-
I-116	1.28**	-0.42	-1.06*	-0.19	0.52**	-2.18**	171.37	-2.44*	
	0.43	9.95	0.34	0.1	0.05	0.62	89.66	0.98	

****** Significant at P= 0.01 level ***** Significant at P= 0.05 level

Gregor Mendel Foundation Proceedings 2006

Differentiation of *Vanilla planifolia* Andrews from *Vanilla tahitensis* J.W. Moore based on anatomical characters

Umamaheswari R[1], Sreekala KV[2] and Mohanan KV[1]
1 Department of Botany, University of Calicut, Kerala- 673 635.
2 Department of Botany, St. Mary's College, Sulthanbathery, Kerala.

Abstract

Three species of Vanilla, Vanilla planifolia Andrews, Vanilla tahitensis J.W. Moore and Vanilla pompona Schiede are cultivated commercially. However, Vanilla planifolia Andrews is commercially the most important since the vanilla obtained from it is superior in quality. In most of the vanilla growing regions in India, planters solely cultivate Vanilla planifolia. Very often, vine cuttings of Vanilla tahitensis get mixed with the planting material of Vanilla planifolia accidentally and hence techniques to differentiate them both at farm level and lab level are very important. The present study was carried out to find out the methods to differentiate the two species anatomically. Observations on stem, leaf and velamen root anatomy revealed remarkable differences between the two species and the study has generated additional information helpful in confirming the identity of the planting material of Vanilla planifolia.

Introduction

Vanilla Plumier ex Miller is a pantropical genus of about 65 species (Kumar and Manilal, 2004) and the plant has long flexuous, succulent, green simple stem producing alternate leaves. The most widely grown species of commercial importance is *Vanilla planifolia* Andrews and two other cultivated species are *Vanilla pompona* Schiede and *Vanilla tahitensis* J.W. Moore. *Vanilla planifolia* is indigenous to humid tropical rainforests of South Eastern Mexico, Central America, the West Indies and northern part of South America. *Vanilla tahitensis*, the Tahitian vanilla is cultivated in the Tahiti islands and *Vanilla pompona* in the South Pacific islands (*Madhusoodanan et al.*, 2003). Vanillin ($C_8H_8O_3$) is chiefly responsible for the unique fragrance and flavour of the processed beans. Even though vanilla beans obtained from *Vanilla tahitensis* are also used in commerce to some extent, due to the inferiority of the beans obtained from it, usually it is considered an adulterant when it is mixed with the beans of *Vanilla planifolia*. Vanilla is propagated by stem cutting in India (Hegde and Kumar, 2002). Vine cuttings of *Vanilla planifolia* get sometimes adulterated with that of *Vanilla tahitensis* knowingly or unknowingly. The present study has been taken up so as to characterise *Vanilla tahitensis* and *Vanilla planifolia* based on anatomical characters so that better differentiation is possible.

Materials and Method

Materials for the present study were obtained from the vanilla collection maintained in the experimental net house of the Genetics and Plant breeding Division of the Department of Botany of Calicut University, Kerala, India. Fresh materials were collected and transections of leaf, stem and velamen root were made with the help of a sharp razor blade by free hand section. Sections and peelings of the stem, leaf and velamen root were double stained and anatomical observations were made and photo micrographs prepared. The anatomical observations were made in the Centre for Medicinal Plants Research, Kottakkal, Kerala.

Results and Discussion

The stem, leaf and velamen root anatomy of *Vanilla planifolia* and *Vanilla tahitensis* has been comparatively analysed presently to compare them at anatomical level (Tables 1, 2 & 3).

Leaf: Leaf is isobilateral with no palisade layer in both the cases. Epidermis is single layered in both with stomata only on the lower epidermis. Hypodermis is single layered and collenchymatous in both and present throughout the lamina. Main vascular bundle was comparatively well developed in *Vanilla planifolia*. The bundle sheath was complete and

with more thick walled cells just below the phloem. Bundle sheath was not complete in *Vanilla tahitensis*. Needle like crystals of calcium oxalate were seen in some of the mesophyll tissues in both the species.

Stem: The epidermal cells of *Vanilla tahitensis* are smaller when compared to that of *Vanilla planifolia*. The mean size of the cell was found to be 22.24 µm in *Vanilla planifolia* and 15.8 µm in *Vanilla tahitensis*. The collenchymatous hypodermis was single layered in both the cases. Cortex was parenchymatous in both with lesser number of collenchymatous cells in *Vanilla tahitensis*. Some of the cells near the endodermis contain granular content in *Vanilla planifolia* and it was absent in *Vanilla tahitensis*. Needle like crystals of calcium oxalate were present in the cortex of both. Endodermis was single layered in both the cases. Vascular bundles were present in four rings but number of bundles was lesser (around 25) in *Vanilla planifolia*, whereas the number of vascular bundles was around 41 in *Vanilla tahitensis*. Bundle cap was of 3-6 layers and made of well developed sclerenchyma in *Vanilla planifolia* and it was 2-3 layered and made of feebly thickened cells in the case of *Vanilla tahitensis*.

Velamen root: Velamen tissue was two layered in both species, outer layer of *Vanilla planifolia* showed distorted cells with wavy radial points. Inner tangential walls of the outer velamen layer are highly thickened in both cases. Cortex was 14-18 layered in *Vanilla planifolia* and 10–14 layered in *Vanilla tahitensis* and the cells contain chloroplasts and vesicular crystals. Inner cortical layer of *Vanilla planifolia* contained 10-12 schizogenous air cavities and it was absent in *Vanilla tahitensis*. Endodermis was single layered in both cases. Periderm was double layered in *Vanilla planifolia* and single layered in *Vanilla tahitensis*. 12 groups of exarch xylem and phloem arranged radially in the stele of *Vanilla planifolia* and 13 groups in *Vanilla tahitensis*. Metaxylem is very large in *Vanilla planifolia* when compared to *Vanilla tahitensis*. Pith was very large in *Vanilla tahitensis* and it was comparatively small in *Vanilla planifolia*.

Anatomical characters can be used to distinguish species in vegetative phase (Metcalfe, 1961). Recent reports on vegetative anatomical studies on other endemic vanilla species confirmed that anatomical features not only significant to distinguish the species but also has the potential value in the study of hybridization and breeding programme (Raju, 1996; Baruah, 1998; Zhao and Wei, 1999). Kaushik (1983) has investigated ecology and anatomy of 54 species of Himalayan orchids. Moss (1923) and Engard (1944) studied the nature of velamen and exodermis in orchid roots. Certain efforts have already been made to differentiate *Vanilla planifolia* and *Vanilla tahitensis* based on morphological characters (Radhakrishnan *et al.*, 2004, Umamaheswari *et al.*, 2003).

Table 1. Stem anatomy

Tissue	*Vanilla planifolia*	*Vanilla tahitensis*
Mean size of epidermal cells	22.24 µm	15.8 µm
Granular contents	Some cells near endodermis contain granular content	Absent
Vascular bundles	4 rings; 25 in number	4 rings; 41 in number
Bundle cap	3-6 layered; Made of well developed schlerenchyma	2-3 layered; Made of feebly thickened cells

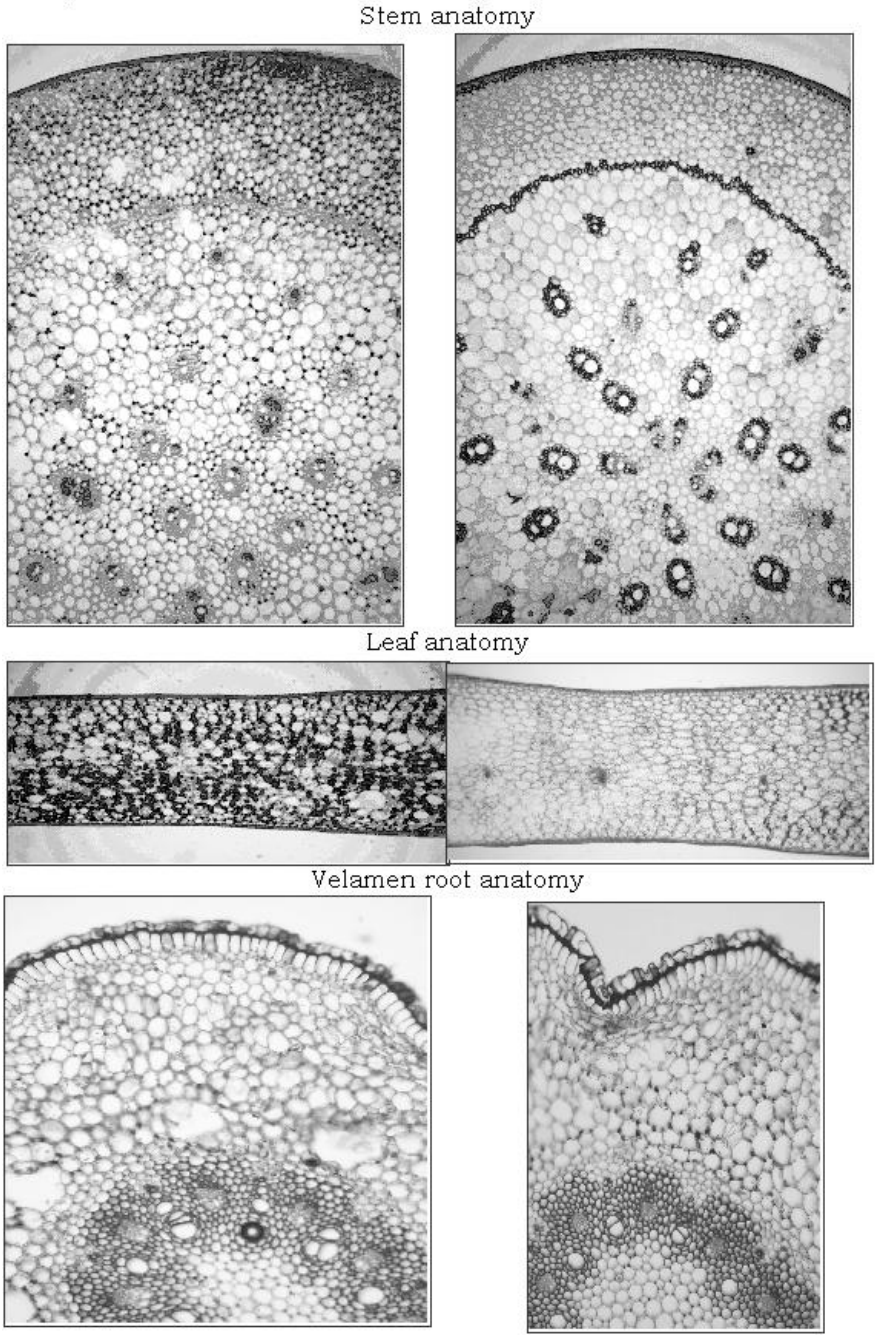
Table 2. Leaf anatomy

Tissue	*Vanilla planifolia*	*Vanilla tahitensis*
Main vascular bundle	Well developed when compared to *Vanilla tahitensis*	Not so much developed
Bundle cap	Complete	Not complete

Table 3. Velamen root anatomy

Tissue	*Vanilla planifolia*	*Vanilla tahitensis*
Velamen tissue	Outer layer shows distorted cells with wavy radial points	Inner tangential walls of the outer velamen layer highly thickened
Cortex	14-18 layered	10-14 layered
Air cavities	Inner cortical layer consists of 10-12 schizogenous air cavities	Absent
Stele	Metaxylum is very large compared to *Vanilla tahitensis*	Medium sized
Pith	Comparatively smaller than *Vanilla tahitensis*	Very large

Fig. 1. Anatomical details of *Vanilla planifolia* and *Vanilla tahitensis*



References

Baruah A 1998. Vegetative anatomy of the endemic orchid *Vanilla pilifera* Holt. *Phytomorphology* 48(1): 101-105.

Engard CJ 1944. Morphological identity of the velamen and exodermis in orchids. *Bot. Gaz.* 105: 457-462.

Hedge MR and Kumar NY 2002. Vanilla – A remunerative spice crop. The Planters' Chronicle 98(2&3): 99-103.

Kaushik P 1983. Ecological and Anatomical Marvels of the Himalayan Orchids. In 'Progress in Ecology, Vol. VIII'. Today and Tomorrow's Printers and Publishers, New Delhi.

Kumar CS and Manilal KS 2004. Orchids of Kerala, India. In 'Orchid Memories- A tribute to Gunnar Seidenfaden (Eds. K.S. Manilal & C. Sathish Kumar), Mentor Books & Indian Association for Angiosperm Taxonomy, Calicut: 155-254.

Madhusoodanan KJ, Radhakrishnan VV and Sudharsan MR 2003. Botany. In 'Vanilla the prince of spices, (Eds.) J. Thomas and Y.S. Rao', Spices Board, Cochin: 5-9.

Metcalfe CR 1961. The anatomical approach to systematics. In 'Recent Advances in Botany', University of Toronto Press, Toronto.

Moss CE 1923. On the presence of velaminous roots in terrestrial orchids. Proc. Linn. Soc., 135th Session: 47.

Radhakrishnan VV, Menon Priya P, Madhusoodanan KJ and Thomas J 2004. Differentiating *Vanilla planifolia* from *Vanilla tahitensis* using a statistical method. Journal of Plantation Crops 33(1): 75-76.

Raju MS 1996. Morpho-anatomical studies of the endemic orchid *Vanilla wightiana* Lind. (Orchidaceae) *Phytomorphology* 46: 371-375.

Umamaheswari R, Hrideek TK and Mohanan KV 2003. Comparative analysis of juvenile characters in *Vanilla tahitensis* and *Vanilla planifolia*. Proceedings of the XIII Swadeshi Science Congress: 23-24.

Zhao GX and Wei ZX 1999. An anatomical study on the stems of two species of Vanilla. *Acta Botanica Yunnanica* 21(1): 65-67.

Acknowledgement

The facilities availed from Centre for Medicinal Plants Research, Kottakkal, Kerala for anatomical studies are gratefully acknowledged.

Gregor Mendel Foundation Proceedings 2006

Studies on combining ability and gene action in sesamum (*Sesamum indicum* L.)

Gangappa E, Veena T, Reddy BGS, Manjunatha YS and Yogeesh LN
Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, GKVK, Bangalore-560 065.

Abstract

A study was undertaken to evaluate the diverse genotypes of sesame for their combining ability and gene action at ZARS, GKVK, Bangalore through a L x T mating design with 16 lines and five testers during summer 2001. Observations were recorded on plant height, number of branches per plant, number of capsules per plant, days to 50 per cent flowering, days to maturity, 1000 seed weight, seed yield, oil content and oil yield. The results revealed significant gca effects in Kayamkulam, Kanakapura local, Co-1, Rajeshwari, Tapi and TMV-3 for seed yield; in Rajeshwari, DS-1, TC-25 and Tapi for oil content and in Kayamkulam for oil yield. The cross Kayamkulam x Surya registered the highest sca effects for seed yield and oil yield. Variance due to sca was higher than gca for all the traits indicating the predominance of non-additive gene action controlling the traits.

Key words: Sesame, Line x Tester, *gca, sca,* dominance

Introduction

Sesame (*Sesamum indicum* L.), the oldest oilseed crop occupies an important place in the oilseed scenario of India after Groundnut and Rapeseed-Mustard. India, considered as a major center of genetic diversity for sesame accounts for 27 per cent of world production in about 40 per cent of world's area. Notwithstanding its cultivation in such a vast area, the average productivity of sesame is a meager 300 kg/ha as against its potential of 700-800 kg/ha [Duhoon, 2004.]. Hence, there is a need to further enhance the sesame crop productivity.

From the past experience in different crops it has been noticed that *per se* performance of parents is not always the true indicator of its potential in hybrid combination. The information on the combining ability status of the genotypes will give an indication as to how well they combine with a given genotype to produce potential and productive population. In this direction, the concept of *gca* and *sca* [Sprague and Tatum, 1942.] helps the breeder to decide upon the choice of parents for hybridization and isolate promising genotypes from the segregating populations. Crop improvement programme depends on adequate knowledge of gene action besides the presence of substantial genetic variability. Several methods employed to assess the genetics of quantitative traits controlled by polygenes so as to understand their inheritance. In the present study, line x tester mating design was employed to study the combining ability of the parents and to know the gene actions governing yield and yield attributes in sesame.

Material and Method

The material for the study comprised of 16 lines *viz.,* TMV-6, YLH-17, TC 289, Navile, Rajeshwari, E-8, ATPT856, VR-11, DS1, TC-25, Kanakapura local, CO-1, UMA 43,RT-264, MT-2, Kayamkulam and five testers *viz.,* Tapi, Ph-till, Purvi-1 TMV-3, Surya. Eighty hybrids and their 21 parents were sown at Zonal Agricultural Research Station, UAS, GKVK, Bangalore during *summer* 2000 following Simple Randomized Block Design (RBD) with two replications. Each genotype was sown in a single row of 3.0 m length with a row-to-row spacing of 30 cm and 10 cm between plants within a row. All the recommended agronomic practices were adopted for raising a healthy crop. Data was recorded on five randomly selected plants from each genotype from each replication for plant height, number of branches per plant, number of capsules per plant, days to 50 per cent flowering, days to maturity, 1000 seed weight, seed yield, oil content and oil yield. The data thus obtained was

subjected for estimation of combining ability and gene actions for yield and yield attributes in sesame by following line x tester method as proposed by Kempthorne (1957).

Results and Discussion

The analysis of variance (Table-1) indicated that variance due to parents and lines was significant for all the characters except for number of primary branches and oil content; variance due to testers was significant for days to 50% flowering, days to maturity, test weight, seed yield and oil yield showed the differences among the parents and variance due to lines v/s testers was significant for plant height, number of capsules, seed yield and oil yield suggesting the involvement of non additive gene action in the inheritance of the these traits. Variance due to crosses and parent's v/s hybrids was found to be significant for all the characters.

The estimates of *gca* and *sca* of 21 parents and 80 hybrids, respectively, for nine quantitative traits are furnished in Table-2 and Table-3. Days to 50 per cent flowering, seed yield, oil content and oil yield are much of practical significance in Sesamum. Hence, the discussion in this study centers mainly on these traits. The line, Rajeshwari, E-8, ATPT-856, TC-25, Kanakapura local, Co-1, UMA-43 and the testers Ph-till and Tapi exhibited significant negative *gca* effects in the desirable direction for earliness. Among the lines, Rajeshwari, Kanakapura local, CO-1 and tester Tapi exhibited significant positive *gca* effects for seed yield, oil content and oil yield besides early flowering. This indicates that these particular parents seem to posses decreasing allele for 50 per cent flowering and increasing allele for seed yield, oil content and oil yield with additive effects.

Among the 80 hybrids, the cross combination TC-25 x TMV-3 manifested negative significant *sca* effects indicating earliness which may be due to negative *gca* effects of female parent. Similar results were reported by Kempthorne 1957; Sharma and Chauhan, 1985. Only thirteen hybrids exhibited significant *sca* effects for oil content. The best cross combination to exhibit high *sca* effects was Kayamkulam x Tapi belonging to low x high type of cross suggesting the involvement of additive x dominance type of interaction. For oil yield, the cross combination Kayamkulam x Surya recorded highest *sca* effects, which may be due to high significant positive *gca* effect of female and male parents. For seed yield, the highest, *sca* effects was registered by the hybrid Kayamkulam x Surya followed by CO-1 x Surya, Kanakapura local x Surya. It is interesting to note that, involvement of one of the positively significant parents for seed yield had contributed for high seed yield in the above cross combinations. Similar results also reported by [Kempthorne 1957; Sharma and Chauhan, 1985; Goyal and Sudhirkumar, 1988].

The estimate of variance due to *gca* and *sca* are usually considered while deciding about nature of gene action. The results of the present study (Table-4) indicated the predominance of non-additive gene action operating for all the characters. Non-additive gene action for yield and yield attributes in Sesamum has been reported by [Dumbre *et al.*, 1990; Tyagi and Singh, 1981].

Since non-additive gene action is predominant in the present study, further selection is not helpful. Hence, for improvement of Sesamum, emphasis should be laid on recombination programme to generate potential segregants and enable selection of the high yielding type with desirable attributes.

Table 1. Analysis of variance for nine quantitative traits in Sesamum

Source	d.f	Plant height (cm)	No. of branches	No. of capsules	Days to 50% flowering	Days to maturity	Test weight (mg)	Oil content (%)	Seed yield Kg/ha	Oil yield (Kg/ha)
Replications	1	26.297	0.178	242.45	2.17	57.82**	0.009	125.78**	334.5	4287.37**
Parents	20	298.08**	1.15	499.99**	5.74**	22.41**	0.113**	3.75	172558.4**	31373.94**
Lines	15	159.75*	1.17	508.2**	6.74**	21.06**	0.124**	4.54*	189529.2**	34222.07**
Testers	4	195.56	1.24	175.37	3.35**	32.65**	0.099**	1.83	146761.9**	27630.09**
Lines Vs Testers	1	2783.14**	0.37	1674.51**	0.28	1.77	0.017	0.477	21183.25**	3627.31**
Hybrids	79	338.8**	1.85**	453.76**	9.87**	43.05**	0.4**	10.27**	170693.9**	33676.59**
Parents v/s hybrids	1	5546.8**	11.35**	10062.39**	6.31**	1382.15**	6.33**	148.26**	80130**	4114.88**
Error	100	88	0.75	131.36	0.83	1.82	0.013	2.44	1762.06	410.96

** Significance at P= 0.01 level * significance at P= 0.05level

Table 2: Estimates of general combining ability effects of lines and testers for nine quantitative traits in Sesamum

Lines	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**
TMV-6	3.59	-0.05	0.79	0.59*	0.21	-0.01	0.23**	-109.3**	-49.43**
YLH-17	13.75**	0.35	4.89	1.69**	4.31**	-0.31**	-1.96**	-38.75**	-26.03**
TC 289	5.64*	-0.26	-2.21	0.89**	1.21**	-0.04	-0.74**	35.92*	9.61
Navile	1.29	0.01	-10.73**	0.59*	-0.19	0.01**	0.6**	-63.95**	-27.84**
Rajeshwari	-0.77	0.07	0.41	-0.81**	1.91**	0.52**	2.68**	102.92**	56.9**
E-8	2.39	-0.35	-7.27*	-1.61**	-3.89**	0.23**	1.56**	-164.8**	-67.87**
ATPT856	2.33	-0.37	-3.07	-1.21**	-2.59**	-0.23**	-1.1**	-44.78**	-21.49**
VR-11	-0.8	0.45	-0.51	-0.31	-0.79	-0.29**	-0.27**	-165.8**	-74.59**
DS1	7.77**	0.51	5.41	0.19	-2.09**	-0.39**	1.78**	-152.6**	-60.97**
TC-25	-5.74*	-0.49*	-8.93**	-0.71**	-2.79**	-0.27**	1.73**	-102.1**	-37.53**
Kanakapura local	-7.85**	-0.47	-1.61	-0.61**	0.81	0.04	0.7**	269.59**	124.94**
CO-1	-7.77**	-0.15	-0.47	-0.91**	3.21**	0.25**	0.88**	223.92**	106.64**
UMA 43	-6.85*	-0.51	7.77*	-1.01**	-0.69	0.37**	-1.3**	-16.41	-9.36
RT-264	-4.41	-0.37	-1.6	1.19**	2.21**	-0.18**	-2.02**	-104.2**	-54.39**
MT-2	1.69	1.17**	9.31**	1.19**	1.91**	0.06	-2.16**	-36.58*	-27.91**
Kayamkulam	-1.19	0.52*	7.85*	0.89**	-2.79**	0.24**	-0.57**	366.72**	159.31**
SE ±	2.45	0.24	3.36	0.23	0.39	0.03	0.04	12.6	5.84
Testers									
Tapi	-1.29	0.01	1.51	-1.1**	0.61*	0.25**	0.67**	72.43**	38.15**
Ph-till	-5.74**	0.13	0.78	-1.21**	-0.42	0.07*	-0.35**	-7.3	-4.41
Purvi-1	-0.98	0.04	-5.31*	1.01**	-1.45**	0.25**	-0.31**	-120.2**	-54.29**
Tmv-3	9.22**	0.14	7.74**	0.83**	1.33**	-0.01	-0.21**	43.17**	18.17**
Surya	-1.24	-0.24	-4.72*	0.48*	-0.07	-0.06**	-0.1**	11.78	2.39
SE ±	1.26	0.12	1.74	0.12	0.2	0.02	0.02	6.33	3.01

Table 3: Estimates of specific combining ability effects of hybrids for nine quantitative traits in sesamum

Hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9
TMV-6 x Tapi	-0.47	-0.45	-4.29	-0.09	3.29**	-0.54**	-3.33**	-160.93**	-83.04**
TMV-6 x Ph-till	1.45	1.03*	9.84	0.01	6.82**	-0.01	-2.16**	257.01**	101.64**
TMV-6 x Purvi	-1.48	0.4	9.73	-1.21**	-3.65**	0.26**	2.45**	38.37	25.00*
TMV-6 x TMV-3	0.72	-0.58	3.48	1.97**	-0.93	0.47**	0.36**	-55.00*	-21.04
TMV-6 x Surya	-0.22	-0.4	-18.76**	-0.68	-5.53**	-0.18*	2.69**	-79.45**	-22.59
YLH-17 x Tapi	1.27	0.25	2.49	-1.19**	-3.31**	-0.34**	-2.19**	-209.76**	100.74**
YLH-17 x Ph-till	6.59	-0.07	1.62	-1.59**	3.72**	-0.01	-0.32**	-75.16**	-32.55**
YLH-17 x Purvi	4.36	0.7	-1.89	-0.31	-1.75*	0.06	-0.06	-47.13	-18.13
YLH-17 x TMV-3	-0.34	0.12	8.76	2.88**	1.97*	0.07	0.45**	509.50**	219.22**
YLH-17 x Surya	-11.88*	-1.00*	-10.98	0.22	-0.62	0.22**	2.13**	-177.45**	-67.80**
TC289 x Tapi	-8.62	0.36	-5.59	-3.39**	6.29**	0.34**	-1.36**	263.90**	102.33**
TC289 x Ph-till	-4.85	-0.11	-12.76	2.21**	4.82**	-0.58**	0.66**	-148.16**	-59.20**
TC289 x Purvi	0.57	-0.19	-6.87	-0.51	-2.15**	-0.21**	1.07**	149.87**	73.55**
TC289 xTMV-3	6.97	-0.57	17.08*	2.17**	-8.93**	0.50**	1.73**	-315.17**	-130.74**
TC289 x Surya	5.93	0.51	8.14	-0.48	-0.03	-0.05	-2.09**	49.55*	14.06
Navile x Tapi	9.03	-0.01	-0.77	-2.09**	4.19**	0.49**	-0.75**	126.10**	51.97**
Navile x Ph-till	-21.05**	-0.83	3.96	-3.99**	-3.78**	-0.33**	0.87**	-174.96**	-74.37**
Navile x Purvi	8.52	0.64	5.85	1.79**	-3.75**	0.09	0.73**	174.74**	81.98**
Navile x TMV-3	1.72	-0.94	-5.00	1.97**	-4.53**	-0.15*	1.84**	-246.97**	-104.74**
Navile x Surya	1.78	1.14*	-4.04	2.32**	-7.88*	-0.10	-2.68**	121.08**	45.16**
Rajeshwari x Tapi	-1.91	1.73**	5.29	1.34**	0.09	-0.12	0.67**	-129.76**	-54.44**
Rajeshwari x Ph-till	-1.89	1.21*	13.62*	3.41**	1.12	0.26**	-1.26**	313.17**	137.68**
Rajeshwari x Purvi	6.18	-0.62	-1.99	1.19**	-0.85	-0.52**	0.95**	-55.46*	-21.74
Rajeshw	8.98	-0.90	14.14	-2.62	1.87	0.19	-1.84	234.50	98.33

ari xTMV-3			*	**	*	**	**	**	**
Rajeshwari x Surya	-11.36 *	-1.42 **	-2.78	-3.28 **	-2.23 **	0.19 **	1.49 **	-362.45 **	-159.84 **
E-8 x Tapi	4.53	-0.95 *	-5.43	-1.89 **	-0.11	-0.13	1.39 **	77.90 **	39.54 **
E-8 x Ph-till	-1.25	1.03 *	16.90 *	1.21 **	-0.58	0.30 **	1.26 **	-10.82	-1.97
E-8 x Purvi	-10.58 *	-0.2	-9.41	0.99 *	3.45 **	-0.18 *	-1.33 **	142.21 **	58.17 **
E-8 x TMV-3	1.72	-0.68	-9.96	0.17	-1.83 *	0.03	-1.17 **	-122.84 **	-58.29 **
E-8 x Surya	5.58	0.80	7.90	-0.48	-0.93	-0.02	-0.14	-86.45 **	-37.45 **
ATPT 856 x Tapi	-19.01 **	0.37	1.57	0.21	-3.91 **	0.33 **	1.90 **	452.94 **	209.75 **
ATPT 856 x Ph-till	21.41 **	1.15 *	31.10 **	-0.19	2.12 **	-0.19 **	-0.23 **	16.76	2.45
ATPT 856 x Purvi	-12.32 *	-0.48	-11.91	1.09 *	-2.35 **	-0.17 *	-0.12	-13.76	-8.11
ATPT 856 x TMV-3	8.08	-0.16	-11.46	-1.23 **	-1. 13	0.09	-0.41 **	-262.80 **	-117.34 **
ATPT 856 x Surya	1.84	-0.88	-9.30	0.12	5.27 **	-0.06	-1.13 **	-193.08 **	-86.75 **
VR-11 x Tapi	-14.48 **	0.05	1.71	0.81	-3.71 **	-0.06	0.02	147.24 **	61.78
VR-11 x Ph-till	0.04	-0.27	-19.96 **	-1.09 *	-4.18 **	0.02	-1.16 **	-36.49	-19.43
VR-11 x Purvi	-16.99 **	-1.70 **	-19.47	-0.31	3.85 **	0.14*	-0.25 **	61.54 *	26.73 *
VR-11 x TMV-3	30.96 **	1.62 **	42.38 **	0.38	-1.93 *	-0.15 *	0.36 **	-121.84 **	-52.51 **
VR-11 x Surya	0.47	0.30	-4.66	0.22	5.97 **	0.05	1.04 **	-50.45 *	-16.57
DS-1 x Tapi	0.05	-0.91	-11.31	-1.69 **	-4.91 **	0.19 **	-3.88 **	207.63 **	-107.84 **
DS-1 x Ph-till	-15.13 **	-0.73	-0.68	-1.59 **	-1.158 *	-0.08	0.94 **	88.64 **	42.89 **
DS-1 x Purvi	-2.06	0.24	2.11	0.69	7.65 **	-0.31 **	1.10 **	85.01 **	38.22 **
DS-1 x TMV-3	7.54	0.76	8.86	1.88 **	3.87 **	-0.55 **	0.84 **	-77.37 **	-38.32 **
DS-1 x Surya	9.60	0.64	1.02	0.72	-4.73 **	0.75 **	2.69 **	111.35 **	65.06 **
TC-25 x Tapi	-9.29	0.09	-6.67	5.71 **	3.29 **	-0.38 **	1.27 **	-91.43 **	-41.83 **
TC-25 x Ph-till	-3.32	-0.03	8.56	-1.69 **	-3.68 **	0.15 *	1.89 **	318.17 **	155.88 **

TC-25 x Purvi	7.85	-0.26	10.55	0.09	-1.15	0.72 **	-1.15 **	39.54	10.90
TC-25 x TMV-3	14.15 **	-0.04	-14.40 *	-3.73 **	3.07 **	0.37 **	-2.89 **	-183.84 **	-91.29 **
TC-25 x Surya	-9.39	0.24	2.06	-0.38	-1.53 *	-0.12	0.89 **	-82.45 **	-33.66 **
Kanakapura local x Tapi	-0.63	-0.13	1.61	1.11 *	2.69 **	0.16 *	-0.95 **	0.24	-8.85
Kanakapura local x Ph-till	0.19	-1.35 **	-2.36	1.21 **	7.22 **	-0.16 *	2.22 **	-201.82 **	-80.63 **
Kanakapura local x Purvi	22.76 **	1.22 *	27.73 **	-1.01 *	-4.75 **	-0.14 *	-1.57 **	-260.46 **	-124.86 **
Kanakapura local x TMV-3	-31.14	-0.56	-23.52 **	-0.83	0.47	0.17 *	2.49 **	249.50 **	137.10 **
Kanakapura local x Surya	8.82	0.82	-3.46	-0.48	-5.62 **	-0.03	-2.18 **	212.55 **	77.24 *
CO-1 x Tapi	-7.41	-1.15 *	-14.13	1.41 **	3.29	-0.70 **	-1.83 **	-562.43 **	-263.77**
CO-1 x Ph-till	13.11 **	-0.57	-12.3	1.51 **	-5.18 **	0.03	-0.41 **	5.51	-3.18
CO-1 x Purvi	-0.82	-0.50	8.39	-2.71 **	6.35 **	0.50 **	0.658 **	28.54	13.74
CO-1 x TMV-3	-2.62	0.22	-9.06	-0.03	3.07 **	-0.09	1.96 **	215.16 **	113.45 **
CO-1 x Surya	-2.26	2.00 **	27.10 **	-0.18	-7.53 **	0.26 **	-0.36 **	313.22 **	139.77 **
Uma-43 x Tapi	10.57 *	0.31	13.03	1.51 **	2.69 **	0.13	3.5 **	269.57 **	137.97 **
Uma-43 x Ph-till	-6.61	-0.81	-22.54 **	-0.39	-0.78	0.76 **	-1.63 **	-157.49 **	-76.13 **
Uma-43 x Purvi	2.86	0.36	13.45 *	-2.61 **	-3.25 **	0.04	-0.22 **	-99.46 **	-45.79 **
Uma-43 x TMV-3	1.56	0.68	12.70	-0.42	-2.03 **	-0.17 *	-0.26 **	250.50 **	101.35 **
Uma-43 x Surya	-8.38	-0.54	-16.64 *	1.92 **	3.38 **	-0.76 **	-1.38 **	-263.12 **	-117.40 **
RT-264 x Tapi	7.73	0.17	15.30 *	0.31	-3.71 **	0.33 **	-0.78 **	381.37 **	153.17 **
RT-264 x Ph-till	2.65	1.75 **	1.93	0.41	-2.68 **	0.01	-0.41 **	-108.02 **	-45.34 **
RT-264 x Purvi	0.22	-0.88	-6.83	1.19 **	4.85 **	-0.02	-0.20 *	30.01	14.24
RT-264 x TMV-3	-17.98	-0.76	-11.23	-1.62 **	-1.93 *	-0.01	0.36 **	-116.37 **	-48.40 **
RT-264 x Surya	7.38	-0.28	0.83	-0.28	3.47 **	-0.31 **	1.04 **	-186.98 **	73.67 **
MT-2 x Tapi	21.53 **	0.33	11.89	1.31 **	-3.91 **	0.13	0.01	-382.76 **	-164.60 **

** Significance at P= 0.01 * significance at P= 0.05

X_1= Plant height
X_2=No. of Branches
X_3 =No. of capsules per plant
X_4= Days to 50% flowering
X_5= Days to maturity
X_6= Test weight
X_7 = Oil content
X_8= Seed yield
X_9= Oil yield

Table 4: Variance due to general and specific combining ability and their ratio for the following nine characters

Sl. No.	Characters	Variance due to GCA	Variance due to SCA	GCA/ SCA
1	Plant height	19.08	101.04	1:5.3
2.	No. Of primary branches/ plant	-0.01	0.51	1:39.4
3.	No. Of capsules /plant	8.61	148.28	1:17.2
4.	Days to 50% flowering	0.75	3.62	1:4.8
5.	Days to maturity	0.31	18.98	1:61.9
6.	Test weight (g)	0.03	0.13	1:4.5
7	Seed yield (Kg/ha)	3262.04	73104.5	1:22.4
8.	Oil content (%)	0.31	2.52	1:8.1
9.	Oil yield (Kg/ha)	800.7	14074	1:17.6

References

Duhoon SS 2004. Exploitation of heterosis for raising productivity in sesame. Proc. 4th International Science Congress: 1899.

Dumbre AD, Pawar PK and Pawar BB 1990. Combining ability studies in sesame through diallel analysis. *J. Maharasatra Agric. Univ*. 15: 211-214.

Goyal and Sudhirkumar 1988. Combining ability for yield components and oil content in sesame. *Indian J. Genet.* 51: 311-314.

Kempthorne O 1957. An Introduction to Genetic Statistics. John Willey and Sons Inc., New York, p. 545.

Reddy MB, Reddy MC, Nageshwara Rao G and Muralimohan Reddy B 1982. Line x tester analysis of combining ability in sesamum. *The Andhra Agric. J.* 9: 18-21

Sharma RL and Chauhan BPS 1985. Combining ability in sesame. *Indian J. Genet.* 45: 45-49.

Sprague GF and Tatum LA 1942. General *v/s* specific combining ability in single crosses of corn. *J. American. Soc. Agron*. 34: 923-932.

Tyagi BP and Singh HG 1981. Heterosis in sesamum. *Indian J. Agric. Sci*. 51: 849-852.

Maintainer and restorer reaction of new sunflower inbred lines on PET-1 system and studies on their combining ability with three nuclear backgrounds

Manjunatha YS, Gangappa E, Yogeesh LN and Shadakshari YG
Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore-560 065.

Abstract

Thirty eight new sunflower inbred lines were evaluated to know their maintainer or restorer behaviour against three established CMS lines during 2004. Those inbred lines which restored fertility in all three CMS backgrounds were considered to study the combining ability following L x T mating design and to estimate heterosis over standard checks. The results revealed that, for CMS234A, 20 inbreds proved to be restorers; seven as maintainers and 11 showed partial restoration; for CMS 851A, as many 21 inbreds proved to be restorers; six behaved as maintainers and 11 showed partial restoration and for CMS 852A, 19 inbred lines restored the fertility; four maintained sterility and 15 behaved as partial restorers. However, only 18 inbred lines restored fertility in all the three CMS backgrounds. These 18 restorer lines, three CMS lines along with their corresponding 54 F_1's and were studied for combining ability. The results indicated the predominance of non-additive gene action for yield and yield contributing traits. The line CMS 234A and the testers, ACC 356 and SOF-133-2 were the good general combiners for the yield attributing characters and none of the crosses was good specific combiners for all the characters studied. However, the crosses CMS 852 x DS-2, CMS 851A x DS-2 and CMS 852A x 1538-5 were good specific combiner for seed yield, oil content and oil yield, respectively.

Introduction

A landmark in sunflower breeding was the discovery of cytoplasmic male sterility, *Petiolaris* (PET-1) source by Leclercq (1969) and fertility restoration by Kinman (1970) that shifted the interest from population breeding to heterosis breeding in sunflower. Lack of diverse–fertility restorers for the available CMS sources and the knowledge on the inheritance of fertility restoration by the newly identified restorers is an impediment in sunflower improvement. This could be compensated to certain extent through the diversification of restorers base for PET based CMS lines and thus exploiting the hybrid vigour to enhance the sunflower productivity.

The success of hybrid breeding programmes depends on the choice of parental material employed for hybridization and the choice of crosses to be advanced among the several crosses affected. This indicates the importance of prior information about the combining ability of the parents to be used in crossing programme; which is not only to obtain a desirable end product but also to save the time and efforts. One of the techniques, that is widely used to extract information about the potential of parental lines and gene action governing the inheritance of traits is Line x Tester.

With this background a study was undertaken to identify new fertility restorer and maintainer lines from the new sunflower inbred lines for the three established male sterile lines (CMS 234A, CMS 851A and CMS 852A) and to studies on their Combining ability in 54 F_1 (the inbreds restored fertility in all three CMS lines were taken for this study) in sunflower.

Materials and Method

The material for the study comprised of three Cytoplasmic Male Sterile Lines *viz.,* CMS 234A, CMS 851A and CMS 852A and 38 new sunflower inbred lines. The hybrids and their parents were sown at Zonal Agricultural Research Station, UAS, GKVK, Bangalore during *Kharif 2004 following* simple Randomized Block Design (RBD) with three replications. Each genotype was sown in a single row of 3.0 m length with a row-to-row spacing of 60 cm and 30 cm between plants

within a row. All the recommended agronomic practices were adopted for raising a healthy crop. All the plants in the F_1's were visually screened for male fertility or sterility reaction to know the restorer or maintainer behaviour of inbred lines based on anther dehiscence and pollen shedding at the anthesis stage. Based on the results obtained the inbred lines used in the study were classified as Maintainer, if all the F_1 plants were sterile; Restorers, if all the F_1 plants were fertile and as Partial restorers, where some of the plants showed normal fertility and some plants normal sterility reaction in the F_1 progenies. Data was recorded on five randomly selected plants from each entry from each replication for days to 50 per cent flowering, plant height, head diameter, stem diameter, 100 seed weight, volume weight, seed yield, oil content and oil yield. The combining ability was estimated made following line x tester method as proposed by Kempthorne (1957).

Results and Discussion

The results pertaining to fertility restoration in the 114 crosses using three elite CMS cytoplasm are presented in the (Table-1) Out of 38 new inbred lines tested with three nuclear background of PET-1 cytoplasm, 20 inbred lines *viz.,* VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7, PS-5016-1 and 128-2 were effective restorers for CMS 234A background. The inbred lines, VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7, PS-5016-1, 128-2 and LIB-2S-3 proved to be effective restorers for CMS 851A. While, VNB-NB-5, 5020, SOF-133-2, X-15NB-10, PS-5016, SFW-1, X-15-NB-6, ACC356, NB-55-NB-13, 1538-5, NB-55-NB-5, VNB-1, X-15-NB-5, 1004, DS-2, PASF-110-8, PS2001, VNB-NB-7 and ACC-1147 behaved as effective restorers for CMS 852A (Table-2).

As many as 18 inbred lines restored the fertility in all the three CMS lines and behaved as common restorers for CMS 234A, CMS 851A and CMS 852A; while four inbred lines *viz.,* 4060, SOF-133, X-15-NB-1 and 4059 behaved as common maintainers for all the CMS lines. This indicated that, though CMS lines differed by nuclear background, the fertility restoring or sterility-maintaining gene might be same. The inbreds X-55-NB-4, 4004, 1078, 1002, 4035, SOF-133-1, 1021, 1147-4, 1079 and X-15-NB-2 restored partial fertility in all the CMS lines indicating the presence of restorer gene in heterozygous condition or a possible contamination with the unknown pollen. Hence these cross needs to be tested for further confirmation. Further, these inbreds can also be selfed for two or more generations until they are fully homozygous and then crossing could be effected. This could develop new restorer lines developed for the existing CMS lines.

The results also revealed that the inbred lines PS-5016-1 and 128-2 behaved as fertility restorer lines for CMS 234A and 851A, but behaved as partial restorers for 852A. The inbreds ACC-1147 and 1361-1 acted as maintainers of 234A and 851A, but behaved as restorer and partial restorer for 852A, respectively. The inbred ACC-873 acted as maintainer for 234A and as partial restorer for 851A and 852A, whereas LIB-2S-3 behaved as partial restorer for 234A and 852A and as a restorer for 851A. It is evident from the present investigation that few inbreds behaved differentially with the three nuclear backgrounds in respect of maintainer and restorer behaviour. Similar results were also reported by Manivannan *et al.* (2002) and Wankhade *et al.* (2004) suggesting the influence of modifying genes for fertility restoration to exhibit partial fertility. As the complexities in the inheritance of partial restoration could be due to high dependency on environment conditions (Wankhade *et al.*, 2004), a detailed investigation with respect to partial and total fertility restoration against the same cytoplasmic background needs to be carried out.

The ANOVA (Table-3) indicated that significant differences among the genotypes for all the traits studied. Among the lines, significant differences were observed for days to 50 per cent flowering, head diameter, stem diameter, hundred seed weight, volume weight, seed yield, oil content and oil yield. On the contrary, testers were found to be variable only for 50 per cent flowering, volume weight and oil content indicating the similarity between them for the majority of the traits. In spite of this crosses derived from them significantly different from each other. Not surprisingly, variance due to line x tester was significant for all the characters indicating the

ability of the parents to produce variability. Significance of variance due to interaction between lines and testers also suggested the involvement of non-allelic interactions in the inheritance of these traits. Significance of variance due to lines, testers, and line x testers interactions were also reported by Giriraj *et al.* (1987) and Gangappa *et al.* (1997).

The ratio of *gca* variance *to sca* is consistently greater than unity for all the characters except for days to 50 per cent flowering (Table-4). This revealed the predominance of non-additive gene action. However, days to 50 per cent flowering appeared to be under the control of additive gene action. The characters such as days to 50 per cent flowering controlled by additive gene action could be improved through simple mass selection. Where as, for the other traits, which are under the control of non-additive gene action, can be exploited through heterosis breeding.

The results on general combing ability effects (Table-5) indicated that the line CMS 234A was the good general combiner for early flowering, volume weight, test weight, oil content and oil yield. The findings of Bajaj *et al.* (1997) and Gangappa *et al.* (1997), also reveals the CMS 234A is good general combiner for majority of the traits. While CMS 851A was a good combiner for head diameter, stem diameter and seed yield. This indicates that line which is a good general combiner for test weight and volume weight may also good general combiner for oil content. Among the restorers, tester, SOF-133-2 was observed to be good general combiner for stem diameter, test weight and seed yield.

None of the hybrids were good specific combiner for all the characters studied (Table-6). However, The cross combination CMS 852A x DS-2 was identified as the best specific combination for seed yield; while, CMS 851A x DS-2 and CMS 852A x 1538-5 were good specific combiner for oil content and oil yield, respectively.

From the present investigation it can be concluded that the inbreds identified as maintainers for different nuclear backgrounds, after testing for combining ability and agronomic performance, can be converted into new cytoplasmic male sterile lines for their utilization in heterosis breeding programme or can be used in synthesizing three way cross hybrids with better heterosis and resistance to pest and diseases. The non-additive variation is found to be an important component of the genetic architecture of the material studied as the variances due to *sca* were higher than *gca* for all the traits except days to 50 per cent flowering indicating the predominance of non additive gene action controlling the trait. Hence, the breeding methods to be followed should exploit non-additive gene effects for further improvement of this crop.

Table 1. Restorer or Maintainer reaction of new inbred lines under three nuclear backgrounds of PET-1 CMS cytoplasm in sunflower

Sl. No.	Inbred Genotype	CMS 234A	CMS 851A	CMS 852A
1	VNB-NB-5	R	R	R
2	PS-5016-1	R	R	PR
3	X-55-NB-4	PR	PR	PR
4	128-2	R	R	PR
5	4004	PR	PR	PR
6	5020	R	R	R
7	1078	PR	PR	PR
8	1002	PR	PR	PR
9	4060	M	M	M
10	SOF-133-2	R	R	R
11	4035	PR	PR	PR
12	SOF-133	M	M	M
13	1361-1	M	M	PR

14	SOF-133-1	PR	PR	PR
15	1021	PR	PR	PR
16	X-15NB-10	R	R	R
17	ACC-873	M	PR	PR
18	PS-5016	R	R	R
19	X-15NB-1	M	M	M
20	SFW-1	R	R	R
21	X-15-NB-6	R	R	R
22	ACC356	R	R	R
23	1147-4	PR	PR	PR
24	NB-55-NB-13	R	R	R
25	ACC-1147	M	M	R
26	1079	PR	PR	PR
27	1538-5	R	R	R
28	NB-55-NB-5	R	R	R
29	VNB-1	R	R	R
30	X-15-NB-5	R	R	R
31	4059	M	M	M
32	1004	R	R	R
33	DS-2	R	R	R
34	PASF-110-8	R	R	R
35	PS2001	R	R	R
36	VNB-NB-7	R	R	R
37	LIB-2S-3	PR	R	PR
38	X-15NB-2	PR	PR	PR

M: Maintainer R: Restorer PR: Partial Restorer

Table-2: Frequencies of maintainers, restorers and partial restorer lines for three nuclear backgrounds of PET- 1 CMS cytoplasm

CMS Lines	Tested Inbreds	Number of lines behaved as		
		Maintainers	Restorers	Partial Restorers
CMS 234A	38	7	20	11
CMS 851A	38	6	21	11
CMS 852A	38	4	19	15

Table: 3 Analysis of variance for nine quantitative traits in sunflower

Source	d.f	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	100 Seed weight (g)	Volume weight (g/100cc)	Seed yield (Kg/ha)	Oil content (%)	Oil yield (Kg/ha)
Replications	2	20.469**	20.50*	0.38	0.06**	0.05	0.22	39488.00	11.98*	7540.00*
Treatments	74	53.057**	6110.45*	18.67**	0.92**	2.34**	53.47**	1454972.50**	137.24**	224717.84**
Parents	20	89.28750**	1387.01**	15.78**	0.82**	2.60**	83.64**	819136.81**	151.23**	122941.30**
Crosses	53	40.06486**	1494.75**	17.94**	0.53**	2.18**	43.03**	1175131.77**	58.53**	124547.02**
Parent Vs Crosses	1	17.0625**	345210.81**	115.16**	23.75**	5.48**	3.54**	290032148.50**	4029.31**	7569303.27**
Lines (L)	2	290.68750**	213.50	66.84*	3.29**	6.28*	167.16**	1995007.26	346.73**	299324.00*
Testers (T)	17	78.42279**	1940.32	22.93	0.47	1.79	63.27*	896256.00	76.84*	91819.30
L x T	34	6.13**	1347.34**	12.66**	0.40**	2.14**	25.60**	1266341.63**	32.42**	130629.88**
Error	148	1.894	4.88	0.33	0.01	0.02	0.30	17529.08	3.10	1901.73

****** Significant at P= 0.01 level ***** significant at P= 0.05level

Table 4. Variance due to general and specific combining ability effects for yield and other economic traits in sunflower

Character	Variance due to GCA	Variance due to SCA	GCA: SCA
1. Days to 50% flowering	5.6639	1.4163	1:0.2501
2. Plant height (cm)	-8.5850	447.4878	-1:52.1244
3. Head diameter (cm)	1.0261	4.0793	1:3.9755
4. Stem girth (cm)	0.0471	0.1290	1:2.7389
5. Volume weight (g/100cc)	2.8449	8.4344	1:2.9647
6. Test weight (g)	0.0602	0.7044	1:11.7010
7. Seed yield (Kg/ha)	5691.7578	416270.6909	1:73.1357
8. Oil content (%)	5.6941	9.7744	1:1.7166
9. Oil yield (Kg/ha)	2061.6436	42909.3567	1:20.8132

Table: 5 Estimates of general combining ability effects of lines and testers for nine quantitative traits in sunflower

Sl.No	Parents	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm))	Volume weight (g/100 cc)	Test Weight (g)	Seed yield (Kg/ha)	Oil content (%)	Oil yield (Kg/ha)
	Lines									
1	**CMS 234B**	-1.99**	**0.47**	-0.82**	-0.29**	2.03**	0.38**	29.52*	2.64**	71.59**
2	**CMS 851B**	-0.56**	**1.71****	1.27**	0.16**	-0.99**	-0.12**	175.75**	-2.42**	5.43
3	**CMS 852B**	2.55**	**-2.18****	-0.45**	0.13**	-1.04**	-0.27**	-205.26**	-0.22	-77.02**
	S.E±	**0.1873**	0.3005	0.0778	0.0139	0.0743	0.0212	18.0170	0.2395	5.9344
	Testers									
1	VNB-NB-5	-2.78**	-2.97**	1.23**	0.27**	2.20**	0.10*	-289.28**	-0.26	-105.76*
2	5020	0.99*	1.85**	-1.04**	0.08**	4.64**	-0.09*	-195.61**	1.82**	-22.14
3	SOF-133-2	2.77**	7.38**	2.88**	0.31**	-3.58**	0.82*	679.94**	-3.97**	111.02*
4	X-15NB-10	1.43**	-0.75	0.61**	0.29**	0.43**	-0.19*	179.72**	-3.07**	0.13
4	PS-5016	-2.78**	0.57	-0.64**	0.03	2.26**	0.11**	237.50**	3.99**	178.92*
6	SFW-1	2.21**	13.05**	-1.03**	-0.01	0.92**	-0.45**	550.17**	0.37	200.20*
7	X-15-NB-6	2.99**	21.09**	0.77**	0.10**	-2.25**	-0.38**	-59.83	-1.14*	-36.27**
8	ACC356	4.77**	25.59**	2.97**	0.06*	-0.67**	0.79**	74.39*	-3.72**	-73.67**
9	NB-55-NB-13	-2.22**	-9.63**	-2.98**	-0.38**	-0.89**	0.23**	153.39**	2.32**	103.20*
10	1538-5	-2.67**	-22.23**	-0.79**	-0.19**	-2.04**	0.49**	-347.17**	0.47	-99.68**
11	NB-55-NB-5	-4.45**	3.29**	-0.17	0.08**	-1.56**	-0.31**	-288.83**	1.38**	-73.57**
12	VNB-1	-4.11**	-30.41**	-1.41**	0.05	-0.90**	0.19**	-97.39*	2.33**	18.82
13	X-15-NB-5	1.88**	-1.72**	0.21	-0.01	-0.63**	-0.71**	178.83**	-1.65**	6.81
14	1004	4.66**	14.75**	0.48**	0.02	-2.74**	-0.34**	-213.28**	-4.85**	-93.11**
15	DS-2	0.55	-1.08	-1.19**	-0.32**	-0.87**	-0.45**	228.61**	-2.11**	-5.49
16	PASF-110-8	-2.46**	-22.90**	-1.84**	-0.53**	7.05**	0.53**	1.39	4.80**	108.29*
17	PS2001	1.11**	7.06**	-0.17	0.19**	-1.43**	-0.37**	-279.28**	-0.95	-115.04*
18	VNB-NB-7	-1.89**	-2.94**	2.11**	-0.06*	0.07	0.02	-513.28**	4.22**	-102.66*
	S.E ±	**0.4588**	0.7360	0.1905	**0.0333**	0.1819	0.0520	44.1324	0.5867	14.5363

****** Significant at P= 0.01 level ***** Significant at P= 0.05level

Table: 6 Estimates of specific combining ability effects of hybrids for nine quantitative traits in sunflower.

Hybrids	Days to 50 % flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	100 seed weight (g)	Volume weight (g/100cc)	Seed yield (Kg/ha)	Oil content (%)	
A x VNB-NB-5	-0.68	-10.69**	-1.42**	0.00	-0.40**	0.39	564.48**	-1.58	1
A x 5020	-0.46	-2.91*	-0.32	-0.26**	-0.79**	4.38**	202.15**	4 .24**	1
A x SOF-133-2	-0.90	-2.95*	-2.12**	-0.35**	1.48**	2.30**	-539.74**	0.54	-1
A x X-15NB-10	-0.90	-5.85**	-1.71*	-0.35**	-0.13	1.30**	-188.19**	-0.23	-7
A x PS-5016	-1.01	-15.74**	-2.59**	-0.11*	1.18**	-2.54**	-67.96	-3.64**	-1
A x SFW-1	1.65*	-13.21**	0.97**	-0.15**	-0.02	-0.34	804.70**	-3.39**	1
A x X-15-NB-6	-0.79	-2.26*	0.17	-0.11*	-0.01	-1.19**	346.04**	1.51	1
A x ACC356	0.43	5.01**	-1.93**	-0.10*	0.76**	8.07**	-347.52**	0.83	-8
A x NB-55-NB-13	-0.90	7.06**	2.62**	0.24**	-0.69**	-1.83**	-426.52**	-0.01	-1
A x 1538-5	-0.46	3.70**	-0.47	0.13**	-0.40**	-2.60**	-142.30*	-1.57	-1
A x NB-55-NB-5	1.32*	-23.35**	1.51**	0.11*	-0.81**	-3.65**	-43.30	0.81	-3
A x VNB-1	-0.01	13.14**	-0.96**	-0.12*	-0.34**	-1.50**	-581.41**	-1.86*	-2
A x X-15-NB-5	0.65	-0.71	0.49	0.29**	-0.07	0.59*	326.04**	5.07**	2
A x 1004	-1.46*	8.02**	0.35	0.24**	1.33**	3.45**	840.15**	2.70**	2
A x DS-2	2.99**	3.62**	0.35	0.18**	-0.42**	-1.44**	-335.07**	0.44	-6
A x PASF-110-8	-0.01	25.23**	1.35**	0.21**	-0.01	-2.10**	364.15**	-0.01	1
A x PS2001	-0.23	6.34**	0.81**	0.13**	-0.42**	-0.11	-230.85**	-2.39**	-1
A x VNB-NB-7	0.77	5.55**	2.89**	0.00	-0.24**	-3.20**	-544.85**	-1.48	-2
A x VNB-NB-5	1.90**	5.61**	3.22**	0.22**	0.75**	0.28	-109.74	-0.13	-3
A x 5020	0.45	-2.25*	-0.55*	0.34**	-0.56**	-3.23**	-175.41*	-3.83**	-1
A x SOF-133-2	0.34	-5.65*	1.56**	0.18**	0.34**	1.52**	328.37**	1.42	1
A x X-15NB-10	0.67	0.95	2.90**	0.80**	1.00**	-0.03	915.59**	0.35	2
A x PS-5016	0.56	18.49**	1.06**	0.08	-0.37**	1.36**	252.81**	0.30	1
A x SFW-1	-1.10	21.75**	-2.56**	-0.02	0.28**	-1.35**	-551.19**	2.08*	-1
A x X-15-NB-6	0.78	20.57**	1.61**	0.37**	0.41**	-0.83**	164.48*	-1.02	9
A x ACC356	-1.66*	2.74*	4.11**	0.58**	-0.72**	-5.81**	734.26**	-0.42	1
A x NB-55-NB-13	1.67*	-9.11**	-1.30**	-0.01	0.17*	2.32**	564.59**	0.01	2
A x 1538-5	-0.88	-13.00**	-0.49	-0.41**	-0.02	3.22**	-686.85**	-0.92	-2
A x NB-55-NB-5	0.90	-51.66**	-3.09**	-0.61**	-0.52**	2.01**	-72.19	-3.06**	-8

CMS 851A x VNB-1	-0.77	-17.43**	-0.94**	-0.17**	0.05	-1.22**	-9.30	0.56	12.22
CMS 851A x X-15-NB-5	0.90	13.70**	-0.65*	-0.24**	-0.45**	-0.50	350.15**	-7.62**	-121.22**
CMS 851A x 1004	-1.22	2.58*	-0.37	-0.12*	-0.65**	-1.79**	-937.41**	4.28**	-104.05**
CMS 851A x DS-2	-2.44**	1.72	-0.80**	-0.07	0.10	2.45**	-942.30**	5.51**	-166.14**
CMS 851A x PASF-110-8	0.90	10.46**	-0.27	-0.07	-0.78**	0.51*	514.59**	-0.86	172.63**
CMS 851A x PS2001	0.34	7.44**	-0.51	-0.37**	0.68**	-0.38	-312.07**	1.95*	-60.71**
CMS 851A x VNB-NB-7	-1.33*	-6.93**	-2.93**	-0.50**	0.29**	1.49**	-28.41	1.42	34.90
CMS 852A x VNB-NB-5	-1.22	5.09**	-1.80**	-0.22**	-0.35**	-0.67*	-454.74**	1.71*	-127.94**
CMS 852A x 5020	0.01	5.16**	0.87**	-0.08	1.35**	-1.15**	-26.74	-0.41	-25.08
CMS 852A x SOF-133-2	0.56	8.60**	0.55*	0.17**	-1.82**	-3.82**	211.37**	-1.96*	20.50
CMS 852A x X-15NB-10	0.23	4.90**	-1.19**	-0.45**	-0.87**	-1.27**	-727.41**	-0.12	-174.03**
CMS 852A x PS-5016	0.45	-2.76*	1.53**	0.03	-0.80**	1.17**	-184.85**	3.35**	1.73
CMS 852A x SFW-1	-0.55	-8.54**	1.59**	0.17**	-0.26**	1.69**	-253.52**	1.31	-54.22*
CMS 852A x X-15-NB-6	0.01	-18.31**	-1.78**	-0.26**	-0.40**	2.03**	-510.52**	-0.49	-165.16**
CMS 852A x ACC356	1.23	-7.75**	-2.18**	-0.49**	-0.05	-2.26**	-386.74**	-0.41	-106.21**
CMS 852A x NB-55-NB-13	-0.77	2.04	-1.32**	-0.24**	0.52**	-0.49	-138.07*	0.00	-45.56*
CMS 852A x 1538-5	1.34*	9.30**	0.96**	0.28**	0.43**	-0.62*	829.15**	2.48**	345.63**
CMS 852A x NB-55-NB-5	-2.22**	75.01**	1.58**	0.49**	1.33**	1.64**	115.48	2.25**	87.01**
CMS 852A x VNB-1	0.78	4.29**	1.90**	0.29**	0.29**	2.73**	590.70**	1.30	249.94**
CMS 852A x X-15-NB-5	-1.55*	-12.98**	0.16	-0.05	0.52**	-0.09	-676.19**	2.55**	-160.78**
CMS 852A x 1004	2.67**	-10.60**	0.01	-0.13**	-0.68**	-1.66**	97.26	-6.98**	-161.85**
CMS 852A x DS-2	-0.55	-5.34**	0.45	-0.11*	0.32**	-1.01**	1277.37**	-5.95**	235.59**
CMS 852A x PASF-110-8	-0.88	-35.69**	-1.07**	-0.15**	0.79**	1.59**	-878.74**	0.87	-334.22**
CMS 852A x PS2001	-0.10	-13.78**	-0.30	0.24**	-0.26**	0.49	542.93**	0.44	195.48**
CMS 852A x VNB-NB-7	0.56	1.37	0.03	0.50**	-0.04	1.71**	573.26**	0.06	219.17**
S.E±	**0.7947**	1.2747	0.3299	0.0558	0.0901	0.3151	6.4397	1.0162	25.1776

** Significant at P= 0.01 level * Significant at P= 0.05level.

References

Bajaj RK, Kamaljit, Anjula K and Chahal GS 1997. Combining ability studies in sunflower (*Helianthus annuus* L.). *Crop Improve*. 24: 50-54.

Enns H, Dorrell DG, Hoes JA and Chubb WO 1970. Sunflower research–A Progress report. *In*: *Proc. 4 thInter., Sunflower Conf.*, Memphis: 162-168

Gangappa E, Channakrishnaiah KM, Harini MS and Ramesh S 1997. Studies on combining ability in sunflower (*Helianthus annuus* L.). *Helia.* 20: 73-84.

Giriraj K, Shantha R, Hiremath and Seenappa K 1987. Combining ability of converted male sterile lines of sunflower (*Helianthus annuus* L.). *Indian J. Genet.* 47: 315-317.
Kempthorne O, 1957. An Introduction to Genetic Statistics. John Willey and Sons Inc., New York. 545p.

Kinman ML 1970. New developments in USDA and state experiment station sunflower breeding progarmmes. *In*: *Proc. 4th Inter., Sunflower Conf.,* Memphis, Tennessee, U.S.A.: 181-183.

Leclercq P 1969. Une sterilite male cytoplasmique chez le tournesol. *Annales del' Ameloration des Plantes* 19: 99-106.

Manivannan N, Muralidharan V and Subbalakshmi B 2002. Fertility restoration in CMS lines in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 19: 110

Reddy VA, Trinadh Kumar G, Sudheer Kumar S and Sokka Reddy S 2002. Inheritance of fertility restoration for different CMS Sources in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* 19: 178-180.

Vranceanu AV and Stoenescu FM 1971. Pollen fertility restorer gene from cultivated sunflower. *Euphytica* 20: 536-541.

Wankhade RR, Rajput JC, Halakude IS, Kulkarni MP, Sawarkar NW and Dalvi PA 2004, Identification of fertility restorers for CMS lines in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res*. 21: 156-157.

Shoot organogenesis from callus cultures of turmeric, *Curcuma longa* L.

Praveen K[1], Martin J[1], Peter KV[2], John Zachariah T[1] and Nirmal Babu K[1]
1 Indian Institute of Spices Research, Calicut, Kerala, India
2 Kerala Agricultural University, Thrissur, Kerala, India

Abstract

An efficient protocol for callus induction and regeneration in two varieties of *Curcuma longa* L (viz. Prabha and Suvarna) using rhizome bud and leaf explants was standardized. Callus induction was best in MS medium supplemented with 8.3 µM picloram. MS medium fortified with 0.5 µM TDZ was best for plantlet regeneration. Highest rooting was obtained on MS liquid medium supplemented with 8.7 µM NAA. No significant differences were obtained between varieties and explants. Morphological, cytological and molecular (RAPD) analysis showed variants among the callus derived plantlets. Thus somaclonal variation can be an important source of variation in shy seed setting crops like turmeric.

Keywords: *Curcuma longa* L**,** Callus.

Abbreviations: 2,4-D: 2,4-Dichlorophenoxyacetic acid, BA: 6-Benzylaminopurine, NAA*:* α-Napthaleneacetic acid, TDZ: Thidiazuron.

Introduction

Turmeric (*Curcuma longa* L.), belonging to the family Zingiberaceae is cultivated as annual (Purseglove et al., 1981). In South East Asia turmeric is used from time immemorial as a remedy for several diseases because of its anti oxidant, anti tumour and cholesterol lowering properties (Khanna 1999). The rare, shy seed set and triploid nature of turmeric makes conventional breeding difficult and hence exploitable variations are limited. In general, the turmeric varieties released so far are mainly through clonal selection from germplasm with emphasis on yield, curcumin content and dry recovery (Khader et al. 1994; Rao and Rao 1994). Prabha and Prathiba are the only varieties developed as seedling progenies (Sasikumar et al., 1996). Only little information is available on *de novo* plant regeneration from callus cultures (Salvi 2001 and Sunitibala et al. 2001). *In vitro* culture offers a method for creating variants and shoot formation through organogenesis is a useful method to create genetic variation (Orton 1984; Karp 1991 and Eapen and George, 1989). The useful somaclonal variants in turmeric can be easily fixed due to vegetative mode of multiplication and programmes can be designed to improve the crop. In this study, we report an efficient protocol for callus induction from rhizome buds and leaf tissue and plantlet regeneration there from.

Materials and Method

Rhizome buds of two varieties of turmeric viz. Prabha and Suvarna were collected from Indian Institute of Spices Research, Calicut. Rhizomes were thoroughly washed in running water and the scales on the rhizome surface were removed. The rhizome buds were surface sterilized with 0.1% $HgCl_2$ solution for 5 minutes, followed by thorough washing with sterile distilled water for three times. Segments of rhizome bud with a portion of rhizome tissue were excised and transferred to basal MS medium for initial culturing.

Callus induction and proliferation: Sterile cultures of rhizome bud and *in vitro* derived leaf tissue were transferred on a series of media with 2,4 –D (2.3-18 µM), picloram (2.3–18 µM), dicamba (2.3-18 µM), NAA (2.6-21.4 µM) and MS (basal) for callus growth and proliferation. The pH was adjusted to 5.8±0.02 prior to autoclaving for 15 minutes at 120^0 C. All the cultures were incubated at 25±2^0C with 16/8 h photoperiod (130 $\mu Em^{-2}S^{-1}$). All the growth regulators were obtained from Sigma, USA.

Plantlet regeneration and rooting: Four week old callus was transferred to MS medium supplemented with BA (2.2-13.0 µM), Kin (2.3-14.0 µM), and TDZ (0.1-2.0 µM) alone or in combination with picloram. *In vitro* regenerated plants were placed in MS medium supplemented with different concentrations of NAA (2.7-16.1 µM), IBA (2.5-14.8 µM) and IAA (2.9-17.1 µM) and MS liquid with NAA (2.7-16.1 µM) for rooting. Observations were recorded at 15 days interval. Each treatment was replicated 10 times and each experiment was repeated thrice.

Morphological screening: Callus regenerated plants were evaluated for their morphological variations. Conventionally propagated plants of Prabha and Suvarna were used as controls. Sixty callus-regenerated plants were studied. Data on number of tillers per plant, number of leaves per plant, height of tillers, yield of fresh rhizomes, rhizome size, number of internodes per finger, internodal length and colour of the rhizome were recorded at the time of maturity.

Cytological analysis: Cytological analysis of plants regenerated from callus was done using root tip squash technique (Johansen, 1940).

Molecular analysis: Total genomic DNA was isolated following modified CTAB protocol (Ausbel et al., 1995). Leaves (3g) were frozen in liquid nitrogen and ground using a mortar and pestle. Extraction was done in 2% CTAB, followed by phenol-chloroform extraction method.

RAPD was performed on Programmable Thermal Controller (PTC-100, MJ Research, Inc.). All the primers used were 10-mer random oligonucleotide sequences obtained from Operon Technologies (Alameda California, USA). Reproducibility of the profiles was confirmed with different DNA preparations isolated on different days from the same samples under stringent PCR conditions. The following OPERON primers viz, OPC 05, OPC 10, OPC 20, OPA 01, OPC 06, OPC 11, OPA 07, OPC 07, OPC 16 and OPA 03 were used in the present study. The following programme was used: Initial denaturation at 93°C for 3 min, 34 cycles of 1 min at 93°C (denaturing), 1 min at 37° C (Annealing), 1 min at 72°C (Extension) and 15 min at 72°C (Final extension). The amplified products were separated on 2% agarose gel in 1x TAE buffer, stained with ethidum bromide and visualized under UV light.

Results and Discussion

Induction of callus and regeneration of plantlets from callus is a prerequisite for production and exploitation of somaclones (George, 1996). Picloram (2.3 to 18.0 µM) resulted in callus growth in both explants and varieties with highest response (90%) at 8.3 µM. The highest amount of vegetative bud derived callus (4.1 and 4.4 g) was obtained at 8.3 µM picloram in Prabha and Suvarna respectively with 90% response (Table 1, Figures 1a and 1d). 2,4-D at concentrations above 2.3 µM induced callus growth in all types of explants in both varieties with maximum response at 13.6 µM (Table 1). A small amount of callusing could be observed at higher concentration above of NAA 10.7 µM. The callus induced by 2,4-D and NAA were found to be more compact. Dicamba was also not effective in inducing. The amount of leaf derived callus was also highest (2.8 and 2.8 g) at 8.3 µM picloram in Prabha and Suvarna respectively with

90% response (Table 1). Concentrations above 16.6 µM picloram resulted in rhizogenesis (Figure 1b). Further proliferation of friable callus was maintained in basal MS or MS with 2.3 µM picloram.

Earlier, Salvi *et al.* (2001) also reported callusing from vegetative buds on MS medium supplemented with dicamba (2.0 mgl^{-1}) or picloram or NAA (5 mgl^{-1}) and BA (0.5 mgl^{-1}). Sunitibala et al. (2001) also reported callusing in turmeric rhizome buds on MS with 2, 4-D (3 mgl^{-1}). Prakash *et al.* (2004) reported induction of semi friable callus from leaf sheath explants of *C. amada* on MS with 9.0 µM 2, 4-D.

Plant regeneration from vegetative bud derived callus: Addition of kinetin (9.3 to 14.0 µM) or TDZ (0.5 or 1.0 µM) to the medium resulted in callus turning morphogenic. Plant regeneration was observed in 90% of the vegetative bud derived cultures in both the concentrations of TDZ (0.5 and 1.0 µM) with a mean number of 27.3 and 18.1 plantlets in Prabha and 26.1 and 20.5 plantlets in Suvarna, respectively (Figures 1d and 1e).

Plant regeneration from leaf tissue derived callus: Medium with TDZ, which gave good plant regeneration from vegetative bud calli, also gave good morphogenesis and plant regeneration from leaf derived callus. The plant regeneration ranged from 28.3 and 24.1 plantlets in Prabha and 26.1 and 22.5 plantlets in Suvarna in the medium containing TDZ at a concentration of 0.5 and 1.0 µM, respectively. About 70 to 90% of the cultures gave plant regeneration in Prabha while all the cultures regenerated to plantlets in Suvarna in this medium.

Plant regeneration was lower (around 13 plantlets per culture) on MS medium with kinetin. Plant regeneration was also noticed when the leaf callus was cultured on MS medium supplemented with kinetin (9.3 µM and 14.0 µM) and with or without picloram. Among these, the best results (70%) were obtained when 9.3 µM kinetin was supplemented with 2.3 µM of picloram, with an average of 13 plantlets per culture in Prabha (Figure 11f). But in Suvarna, kinetin alone at 14.0 µM gave highest number of plantlets (12.5) per culture with 70% response (Figure 1e). For induction of morphogenesis addition of kin or TDZ was essential (Pelah et al., 2002). Regeneration from callus was noticed in 80% of the cultures with 18.1 to 27.3 plantlets per explant culture in both varieties.

In the present study both varieties responded similarly with minor differences, indicating the absence of genotypic difference in morphogenic response. Histological studies have revealed indirect organogenesis (Figures 1c).

All the above workers have used MS basal medium supplemented with either BA or kinetin. The results showed that BA alone or in combination with picloram did not result in morphogenesis in both the genotypes. When the freshly induced callus was cultured on growth regulator free medium it resulted in rhizogenesis.

Hardening and planting out: The rooted plants were hardened with high humidity in humid chamber for 20-25 days with 80% establishment. Being a vegetatively propagated plant, the acclimatized plants can be established in soil. The earlier reports of planting out of tissue cultured plants of turmeric indicated 70 to 95% success (Nirmal Babu et al., 1997, Salvi et al., 2002 and Rahman *et al.*, 2004).

Screening of somaclones

Morphological: Two variegated plant types were observed in both Prabha and Suvarna. These variants retained the variegated nature during the second year of growth. Most of the somaclones resembled the mother plant with respect to various rhizome characters.

However, 10 to 20% somaclones showed detectable variations in rhizome characters in both varieties. Turmeric varieties exhibited distinct variation in the pattern of the rhizome development, orientation and number of primary and secondary rhizomes, internodal and nodal distances. (Figure 1f). Rhizomes with 'horn' like primaries and longer internodes were observed among the somaclones. The other variants were rhizomes with shorter internodes and more number of nodes in primaries and secondaries. Salvi *et al.* (2002) also reported that out of 48 turmeric regenerated plants, 2 showed variegated leaves. Here it was observed that higher the number of nodes higher is the axillary buds. Thus smaller units of rhizomes are required for planting thereby reducing the cost of planting material. Higher number of nodes combined with lesser internodal distances results in high dry recovery.

Cytological: Cytological observations indicated that among the somaclones, one of the callus regenerated plants from Prabha showed aneuploid number of 2n=74 (Figure 2c), indicating a variant. In ginger, Ramachandran and Chandrasekharan Nair (1992) reported production of tetraploids by colchicine treatment. The variable chromosome numbers observed in the study may be due to variation induced due to somaculture. Extensive aneuploidy may be produced in the fast growing phases of callus induction in a primary explant (Geum–Sook Do et al., 1999). Aneuploidy was also reported in *in vitro* cultures of *Haplopapus gracilis, Daucas carota* and *Nicotiana tabacum*, *Triticum aestivum* and *Solanum tuberosum*. Various mechanisms for generating aneuploidy in cultured cells are reported to be mitotic spindle abnormalities like division of two nuclei on a common spindle or multipolar spindle formation, non-disjunction, lagging chromosomes and chromosome bridges (Orton1980). This is the first report of chromosomal variation among the somaclones of turmeric.

Molecular: Out of ten primers tested, two detected polymorphism among the somaclones. The primer OPA-10 generated uniform banding patterns in all the callus regenerated plants of Prabha except in clone CP-5 where two amplicons of 1100 and 700 bp were absent. Amplicons at 500 bp region was absent in CS-2. OPC-06 detected a minor band at 600 bp region in CP-3 (Figure 2h). The present study showed that variation occurs in callus regenerated plants and could be confirmed by RAPD analysis.

AI-Zahim *et al.* (1999) also detected somaclonal variation in garlic (*Allium sativum*. L) using RAPD. Similarly, in tomato Soniya et al. (2001) reported 5% variation in callus regenerated plants. Genetic polymorphism among the regenerants was detected by RAPD in *Apium* sp. (Isabel *et al.*, 1993) and *Prunus* sp. (Yang and Quiros, 1993). The *in vitro* regeneration process was shown to be mainly responsible for RAPD banding difference among the somaclones as reported earlier in peach and beet (Munthali et al., 1996 and Hashmi et al., 1997).

Conclusion

An efficient system for callus initiation and proliferation for turmeric has been described that produces friable callus from rhizome buds and leaf tissue. The present study indicates variation among the somaclones of turmeric as evident from morphological, cytological and molecular variations. This can be expected in continuously vegetatively propagated crops like turmeric and ginger. This variation can be exploited for crop improvement programme of vegetative crops like turmeric.

Table 1. Effect of auxins on callus induction in different explants of *C. longa* on MS medium

Growth regulator	Conc. (µM)	Variety							
		Prabha				Suvarna			
		Vegetative bud		Leaf tissue		Vegetative bud		Leaf tissue	
		Response (%)	Mean wt. of callus (g)	Response (%)	Mean wt. of callus (g)	Response (%)	Mean wt. of callus (g)	Response (%)	Mean wt. of callus (g)
2,4-D	2.3	00	0.0	00	0.0	00	0.0	00	0.0
	4.5	40	0.7	50	0.1	40	0.9	50	0.2
	8.3	70	2.9	70	2.3	80	3.1	70	2.5
	13.6	90	3.0	90	2.5	90	3.3	90	2.8
	18.0	60	2.5	70	1.6	50	2.1	80	1.8
Picloram	2.3	30	0.9	60	1.5	40	0.7	60	1.7
	4.5	70	3.6	90	2.8	70	3.3	90	2.8
	8.3	90	4.1	90	2.6	90	4.4	90	2.5
	13.6	70	3.5	80	1.9	80	4.2	80	2.0
	18.0	60	2.9	50	1.0	50	3.6	60	1.1
Dicamba	2.3	00	0.0	0	0.0	00	0.0	00	0.0
	4.5	40	0.1	30	0.2	30	0.2	30	0.3
	8.3	50	1.5	50	1.2	50	1.8	50	1.2
	13.6	70	1.6	70	1.5	70	1.4	70	1.5
	18.0	70	1.9	70	1.8	70	1.5	70	1.6
NAA	2.7	00	0.0	00	0.0	00	0.0	00	0.0
	5.4	00	0.0	00	0.0	00	0.0	00	0.0
	10.7	10	0.1	10	0.1	10	0.1	10	0.1
	16.1	20	0.3	30	0.2	30	0.2	40	0.2
	21.5	50	0.3	50	0.3	50	0.3	50	0.3

References

Al-Zahim MA, Ford Loyd BV and Newbury HJ 1999. Detection of somaclonal variation in garlic (*Allium sativum* L.) using RAPD and cytological analysis. *Plant Cell Rep*. 18: 473-477

Ausubel FM, Brent R, Kingston RE, Moore DD, Seichman SG, Smith JA and Struht K 1995. Current Protocols in Molecular Biology. Vol.1 John Wiley & Sons, Inc.: 2.3.1-2.3.7.

Eapen S and George L 1989. High frequency plant regeneration through somatic embryogenesis in finger millet (*Elucine coracana* Gaertn.). *Plant Sci*. 61: 127-130.

George EF 1996. Plant Propagation by Tissue Culture. Part I. The Technology. Exegenetics Ltd., England.

Isabel N, Tremblay L, Michand M, Tremblay FM and Bousquet J 1993. RAPDs as an aid to evaluate the genetic integrity of somatic embryogenesis derived population of *Picea mariana*. *Theor. Appl. Genet.* 80(1): 81-87.

Johansen DA 1940. Plant Microtechnique. Mc Graw Hill, New York.

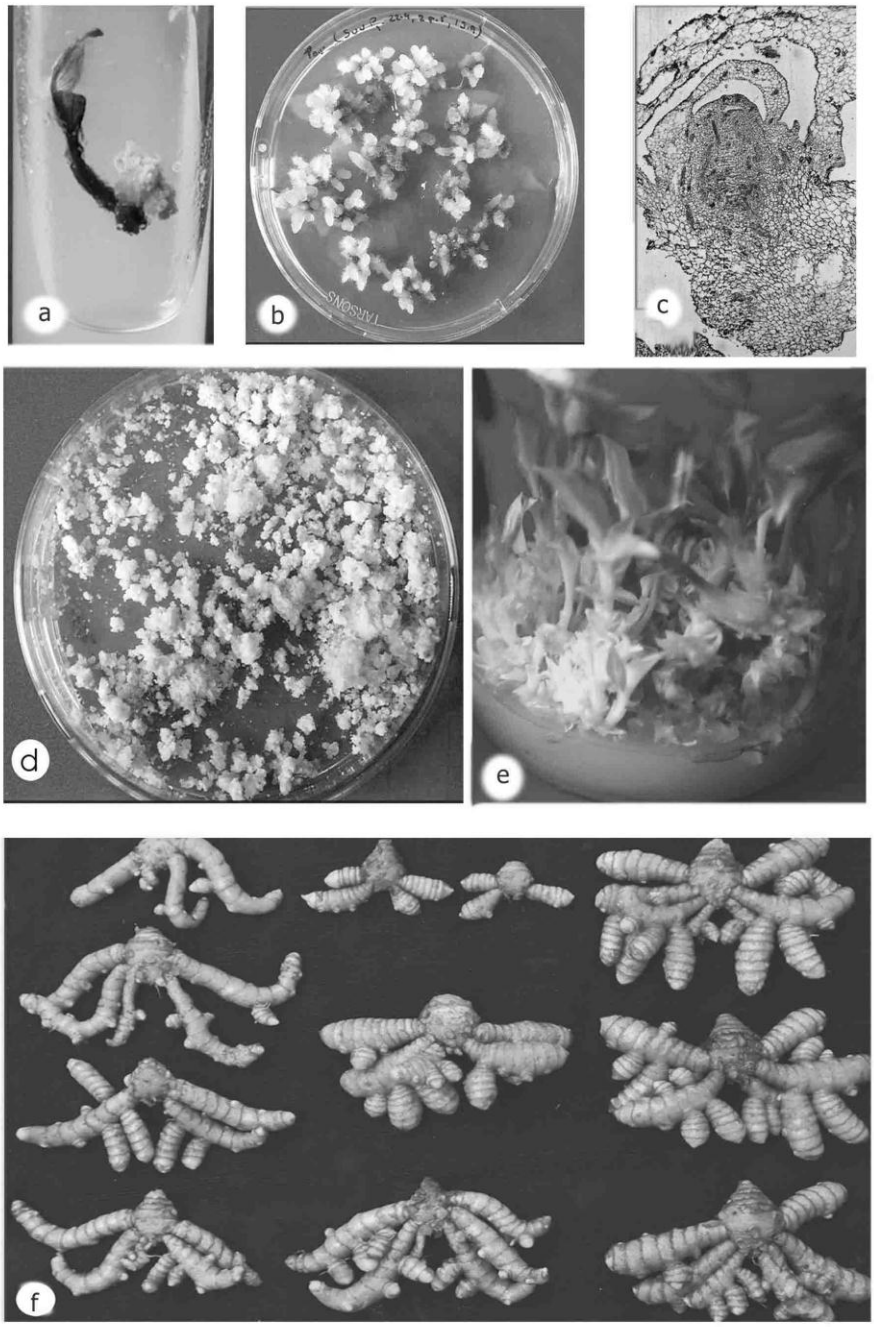


Figure 1 a) Callus induction from leaf after two weeks of culture on MS with 8.3 µM picloram. b) Rhizogenesis from callus on MS with 16.0 µM picloram. c) Histological evidence of indirect organogenesis. d) Shoot regeneration from callus after four weeks of culture on MS with 0.5 µM TDZ. e) Well developed plantlets after two months of culture in basal MS. f) Variability in rhizome characteristics of the somaclones.

Karp A 1991. Somaclonal variation as tool for crop improvement. *Euphytica* 85: 295-302.

Khader MA, Vedamuthu PGB and Balashanmugham PB 1994. Improvement of turmeric. In: Chadha KL & Rethinam P (Eds). "Advances in Horticulture" Vol. 9, Plantation Crops and Spices. Malhotra Publishing House, New Delhi: 315-332.

Khanna NM 1999. Turmeric- Nature's precious gift. *Curr. Sci.* 76 (10): 1351-1356.

Munthali T, Newbury HJ and Ford-Lloyd BV 1996. The detection of somaclonal variants of beet using RAPD. *Plant Cell Rep*. 15: 474-478.

Murashige T and Skoog F 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* 15: 473-497

Nirmal Babu K 1997. *In vitro* studies in *Zingiber officinale* Rosc. Ph.D. thesis, University of Calicut, Kerala, India.

Orton TJ 1984. Genetic variation in somatic tissue-method or madness? *Adv. Plant. Pathol*. 2: 153-159

Pelah D, Kaushik RA, Mizrahi Y and Sitrit Y 2002. Organogenesis in the vine cactus *Selenicereus megalanthus* using thidiazuron. *Plant Cell Tiss. Org. Cult.* 71: 81-84.

Prakash S, Elangomathavan R, Seshadri S, Kathiravan & Ignacimuthu S 2004. Efficient regeneration of *Curcuma amada* Roxb. plantlets from rhizome and leaf sheath explants. *Plant Cell Tiss. Org. Cult.* 78: 159-165.

Purseglove JW, Brown EG, Green CL and Robbins SRJ 1981. Spices. Vol.2, Turmeric. Longman Inc. New York: 532-580.

Rao RM and Rao 1994. Genetic Resources of Turmeric. In: 'Chadha KL & Rethinam P (eds), Advances in Horticulture Part I, Vol. 9. Plantation and Spice Crops: 132-149.

Salvi ND, George L & Eapen S 2001. Plant regeneration from leaf base callus of turmeric and random amplification polymorphic DNA analysis of regenerated plants. *Plant Cell Tiss. Org. Cult.* 66(2): 113-119.

Salvi ND, George L and Eapen S 2002. Micropropagation and field evaluation of micropropagated plants of turmeric. *Plant Cell Tiss. Org. Cult.* 68(2): 143-151.

Sasikumar B, Johnson KG, John Zachariah T, Ratnambal MJ, Nirmal Babu K and Ravindran PN 1996. IISR Prabha and Prathiba- two new high yielding and high quality turmeric (*Curcum longa* L.) varieties. *J. Spices and Aromatic Crops* 5(1): 41-48.

Sunitibala H, Damayanti M and Sharma GJ 2001. *In vitro* propagation and rhizome formation in *Curcuma Longa* L. *Cytobios* 105: 71-82.

Yang YW, Kuo HJW and Wong TH 1998. Genetic polymorphism of 7 populations of *Capsella bursa pastoris* based on RAPD markers. *Botanica Bulletin of Academia Sinica* 39(1): 17-21.

Medicinal uses of the weeds commonly found in Bay Islands

Sheeja TE[1], Mandal AB[2] and Martin J[1]
1 Indian Institute of Spices Research, Marikunnu P.O., Calicut, Kerala, India.
2 Central Agricultural Research Institute, Andaman and Nicobar Islands, India.

Abstract

Andaman and Nicobar Islands of India has unique flora and fauna due to the tropical humid climate and insular nature of the territory. A numbers weed species found here possess medicinal value. Information regarding the medicinal value of these weeds and the occurrence, habitat and the life form in which they exist in various place in the islands was gathered from local Vaidhyas, inhabitants and available literature. A total of 76 plants were found useful in cure of 35 different ailments. They were reported to be harmless without any side effects. Though a number of surveys were conducted for evaluating the medicinal potential of the flora of Andamans no similar work was conducted on the weed flora. This study shall help in judicious exploitation and sustenance of the weed diversity of the islands.

Weeds have always been considered as unwanted since they grow in unwanted places veraciously affecting economical crop yields. However, many of these weeds are being used herbal cure since time immemorial. In Andaman and Nicobar Islands the flora and fauna is unique due to the tropical humid climate and insular nature of the territory. A number of weed species is found to grow inoccusiouly in the rice, vegetable fields, water bodies, forest areas, marshy lands and pastures. Dagar *et al* (1991) has given an exhaustive report regarding the distribution and integrated management of the weeds of Bay Islands. Many of these were found to possess medicinal value as evident from their prolonged use in health care system.

Though a number of surveys were conducted for evaluating the medicinal potential of the flora of Andaman's no similar work was conducted on the weed flora. Hence an exclusive, survey was conducted encompassing the rice fields, vegetable fields and other areas to identify and record the same.

Relevant information was collected from earlier reports of Dagar *et al* 1991 for locating the place of availability of these weeds. Besides information was also gathered from literature on the occurrence, habitat and the life form in which there species exist in various place in the islands. (Table 1). Mostly the informers were asked to accompany the group to identify the plants and information was recorded on spot while in certain cases the plants was collected and identified with the help of BSI, Port Blair. The present study has yielded valuable information on the weed flora found in the islands.

These weeds were found to be used for more them 35 common ailments. A total of 76 plants were used in cure of 35 different kinds of diseases. A number of plants were found to possess multipurpose functions, which potentiates their effective use in health care. They were reported to be harmless without side effects. However, a general concern regarding the destruction of many of them was raised due to the inadvertent use of weedicides, herbicides and other harmful chemicals.

It is felt that the attempt made is very important for sustaining the weed diversity, which is gradually declining due to ignorance about their importance, Many species like *Lantana, Lippia, Portulaca, Solanum, Anesomeles*, etc may be also explored for extraction of aromatic oils, species like *Jatropha, Chromolaena oderata* are already

known for their potential use as biofuels. And many like *Ipomea* sp, *Marsilia cordata*, *Bacopa monnieri, Centella asiatica, Dioscorea*, *Polygonum plebeium*, *Portulaca oleracea*, *Boerhavia diffusa* are weeds with high nutritive value. Chemical analysis and adoption of judicious bioprospecting strategies for effective management is the need of the hour. Once they are scientifically validated in terms of the bioactive principle encoded by them, a commercially useful compound can be derived. This not only helps in management of weeds but also helps to fetch economic returns out of these so-called "trash" plants.

Table 1. Common weeds and their medicinal uses

Weed species	Occ.	Life form	Hab.	Medicinal value	Part used
Acalypha indica L.	f	An He	F	Scabies, snakebite, rheumatism and arthritis, asthma, gastrointestinal troubles	Leaf
Achyranthes aspera L.	o	An He	Ba	Fever, vomiting, headache, asthma, Jaundice, antihelmintic, antifertility	Whole plant
Acrostichum aureumL.	f	He	F	Kidney problem, dysentery	Leaf and frond
Aerva lanata(L Juss.	f	An He	B	Cuts and wounds, diuretic, antihelmintic, gastrointestinal troubles, malarial fever	Whole plant
Ageratum conyzoides L.	a	An Em, He	B, F	Tetanus, cut, wound, itch, fever, eyedisorder, piles, skin disease	Leaf, flower
Alternanthera sessilis (L) R.Br	r	An Em	B, D, F	Reduce pain in delivery, measles and blood purifier, rheumatism	Whole plant
Amaranthus spinosus	o	An He	F	Anaemia, diuretic, laxative, antiemetic, piles, gonorrhoea, skin disease	Leaf, root
Ammania bacifera L	o	An Em	BF	Scurvy, hypotensive, cold & cough	Whole plant
Aphanamixis polystachya	f			Tumours, rheumatic pain	Bark
Andrographis laxiflora (B1.) Lind.	F	An He	F	Worms, fever, liver problem	Whole plant, leaf, root
Andrographis paniculata	F	An He	F	Antimalarial, antidiabetic, Hypotensive	Whole plant, leaf, root
Anisomeles indica L O.K	f	An He	f	Cuts, wounds	Leaf
Asystasia gangetica L. T. And.	f	An Hp	Ba F	Antihelminthic, wormicide	Leaf
Barleria prionitis	f	Pe Ush	F	Antirheumatic, cough, dropsy, malarial fever, swellings and bone fracture	Leaf
Bacopa monnieri L Wettst	f	Pe, An		Brain tonic, epilepsy, fits and headache	Whole plant,

					leaf
Blumea lacera (Burm:f) DC	f	An He	F	Earache, mouth ulcer, bronchitis	Root, leaf
Boerhavia diffusa L.	r	Pe Hp	F	Diuretic, jaundice, cardiotonic, epilepsy, head ache, liver disorder	Leaf, whole plant, root
Cassia alata L.	o	Pe He	Ba	Allergy, fever cuts and wounds, boils	Leaf, bark, root
Cassia occidentalis L.	f	An He	F	Pain, fever, skin disease	Leaf
Celosia urgentea L.	o	An He	F	Ear pain, cut, wound	Leaf
Centella asiatica L Urb.	F	Pe Hp	F.B.Ba	Syphilis, fever, jaundice, tooth, stomach pain, epilepsy, nerve tonic	Leaf, whole plant
Chromolaena ordorata L R.M. King a &Robins	f	Pe He	f	Cuts and wounds	Leaf
Cleome rutidosperma DC	o	An He	F	Migraine	Leaf, whole plant
Cleome viscose L.	f	An He	F	Migraine, body ache, joint pain	Leaf, whole plant
Clerodendrum sp.L.	f	peHe	Bo	Antirheumatic, febrifuge, antimalarial, sprain and fracture	Leaf, root
Coldenia procumbens	f	An He	F	Rheumatic pain	Shoots, leaves
Commelina bengalensis L.	f	Pe Em	BDF	Wounds, laxative and emulcent tubers	Leaf, rhizome
Cyanodon dactylon L Pers.	a	Pe Hp	BF	Stomach disorder, centipede bite, headache, cold, cough	Whole plant, leaf, root
Cyperus differmis L.	f	An Em	F B	Dysentery, diarrhoea, stomachic	Rhizome , whole plant
Desmodium trifolium L Dc	r	An Hp	F	Anti rheumatic, rejuvenant	Root
Dioscorea alata	r	Pe Htw	F, Bo	Antifertility	Tubers
Eclipta alba L Hassk.	F	An Em	BF	Hair growth promoter, eye disease	Leaf, whole plant
Elephantopus scaber L	f	An He	F	Dysentery, tooth ache, stomach problem, cardiotonic, swellings and fracture, asthma, dropsy	Leaf, whole plant
Emelia sonchifolia	f	An He		Febrifuge, eye diseases	Leaf, whole plant
Euphorbia hirta L.	f	An Hp	BF	Improve lactation, asthma, gastrointestinal troubles	Leaf and plant
Evoloulus alsinoides L h	r	An Hp	F	Chromic asthma,	Leaf,

				bronchitis antipyretics, brain stimulant & hair growth promoter	root
Heliotrapium indicum L	r	An He	F	Cold & fever, boils wounds & ulcers, anti venom for insect string, stomachache.	Seed, plant
Ipomoea acquatica Forssk. Fi (con.)	f	An (Pe) Fe	FD	Rice, ponds emetic, nerve stimulant.	Plant
Ipomoea pescaprae L R.Br.	r	Pe Htw	Ba	Emetic, nerve tonic and rejuvenator, rheumatic pain, astringent, malarial fever	Plant
Ischaemum indicum (Houtt.) Merr.	F	An Em	B,F	Pain ears	Leaf
Jatropha curcas L.	o	Pe Ush	Bo	Purgative	Seed
Jatropha gossypifolia L.	f	Pe Ush	Bo	Purgative	Seed
Lantana camera	l, f	Pe sh	F	Skin disease, malarial fever, heumatic pain	Leaf
Leea indica L R.Br.ex Vatke	r	An He	Bo,B	Cough	Leaf
Lippia geminata HBIC	f	Pe Ush	BO	Stomachic, antihelminthic, antivenom for snake bite	Leaf, seed
Ludwigia hyssopifolia (G.Don) Exell	f	An Em He	B, F	Dysentery	Plant
Ludwigia octovalvis (Jacq.) Raven	f	An Em He	B,F	Dysentery	Plant
Ludwigia perennis L	f	An Em He	B, F,	Antipyretic, applied on sprains and boils	Whole plant, leaf
Lygodium sp.	o	Pe Hp	Ba	Sprain, scabies, ulcer, cut, wound	Leaf, root
Marsilea quadrifolia L.	la	An Em	F, Ba	Sleep inducer	Leaf
Melastoma malabathricum L.	a	Pe, Sh	Bo, F	Ulcer, stomach disorders, rheumatic pain, tumour	Leaf, root
Melochia corchorifolia L.	f	Pe Em	B, Bo	Snake bite	Plant, leaf
Mimosa intsia L	lf	Pe, Ush	F	Jaundice	Leaf, plant
Mimosa pudica L.	a	Pe, Hp	F	Dysentery, asthma, cuts, wounds, jaundice	Leaf, root
Ocimum tenuifolium L.	r	An He	F	Cuts, fever	Leaf
Passiflora foetida L	f	An Hel	Bo	Asthma, headache, brain stimulant.	Leaf
Peperomia pellucida L HBK	r	An He	F	Purgative, stomach problems, diuretic, epilepsy, head ache, malarial fever	Leaf
Phyla nodiflora L Gaertn.	F	An Em	B	Dandruff, bronchitis, gonorrhea, jaundice, anticancer, antimalarial	Leaf, plant
Phyllanthus amarus Schun x Thon	f	An He	F	Jaundice	Whole plant

Phyllanthus urinaria L.	r	An He	f	Jaundice	Whole plant
Physalis minima L.	f	An He	F	Stomach pain, bowel complaint Blood pressure	Leaf, fruit
Portulaca oleracea L	a	Am Hp	F	Liver stimulant, body coolant.	Leaf, fruit
Rungia pectinata L nees.	f	An Hp	F	Skin diseases, rashes, boils	Leaf
Scoparia dulcis	f	An He	B, F	Antiemetic, jaundice, fever, headache, antimalarial, anticancerous	Leaf, root
Sida acuta Burm .f.	o	An (Pe) He	F	Stomach pain, antiemetic, anticancer, snake bite	Leaf, root
Sida rhombifolia L.	o	An (Pe) He	F	Pain, toothache	Leaf, root
Solanum indicum L.	r	An He	F	Headache	Leaf, fruit, plant
Solanum nigrum L.	R	An He	F	Respiratory diseases, cardiac diseases	Fruit, root
Solanum surattense Burm.f.	r	An He	F	Anemia, fever, pain, headache	Leaf, fruits
Solanum torvum Sw.	r	An He	F	Toothache, anemia, respiratory troubles, cardiac problems	Fruit, root, seed
Stachytarpheta jamaicensis L Vahl.	A	Pe Ush	F	Snake bite	Leaf
Synedrella nodiflora L Gaertn.	F	An He	F	Tooth ache	Flower bud
Tridax procumbens L.	f	An He	FB	Cuts and wounds, hair growth promoter	Leaf, flower
Triumfetta rthomboidea Jacq.	F	Pe He	B, F	Asthma, astringent, dysentery and diarrhoea	Leaf, flower, fruit, root
Urena lobata L.	a	An (Pe) He	F	Boils, eye disorder, gastrointestinal disorder, rheumatic pain	Leaf
Vernonia cineria L legs	f	An Em He	B, F	Antihelminthic, piles, wounds & cuts, febrifuge, diaphoretic	Seeds, whole plant

d=dominant; a= abundant; f=frequent; o=occasional; r=rare; l=local
Pe=perennial; An= Annual; em=Emergent; He=herb erect; Hp=herb prostrate; Htw= herb twiner; Hcl= Herb climber; Ush= Undershrub; sh= shrub
Ba= bank; B=Bund; F=Field; Bo= Border; D= Ditch; Aqs= Aquatic submerged; Aqf= Aquatic floating; Aq Fl= Aquatic floating leaves

References

Dagar *et al., 1991.* Weeds of A&N Islands, Vol. 7, No:1: 32-43

Conservation and augmentation of natural enemies of insect pests in small cardamom agroecosystem.

Varadarasan S, Chandrasekar SS and Ansar Ali MA
Division of Entomology, Indian Cardamom Research Institute (Spices Board),
Myladumpara, Kailasanadu, Idukki, Kerala- 685 553.

Abstract

Small cardamom, Elettaria cardamomum Maton has been cultivated as a monocrop in the Western Ghat region of Southern India over a Century. In the early years of cardamom cultivation, the pest problem was minimum in spite of its mono-culturing; the agro-ecosystem was least disturbed, the shade condition as well as the soil (rhizosphere) were not much altered or disturbed. But with intensive cultivation of cardamom which necessitated the change in the agro-ecosystem such as reducing the shade condition, soil tillage and use of chemical pesticides, the pest damage intensity on cardamom not only increased, but the number of insect pests also increased considerably; many a minor pests became major pest under conditions of abnormal use of chemical insecticides. Study on a few cardamom agro-ecosystem, where chemical inputs were not used / used minimally as well as the shade pattern was undisturbed, revealed that the pest incidence and the intensity of damage was minimum; a host of natural enemies of insect pests were recorded in such undisturbed agro-ecosystem. Surveillance of insect pest in cardamom in various areas where insecticide usage has been (a) in excess, (b) need-based, (c) minimum and (d) organic system of plant protection indicated that natural enemies of major insect pest have been considerable in plantations where chemical insecticide usage was minimum or need-based or where organic pesticides were used. These observations indicated that natural enemies of cardamom pest, which help in reducing pest population, has been suppressed by excess use of insecticides under intensive agriculture; so there is an absolute need for conserving these natural enemies as well as augmenting them in cardamom agro-ecosystem. This paper discusses the various methods of conserving and augmenting the natural enemies of insect pest in cardamom agro-ecosystem.

Key words: natural enemies, small cardamom, cardamom pests, conservation and augmentation

Introduction

Small cardamom, the "Queen of Spices" (*Elettaria cardamomum* Maton) is being cultivated in the evergreen Western Ghat regions of Southern India at elevations of 800 – 1,300 meters above MSL. It was an important forest produce for the local tribal community in the early years of cultivation, until then the crop was free from pest attack (Murugan, 2005). But, the present scenario of intensive cardamom monoculture resulted in soil degradation and indiscriminate tree falling paving way for climatic aberrations; this again in turn resulted in the loss of natural enemies of pests as well as build-up of newer pest problem (Varadarasan, *et al.*, 2005). At present nearly 60 species of insect pests have been reported to infest cardamom in different stages of plant growth (Kumaresan and Varadarasan, 1987). To overcome the pest problem, planters resort to indiscriminate use of insecticides, which in turn leading to outbreak of minor pests and elimination of natural enemies rather than controlling the target pests. Therefore, the present study is aimed at understanding the changing trend of pest complex with the different plant protection strategies – organic, low insecticide and high insecticide strategies – to ascertain the importance of conserving natural enemies and to augment them in the cardamom hill agro-ecosystem.

Materials and Methods

This study was conducted in the Indian Cardamom Research Institute, Myladumpara, Kerala for a consecutive period of three years from 2002-2003 to 2004-2005.

a. Survey in Cardamom Plantations: Insect pest and natural enemy survey was undertaken in the fixed cardamom plantations of Western Ghat regions of Rajakkad, Santhanpara, Udumpanchola, Nedumkandam, Pampadumpara, Kattappana, Vandanmedu and Kumily areas of Idukki District, Kerala, India. Based on the quantum of chemical insecticide usage (number of spray imposition per year and concentration of insecticides) in the plantations, they were classified as organic plot, Less insecticide usage plot or High insecticide usage plot. In the Organic plot only organic bio-pesticides were used for plant protection measures. In the less insecticide usage plot four to five applications of insecticides per year were imposed; in high insecticide usage plots insecticide application is once in 21-days (total of 14–18 sprays per year). Monthly observations on the incidence of various pests and natural enemies were recorded from all the three categorized plots.

b. Survey for pests and natural enemies in neglected forest areas: Survey for pests and natural enemies were also conducted in the undisturbed, cardamom-neglected-forest areas. In Kerala the survey was conducted at Kerala Forest Development Corporation's (KFDC) cardamom Plantations at Pachakanam and in Tamil Nadu at Lower Pulneys, Vaithamalai, Mailodai and Kalakad-Mundanthurai reserve forest areas.

Results and discussion

The results of insect pest survey conducted in the fixed plots of Idukki district, Kerala for a consecutive period of three years is presented in the tables 1, 2 and 3 under each category *viz.,* Organic plot, less insecticide usage plot and high insecticide usage plot.

The comparison of incidence of pests and natural enemies in different categories of management indicated that in the organic plot though the pest damage was more than 5% in all the three years, the percentage natural enemy incidence was above 20%; this progressively increases every year. In the less- and high-insecticide usage plots though the percentage pest incidence was moderate and less respectively, the natural enemies were noticed only in the less insecticide usage plot and not in high insecticide usage plot. The incidence of whitefly was noticed in the high insecticide usage plot alone. In the IPM plot there was no incidence of whiteflies and the natural enemy incidence was 5%. The results of insect pest/ natural enemy survey conducted in neglected-cardamom grown forest areas are presented in the table 5 below. The natural enemies collected are predators, parasites (larval, larval-pupal, pupal), Entomopathogenic Fungus (EPF), Entomopathogenic Nematodes (EPN), etc. which are listed below in the table 6.

From the above tables it is inferred that an innumerable natural enemies of pests of cardamom are active in the plantation, which are to be exploited for effective management for cardamom pests.

The preference for colonization and multiplication of an insect on any host plant depends on various biotic and abiotic factors (Ananthakrishnan, 2002). In the preferred host the pests cause damage to a greater extent. Accordingly in cardamom, the most destructive and persistent pest is cardamom thrips, *Sciothrips cardamomi* (Ramk.), which reduces the quality and quantity of the produce (Gopakumar and Chandrasekar, 2002). The common method being the chemical control, planters resort to

indiscriminate use of insecticides, which results in unforeseen invited problems of pest outbreak.

In the present study of insect pest surveillance the percentage incidence of thrips damaged capsules in the organic, less- and high-insecticide usage plots of cardamom plantation indicated that though the thrips damage is under check (<5%) in the high-insecticide usage plot, there was high incidence of whitefly in all the three years. But in the IPM plot -where there is application of insecticides on need-basis- 5% incidence of natural enemies were noticed and there was no whitefly incidence. This further confirms the fact that in a cardamom ecosystem with the indiscriminate use of insecticides, not only the target pests were controlled, but also the natural enemies got depleted and resulted in outbreak of minor pests like whiteflies, red-spider mites. In the near future, there is also a possibility of major pests developing resistance to various pests, if the same trend continues (Ananthakrishnan, 2002). Varadarasan (1995) has reported a numbers of bio-agents of pests of cardamom; from which a system of utilizing potential natural enemies for pest management has to be exploited.

The survey of natural enemies of pests of cardamom conducted from neglected cardamom growing areas from Kerala and Tamil Nadu revealed that the incidence of various pests are <6%, and the percentage natural enemies are considerably higher (30 – 43%). Here, in the neglected cardamom forest ecosystem, Natural Selection favored the multiplication of natural enemies, which in turn checked the population of pests from causing higher damage. The natural enemies identified from forest areas of Kerala and Tamil Nadu were already been reported by Varadarasan (1985).

From the above study it is inferred that there is an absolute need for the conservation and augmentation of natural enemies – entomopathogenic fungi, parasites/ parasitoids, entomopathogenic nematodes, etc. – of pests of cardamom; this will release the hands of Natural Selection from the disturbed and deteriorated cardamom pest ecosystem.

The conclusion is that an awareness of the involvement of the host plant, pests and natural enemies in effective pest management strategies will revolutionize the concept of biological control of insect pests of cardamom.

Table: 1. Incidence of pests and natural enemies in the Organic plots:

Pest damage / Natural enemy	2002-'03	2003-'04	2005-'06
1. Percentage thrips damage	19.50	12.09	13.10
2. Percentage shoot borer damage	10.50	9.39	0
3. Percentage panicle borer	0.30	0.27	0
4. Percentage natural enemy	23	27	32

Table: 2. Incidence of pests and natural enemies in the Less-insecticide usage plots

Pest damage / Natural enemy	2002-'03	2003-'04	2005-'06
1. Percentage thrips damage	12.26	9.37	4.23
2. Percentage shoot borer damage	5.93	7.22	5.11
3. Percentage panicle borer	5.79	3.36	1.03
4. Percentage natural enemy	3	7	5
5. Whitefly incidence (No. per leaf)	0	0	0

Table: 3. Incidence of various pests and natural enemies in the high- insecticide usage plots

Pest damage / Natural enemy	2002-'03	2003-'04	2005-'06
1. Percentage thrips damage	4.40	2.25	1.91
2. Percentage shoot borer damage	4.90	4.21	1.49
3. Percentage panicle borer	1.60	2.27	0.06
4. Percentage natural enemy	0	0	0
5. Whitefly incidence (No. per leaf)	6.75	12.45	5.33

Table: 4. Incidence of various pests and natural enemies in the IPM plot of ICRI, Myladumpara

Pest damage / Natural enemy	2002-'03
1. Percentage thrips damage	4.46
2. Percentage shoot borer damage	9.32
3. Percentage panicle borer	0.41
4. Percentage natural enemy	5
5. Whitefly incidence (No. per leaf)	0

Table: 5. Incidence of pests and natural enemies in neglected cardamom grown forest areas

Pests	Percentage incidence (Kerala)	Percentage incidence (Tamil Nadu)
1. Thrips	4.25	5.23
2. Shoot borer	2.35	4.53
3. Panicle borer	0	0
4. Natural enemies	34.00	42.00

Table: 6. Survey of natural enemies from neglected forest cardamom plantations:

Major insect pest	Natural enemy	Predator/parasite
Cardamom thrips, *Sciothrips cardamomi*	*Montandoniola moraguesi* (Anthocoridae)	Predator
	Chrysopersla carnea (Chrysopidae)	Predator
Shoot / panicle / capsule borer *Conogethes punctiferalis*	*Eriboorus trochanteratus*	Larval parasitoids
	Bracon brevicornis	
	Microbracon hebetor	
	Theronia inaareolata	
	Apanteles sp.	
	Friona sp.	
	Agrypon sp.	Larval-pupal parasitoids
	Temeleucha sp	
	Xanthopimpla australis	Pupal parasitoids
	X.kandiensis	
	Synopiensis sp.	
	Gotra sp.	
	Brachymeria sustralis	
Root grub *Basilepta fulvicorne*	*Metarhizium anisopliae*	EPF
	Beauveria bassiana	EPF
	Heterorhabditis sp.	EPN
	Steinernema sp.	EPN
Whitefly, *Singiella cardamomi*	*Aschersonia placenta*	EPF
	Verticillium sp.	EPF

Hairy caterpillars, *Eupterote cardamomi*	*Apanteles sp.* *Beauveria bassiana*	Larval parasitoid EPF

References

Ananthakrishnan TN 2002. Insects, Plants and Molecular Interactions. Madras Science Foundation, Chennai, India. p 120.

Gopakumar B and Chandrasekar SS 2002. Pests of cardamom. In 'The Genus *Elettaria* (Eds. P.N. Ravindran and K.J. Madhusoodanan)', Taylor and Francis: 180 – 206.

Kumaresan D and Varadarasan S 1987. Review and current status of research on insect pet control in cardamom cropping system. Proc. Workshop on insect pest management on coffee, tea and cardamom cropping systems, 1987, Chikmagalur, India.

Murugan M 2005. Cardamom and climate change. Cardamom Growers' Association Souvenir 2005, Cardamom Growers Association, Vandanmedu, Kerala: 15-17.

Varadarasan S 1995. Biological control of insect pests of cardamom. In 'Biological control of social forest and plantation crops insects', Oxford & IBH Pub. House, New Delhi, India: 109-119.

Varadarasan S, Chandrasekar SS and Ansar Ali, MA, 2005. Integrated management of pests of cardamom. Cardamom Growers' Association Souvenir 2005. Cardamom Growers Association, Vandanmedu, Kerala: 41 – 51.

Acknowledgement

The authors are thankful to Dr. J. Thomas, Director (Research), Indian Cardamom Research Institute, for his interest in this work and encouragement.

Gregor Mendel Foundation Proceedings 2006

Effect of systematic acquired resistance inducing compound Benzothiadiazole (Bion) on powdery mildew and *Colletotrichum* leaf diseases of rubber

Edwin Prem E, Sadanand K. Mushrif, Srinivas P and Kuruvilla Jacob C
Rubber Research Institute of India, Kottayam, Kerala- 686 009.

Abstract

Management of rubber (Hevea brasiliensis) diseases are mainly confined to the use of systemic and contact fungicides. Benzothiadiazole, a systemic resistance inducing compound was evaluated for the expression of three defence related enzymes viz. peroxidase, polyphenol oxidase and catalase activity. In vivo studies for the management of powdery mildew (Oidium heveae) and Colletotrichum (Colletotrichum acutatum and C. gloeosporioides) leaf diseases under taken in the nursery and juvenile field plants clearly indicated that the bezothiadiazole was able to activate the enzymes studied. Benzothiadiazole when sprayed at copper brown leaf stage yielded better protection against O. heveae. Nursery and field evaluation of benzothiadiazole revealed its effectiveness in protecting H. brasiliensis against powdery mildew and colletotrichum leaf diseases and it was comparable to the recommended fungicides. The effectiveness was observed to be enhanced by the application of benzothiadiazole in combination with fungicides.

Key words: *Oidium, Colletotrichum, Hevea*, benzothiadiazole, systemic acquired resistance, peroxidase, polyphenol oxidase, catalase, disease control

Introduction

Powdery mildew (*Oidium heveae*) and Colletotrichum leaf disease (*Colletotrichum gloeosporioides and C. acutatum*) cause considerable damage to the foliage of nursery, young and mature plants of rubber (*Hevea brasiliensis*). Powdery mildew disease (PMD) assumes epidemic proportions during refoliation phase, leading to severe defoliation. The resultant poor canopy and vigour of trees reduce yield (Radziah *et al.,* 1992; Jacob *et al.,* 1992; Mondal and Jacob, 2002). *Colletotrichum* infects the new flushes of young rubber plants of age 1 – 4 years causing severe deformation and defoliation of leaves. This results in growth retardation and prolongation of the immaturity period of rubber plants (Manju *et al.,* 1999). The use of systemic and contact fungicides has been the main strategy for controlling the diseases. Fortnightly application of mancozeb (0.2%), carbendazim (0.05%) or Bordeaux mixture (1%) is recommended for colletotrichum leaf disease (CLD) control (Edathil *et al.,* 2000). Protective applicaton of sulphur fungicide either as dust or wettable powder has been in practice for the control of PMD. Use of systemic dust formulation of tridemorph (Edathil *et al.,* 1988), carbendazim (Jacob *et al.,* 1996) and hexaconazole (Prem *et al.*, 2002) were found to be effective against *Oidium*.

A new strategy for crop protection involves the induction of systemic acquired resistance (SAR) in plants, which activates the plant's own defence mechanisms leading to an increased plant resistance against diseases. Resistance to disease can be induced systemically in a number of plant species by biological and chemical means (Hammerschmidt and Kuc, 1995). Few endophytic bacteria are capable of inducing SAR in plants (Van Peer and Schippers, 1989). The most commonly used biological method is inoculation of a leaf with a local lesion –causing pathogen. Some chemical agents are known which appear to mimic the systemic effects of localized infection and they include 2,6-dichloroisonicotinic acid (INA), salicylic acid (Kessmann *et al.*, 1994)

and benzo-(1,2,3)-thiadiazole-7-carbothioic acid S-methyl ester (BTH) (Lawton *et al.,* 1996 and Kessmann, 1996). Frey and Carver (1998) reported the induction of SAR in pea to powdery mildew by exogenous application of salicylic acid. In tobacco and *Arabidopsis* benzothiadiazole induced systemic acquired resistance has been reported (Lawton *et al.,* 1996). Benzothiadiazole reduced the lesion development by *Alternaria* in cotton (Brock *et al.*1994 and Colson-Hanks and Deverall, 2000). The present study was aimed to evaluate benzothiadiazole (Bion) for the induction of systemic acquired resistance and management of powdery mildew and colletotrichum leaf diseases in rubber.

Materials and Mthod

Bio-chemical studies: Budded plants of RRIM 600 grown in poly bags were used to determine the induction of bio-chemical changes in the plants due to the spraying of two chemicals viz. salicylic acid and benzothiadiazole. Control plants were maintained and sprayed with sterile water. Leaf samples were collected at 24h, 48h, 72h and 96h after spraying and the activity of peroxidase, polyphenol oxidase and catalase were determined spectrophotometrically.

Estimation of peroxidase: Peroxidase activity was estimated using guaiacol as substrate (Putter, 1974). One gram of leaf sample was ground in a pre-cooled mortar and pestle by adding 3 ml of 0.1 M phosphate buffer (pH 7.0). The homogenate was centrifuged at 18,000 rpm at 5^0C for 15 minutes. The supernatant collected served as the enzyme source. From the enzyme extract 0.1 ml was drawn into a separate test tube and 3.0 ml of phosphate buffer solution, 0.05 ml guaiacol solution and 0.03 ml hydrogen peroxide were added. The peroxidase activity was determined spectrophotometrically (Shimadzu, UV-1601, Japan) at 436 nm. The enzyme activity was expressed in units per litre of the extract.

Estimation of polyphenol oxidase: Polyphenol oxidase activity was measured according to Sridhar *et al* (1969). The reaction mixture contained 2ml catechol, 0.5ml phosphate buffer and0.5ml enzyme extract. Polyphenol oxidase activity were assayed by determining the absorbance increase at 470nm and expressed as unit change in absorbance (ΔA/minute/mg protein)

Estimation of catalase: Catalase activity was measured according to Luck (1974). Pipetted 2.5ml 0.1M phosphate buffer into cuvette and added 0.1ml hydrogen peroxide and 0.05ml enzyme extract. The reaction was closely monitored by recording changes in absorbance at 240nm, for 75 seconds at 15 seconds interval starting from the first reading recorded 15 seconds after the addition of hydrogen peroxide. A cuvette containing tissue extract and buffer was used to adjust the absorbance to zero. The enzyme activity was expressed in units per mg protein, where one enzyme unit was defined as the change in absorbance per minute caused by enzyme reaction.

Evaluation of benzothiadiazole against Oidium heveae

Influence of leaf stages and concentration of benzothiadiazole on powdery mildew intensity: The experiment was conducted in the RRII Farm, Kottayam using the budwood nursery plants of the *Oidium* susceptible clone PB 5/51. Benzothiadiazole was sprayed on the different stages of leaves viz. copper brown, light green and mature leaves. Each stage of leaves was sprayed at a concentration of 0.05%, 0.1%, 0.25%, 0.5%, and 1%. Two rounds of spraying were undertaken at an interval of 3 days. Observation on the powdery mildew disease intensity was assessed after 15days. Scoring was done on a 0-5 scale based on the intensity of spotting and deformity of leaves.

0 = no disease

1 = 1-10% of leaf area infected (very light)

2 = 11-20% leaf area infected (light)
3 = 21-40% leaf area infected (moderate)
4 = 41-75% leaf area infected (severe)
5 = >75% area infected and leaf fall (very severe)

The percent disease intensity (PDI) was calculated (Horsfall and Huberger 1942) using the following formula

$$PDI = \frac{\text{Sum of numerical ratings}}{\text{No. of plants observed} \times \text{maximum disease grade}} \times 100$$

Nursery evaluation: Two experiments were carried out in the nursery at Central Experiment Station (CES) of the RRII and RRII Farm, Kottayam to evaluate the efficacy of benzothiadiazole using the budded plants of clone RRII 105 and RRIM 600 respectively. In the first location, benzothiadiazole (0.05%) was compared with recommended fungicides wettable sulphur (0.2%) and carbendazim (0.05%). A chelated zinc (0.05%) formulation was also applied. Control plants were maintained without spraying. At the second location, seven treatments were imposed. Benzothiadiazole (0.05%), carbendazim (0.05%), wettable sulphur (0.2%) and difenconazole (0.025%) were sprayed individually. Further, a combination of benzothiadiazole (0.05%) + carbendazim (0.05%) and benzothiadiazole (0.05%) + hexaconazole (0.02%) were sprayed to assess the cumulative effect of these treatments. A control plot was maintained for comparison. Both the nursery trials were conducted in completely randomised design with 15 replications. Observation on the disease intensity was recorded as described earlier. Percentage disease index (PDI) was calculated and analysed statistically.

Field evaluation: A field experiment was undertaken at TR & T estate, Mundakayam on juvenile (First year) plants of clone RRII 105 to evaluate the performance of benzothiadiazole against PMD. Seven treatments were applied. Benzothiadiazole at two concentrations (0.25 and 0.1%), carbendazim (0.05%), and difenconazole (0.025%) were sprayed individually. Combined effect of benzothiadiazole (0.05%) + carbendazim (0.05%) and benzothiadiazole (0.05%) + hexaconazole (0.02%) were also evaluated. An unsprayed control was also maintained. The experiment was laid out in a randomised block design with four replications each comprising of 25 plantlets. Fungicides were applied at weekly intervals using a knap-sack sprayer. Observations on the disease intensity were assessed as described earlier. Percentage disease index (PDI) was calculated and analysed statistically.

Evaluation of benzothiadiazole against Colletotrichum

Nursery evaluation: Nursery trials were undertaken at CES, Chethackal and RRII Farm, Kottayam to evaluate the efficacy of benzothiadiazole against CLD using the budded plants of clone RRII 105 and RRIM 600 respectively. In CES, benzothiadiazole (0.05%) was compared with recommended fungicides carbendazim (0.05%) and mancozeb (0.2%). In RRII Farm, six treatments were imposed. Benzothiadiazole (0.05%), carbendazim (0.05%), and difenconazole (0.025%) were sprayed individually. A combination of benzothiadiazole (0.05%) + carbendazim (0.05%) and benzothiadiazole (0.05%) + hexaconazole (0.02%) were sprayed to assess the combined effect. Control plots were maintained for comparison at both locations. The trials were conducted with a completely randomised design with 15 replications. The disease intensity was assessed after each round of spraying by grading diseased leaves on a 0 – 5 scale based on the percentage leaf area infected. Percentage disease index (PDI) was calculated and analysed statistically.

Field evaluation: A field experiment was undertaken at TR & T estate, Mundakayam using the first year plants of clone RRII 105 to evaluate the field performance of benzothiadiazole to control CLD. Seven treatments were applied. Benzothiadiazole at

two concentrations (0.25 and0.1%), carbendazim (0.05%), and mancozeb (0.2%) were sprayed individually. In addition, combined effect of benzothiadiazole (0.05%) + carbendazim (0.05%) and benzothiadiazole (0.05%) + hexaconazole (0.02%) were evaluated. Unsprayed control was also maintained. The experiment was laid out in a randomised block design with four replications, each replication comprising of 25 plants. Fungicides were applied at weekly intervals using a knap-sack sprayer. Observations on disease intensity was assessed, as described earlier and analysed statistically.

Results and Dscussion

Studies on the induction of defence related enzymes in the treated clone RRIM 600 showed increased peroxidase activity. The activity increased with time after application upto 72 hours. Induction of salicylic acid was slightly higher than benzothiadiazole (Fig .1). The application of benzothiadiazole and salicylic acid showed a higher induction of polyphenol oxidase activity at 24 h after treatment. A slight decline was noticed at 48 h. At 72 hours after treatment benzothiadiazole recorded an increasing trend in the polyphenol oxidase activity. Sharp increase in the catalase activity was observed with salicylic acid after 24 h but it declined at 48 h and 72 h. In the case of benzothiadiazole catalase activity increased at 24 h and slightly decreased at 48 h but increased later at 72 h.

Peroxidase activity of tissues has been reported to be well correlated with the expression of disease resistance in different crops (Smith and Hammerschmidt 1988; Angelini *et al.,* 1993; Jite and Tressa 1999). The expression of resistance is often accompanied by the activation of phenol oxidising enzymes such as peroxidase and polyphenol oxidase (Goodman and Novacky 1994). In the present study increased activity of peroxidase was observed on the treated leaves of RRIM 600. Cools and Ishii (2002) showed that in cucumber peroxidase was directly induced by benzothiadiazole and its expression was further enhanced upon elicitation with fungal pathogen. Increase in polyphenol oxidase activity may contribute to defence through the production of oxidized forms of quinines, which can inactivate pectinolytic enzymes produced by the pathogen (Leatham *et al.,* 1980). Application of benzothiadiazole showed increased production of polyphenol oxidase in the treated plants in the present study. Gradual increase in the catalase activity was observed with the application of benzothiadiazole on RRIM 600 plants. Changes in the catalase activity as a result of fungal infection have been reported in various host-pathogen combinations and were related to diseases resistance (Vir and Grewal, 1974; Lebela *et al.,* 2001; Ronald, 2001). Fric and Fuchs (1970) observed marked increase in catalase activity of resistant wheat leaves infected with *Puccinia graminis tritici.* Mushrif *et al.* (2004) reported that the activity of peroxidase was more in clone RRIM 600 inoculated with *Colletotrichum* spp.

Application of benzothiadiazole on various stages of leaves indicated better protection against *Heveae* when the copper brown leaves were sprayed (Fig.2). The lowest concentration of benzothiadiazole (0.05%) when applied at copper brown stage recorded less than 30% disease intensity. Colson-Hanks and Deverall (2000) reported that the wettable granule formulation (35µg/ml) of benzothiadiazole applied on cotyledons reduced lesion formation by *Alternaria macrospora* in the successive leaves on cotton.

In the evaluation against powdery mildew disease, benzothiadiazole recorded lowest disease intensity (14.75%) on the budded nursery plants of RRII 105.(Table 1). Carbendazim, chelated Zinc and wettable sulphur were on par in their efficacy. However, in the budded plants of RRIM 600, benzothiadiazole was on par with other fungicides (Table 2). Combination of benzothiadiazole along with carbendazim recorded the lowest disease (14.8%). In the field evaluation, benzothiadiazole (0.25% and 0.1%)

performance was on par with all other treatments (Table 3). But, the combination of benzothiadiazole+carbendazim recorded minimum disease intensity (11.34%).

Nursery evaluation of benzothiadiazole (0.05%) recorded lowest disease intensity (3.57%) in the clone RRII 105 against colletotrichum leaf disease (Table 4). However, it was on par with recommended fungicides viz. mancozeb and carbendazim. Similar observation was recorded in the nursery trial (Table 5) with the clone RRIM 600 also. Combined application of benzothiadiazole (0.05%) and a triazole fungicide hexaconazole (0.02%) recorded lowest disease (16.0%). In the field study (Table 6), individual application of benzothiadiazole (0.1% and 0.25%) were on par in their effectiveness with mancozeb (0.2%) and carbendazim (0.05%). However, when applied in combination with mancozeb disease intensity was much lower.

Benzothiadiazole is translocated systemically in plants and can take the place of salicylic acid in the natural SAR signal pathway, inducing the same spectrum of resistance (Oostendorp *et al.,* 2001; Kunz *et al.,* 1997). Chemicals that have been shown to mimic more closely the mode of action of SA are 2,6-dichloroisonicotinic acid and benzothiadiazole. Crops where they showed best results under field conditions include tobacco, tomato, and vegetables for protection against a broad spectrum of pathogens. (Oostendorp *et al.,* 2001). Treatment of benzothiadiazole on the first leaves reduced the susceptibility to powdery mildew caused by *Uromyces viciae-fabae* and leaf spot pathogen *Mycosphaerella pinodes* on pea (Dann and Deveerall, 2000).

In the present study it was evident that the benzothiadiazole could induce the activity of peroxidase, polyphenol oxidase and catalase. Such triggering of enzymes related to systemic resistance could protect plants from the subsequent invasion of pathogen. It was evident from the nursery and field studies that, benzothiadiazole is comparable to recommended fungicides in the control of powdery mildew and colletotricum leaf disease of rubber. However, the effectiveness could be further enhanced by the application of benzothiadiazole in combination with fungicides.

Table 1. Effect of benzothiadiazole on the powdery mildew disease intensity in the nursery plants of clone RRII 105

Fungicides	Concentration (%)	Disease intensity (%)
Carbendazim	0.05%	19.39
Chelated Zinc	0.05%	19.29
Flowable sulphur	0.2%	19.92
Benzothiadiazole	0.05%	14.75
Wettable sulphur	0.2%	19.92
Control-unsprayed	--	22.47
CD(P≤0.05)		3.47

Table 2. Effect of benzothiadiazole on the powdery mildew disease intensity in the nursery plants of clone RRIM 600

Fungicides	Concentration(%)	Disease intensity (%)
Benzothiadiazole	0.05%	19.6
Carbendazim	0.05%	16.5
Difenconazole	0.025%	15.1
Carbendazim+benzothiadiazole	0.05%+0.05%	14.8

Hexaconazole+benzothiadiazole	0.02%+0.05%	16.8
Wettable sulphur	0.2%	17.0
Control-unsprayed	--	29.4
CD (P≤ 0.05)		6.1

Table 3. Efficacy of benzothiadiazole on the powdery mildew disease intensity in the first year plants of clone RRII 105

Fungicides	Concentration(%)	Disease intensity (%)
Carbendazim	0.05%	14.3
Difenconazole	0.025%	14.2
Benzothiadiazole	0.25%	13.0
Benzothiadiazole	0.1%	13.7
Carbendazim+benzothiadiazole	0.05%+0.1%	11.3
Difenconazole+benzothiadiazole	0.025%+0.1%	12.3
Control-unsprayed	--	24.7
CD (P≤ 0.05)		4.2

Table 4 Effect of benzothiadiazole on the colletotrichum leaf disease intensity in the nursery plants of RRII 105

Fungicides	Concentration	Disease intensity (%)
Carbendazim	0.05%	4.71
Mancozeb	0.2%	5.51
Chelated Zinc	0.05%	13.92
Benzothiadiazole	0.05%	3.57
Control-unsprayed	--	25.89
CD (P≤ 0.05		6.07

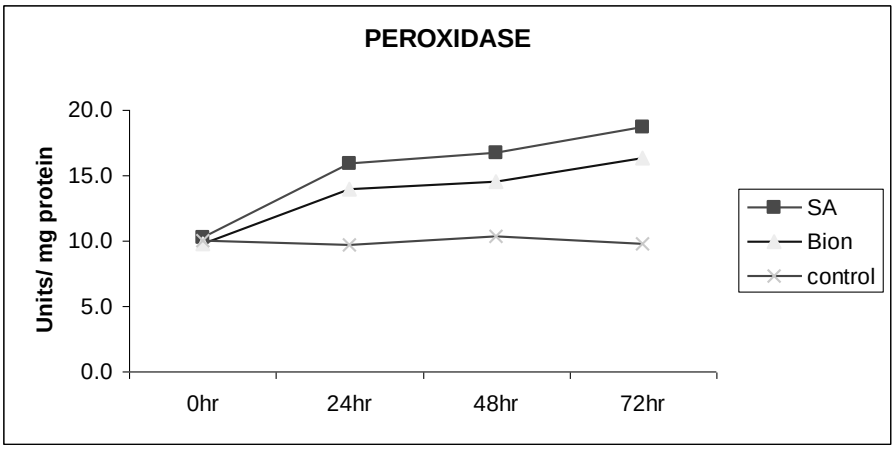
Table 5 Effect of benzothiadiazole on the colletotrichum leaf disease intensity in the nursery plants of RRIM 600

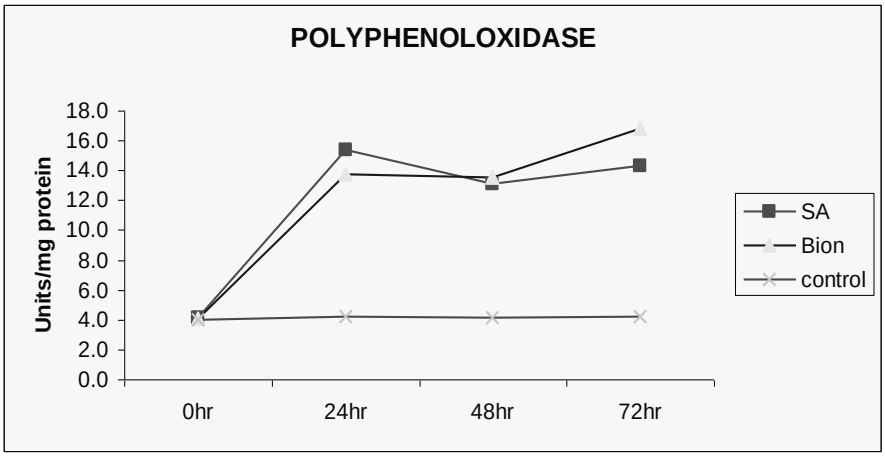
Fungicides	Concentration	Disease intensity (%)
Benzothiadiazole	0.05%	18.1
Carbendazim	0.05%	17.5
Difenconazole	0.025%	16.8
Carbendazim+benzothiadiazole	0.05%+0.05%	17.8
Hexaconazole+benzothiadiazole	0.02%+0.05%	16.0
Control - unsprayed	--	25.10
CD (P≤ 0.05)		6.73

Tablel 6. Efficacy of benzothiadiazole on the colletotrichum leaf disease intensity in the first year plants of RRII 105

Fungicides	Concentration	Disease intensity (%)
Mancozeb	0.2%	12.1
Carbendazim	0.05%	14.0
Benzothiadiazole	0.25%	16.2
Benzothiadiazole	0.1%	19.1
Mancozeb +benzothiadiazole	0.2%+0.1%	9.3
Carbendazim +benzothiadiazole	0.05%+0.1%	11.1
Control – unsprayed	--	29.3
CD (P≤ 0.05)		4.8

Fig. 1 Changes in peroxidase, polyphenol oxidase and catalase activities in the leaves of the clone RRIM 600 treated with benzothiadiazole





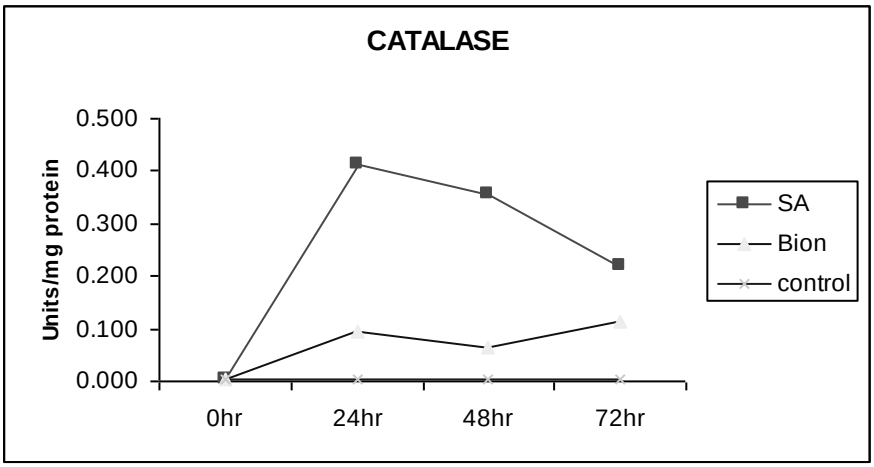
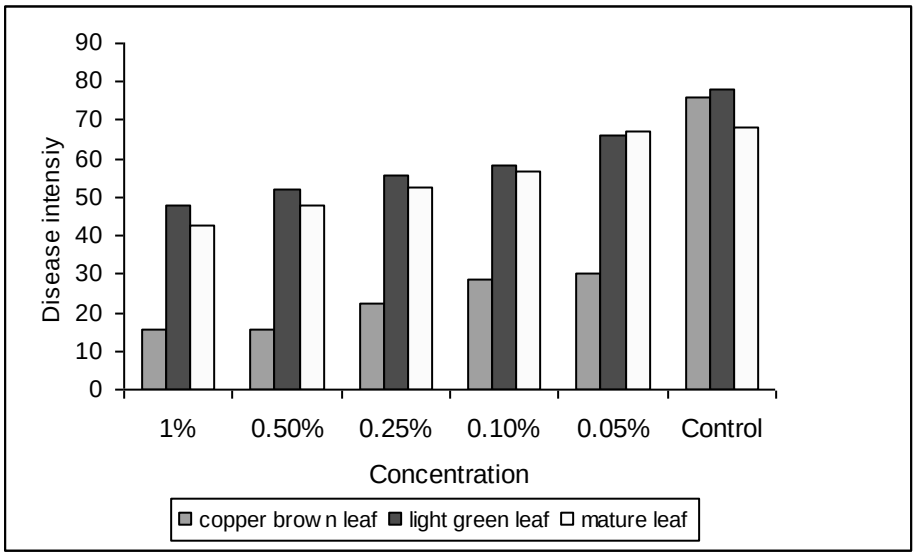


Fig. 2 Effect of leaf stages and concentration of benzothiadiazole on the powdery mildew disease intensity in clone PB 5/51



References

Angelini R, Bragaloni M, Federico R, Infantino A and Portapuglia A 1993. Involvement of polyamines, diamine oxidase and peroxidase in resistance of chickpea to *Ascochyta rabiei. Journal of Plant Physiology* 142: 704-709.

Brock PM, Inwood JRB and Deverall BJ 1994. Systemic induced resistance to *Alternaria macrospora* in cotton. *Australasian Plant Pathology*. 23 : 81-85.

Colson-Hanks ES and Deverall BJ 2000. Effect of dichloroisonicotinic acid and its formulation material and benzothiadiazole on systemic resistance to Alternaria leaf spot in cotton. *Plant Pathology* 49: 171—178.

Cools HJ and Ishii H 2002. Pre-treatment of cucumber plants with acibenzolar-S-methyl systemically primes a phenylalanine ammonia lyase gene (PAL) for enhanced

expression upon fungal pathogen attack. *Physiological Molecular Plant Pathology* 61: 273-280.

Dann E E and Deverall BJ 2000. Activation of systemic disease resistance in pea by an avirulent bacterium or a benzothiadiazole, but not by a fungal leaf spot pathogen. *Plant Pathology* 49: 324-332.

Edathil TT, Krishnankutty V, Idicula SP and Jayarathnam K 1988. Powdery mildew disease management in *Hevea brasiliensis* using non-sulphur fungicides. *Indian Journal of Natural Rubber Research* 1(2): 61-65.

Edathil TT, Jacob CK and Joseph A 2000. Leaf diseases. In: 'Natural Rubber: Agromanagement and Crop Processing (Eds. P.J. Goerge and C. Kuruvilla Jacob), Rubber Research Institute of India: 273-296.

Frey S and Carver TLW1998. Induction of systemic resistance in pea to powdery mildew by exogenous application of salicylic acid. *Journal of Phtopathology* 146: 9-245

Fric F and Fuchs WH 1970. *Veranderungen der Aktivitat einiger enzyme im weizenblatt in Abhangigikeit von der temperature labilen vertraglichkeit fur Puccinia graminis tritici. Phytopathologische Zeitschrift* 67: 161-174

Goodman RN and Novacky AJ 1994. The bacteria-induced hypersensitive reaction. Pages 117-173 in: The Hypersensitive Reaction in Plants to Pathogens. *The American Phytopathological Society*, St. Paul, MN.

Hammerschmidt R and Kuc J (Eds.) 1995. Induced Resistance to Disease in Plants. Dordrecht, Netherlands, Kluwer.

Horsfall JG and Heuberger JW 1942. Measuring the magnitude of a defoliation disease of tomato. *Phytopathology* 32: 226-232.

Jacob CK, Edathil TT, Idicula SP and Jayarathnam K 1992. Effect of powdery mildew disease on the yield of rubber trees in Kanyakumari district. *Indian Journal of Natural Rubber Research* 5 (1&2): 245-247.

Jacob CK, Idicula SP, Edathil TT and Jayarathnam K 1996. Evaluation of dust formulation of two systemic fungicides for the control of powdery mildew disease of *Hevea brasiliensis. Journal of Plantation Crops* 24(Supplement): 229-232

Jite PK and Tressa J 1999. Biochemical changes in *Jasminum grandiflorum* infected by *Uromyces hobsoni*. *Indian Phytopathology* 52(1) : 77-78.

Kessmann H 1996. Systemic activated resistance. A new technology for plant disease control. *Pesticide Outlook*. **7**(3): 10–13.

Kessmann H, Staub T, Hofmann C, Maetzke T and Herzog J 1994. Induction of systemic acquired disease resistance in plants by chemicals. *Annual Review of Phytopathology* 32: 439-459.

Kunz W, Schurter R and Maetzke T 1997. The chemistry of benzothiadiazole plant activators. *Pesticide Science* 50: 275-282.

Lawton K, Friedrich L, Hunt M, Weymann K, Delaney T, Kessmann H and Staub T 1996. Benzothiadiazole induces disease resistance in *Arabidopsis* by activation of the systemic acquired signal transduction pathway. *The Plant Journal* 10: 123-110.

Leatham GF, King M and Stahmann MA 1980. *In vitro* protein polymerization by quinones or free radicals generated by plant or fungal oxidative enzymes. *Phytopathology* 70: 1134-1140.

Lebeda A, Luhova L, Sedlarova M and Jancova D 2001. The role of enzymes in plant-fungal pathogens interactions. *Journal of Plant Disease Protection.* 108: 89-111

Luck H 1974. In: Methods of Enzymatic Analysis II (Ed. Bergmeyer). Academic Press, New York p. 685.

Manju MJ, Idicula SP, Joseph A, Joy M and Kothandaraman R. 1999. Incidence and severity of *Gloeosporium* leaf disease of rubber in South India. *Indian Journal of Natural Rubber Research* 12(1&2): 34-38

Mondal GC and Jacob CK 2002. Effect of powdery mildew disease on the yield of rubber in Northern part of West Bengal. *Proceedings of Placrosym* – XV: 531-534.

Mushrif SK, Philip S, Joseph A, Prem EE and Jacob CK 2004. Factors affecting growth and sporulation of *Colletotrichum acutatum* and *C. gloeosporioides* and changes in biochemical parameters in two *Hevea brasiliensis* clones due to their infection. *South Zone IPS,* Gulburga University. 24-26 December 2005.

Naruska Y, Naruska M, Horio T and Ishii H 1999. Comparison of local and systemic induction of acquired disease resistance in cucumber plants treated with benzothiadiazole or salicylic acid. *Plant Cell Physiology* 40(4): 388-395.

Oostendorp M, Kunz W, Dietrich B and Staub T 2001. Induced disease resistance in plants by chemicals. *European Journal of Plant Pathology* 107: 19-28.

Prem E E, Manju MJ, Mushrif SK, Idicula SPand Jacob CK 2002. Evaluation of dust formulation of hexaconazole for the control of powdery mildew disease of *Hevea brasiliensis. Proceedings of Placrosym* – XV: 572-575.

Putter J 1974. In: Methods of enzymatic analysis 2 (Ed. Bergmeyer). Academic Press, New York, p. 685.

Radziah NZ, Hashim K and Shamshuri MH 1992. Effect of selected fungicides on *Oidium heveae* and *Corticium salmonicolor* affecting rubber in West Malaysia. *Indian Journal of Natural Rubber Research.* 5 (1&2): 66-72.

Ronald P 2001. Signalling in rice disease resistance. In : 'Delivery and perception of pathogen signals in plants (Eds. Noel, T. Keen, Shigeyuki Mayama, Jan E. Leach and Shinji Tsuyumu)'. APS Press, The American Phytopathological Society, St. Paul, Minnesota: 137-144.

Smith JA and Hammerschmidt R 1988. Comparative study of acidic peroxidases associated with induced resistance in cucumber muskmelon and water melon. *Physiological and Molecular Plant Pathology* 33: 255-261.

Sridhar R, Chandramohan D and Mahadevan A 1969. The role of parasite and its metabolites in triggering host physiology. *Phytopathologische Zeitschrift* 64: 21-27.

Van Peer R and Schippers B 1989. Plant growth response to bacterisation with selected *Pseudomonas* spp. strains and rhizosphere microbial development in hydroponic cultures. *Canadian Journal of Microbiology* 35: 456-463.

Vir S and Grewal JS 1975. Changes in catalase activity of gram plant induced by *Ascochyta rabiei* infection. *Indian Phytopathology* 28: 223-225.

Acknwledgement
The authors are thankful to Dr. N.M. Mathew, Director, RRII for providing the facilities. They are also grateful to the management of Manickal Estate, Mundakayam for providing all assistance in carrying out the field experiment.

A survey of indigenous natural enemies of coffee mealy bugs in wayanad district of Kerala

Abdul Rahiman P[1], Naik Prakash R[2] and Vijayalakshmi CK[1]
1 Regional Coffee Research Station, Chundale, Wayanad, Kerala- 673123.
2 Department of Studies in Zoology, University of Mysore, Manasagangotri, Mysore, Karnataka- 570006, India.

Abstract

In Wayanad, coffee is attacked by mealy bugs viz., Planococcus cirri (Risso) and Planococcus lilacinus (Cockerell). Several workers have reported a number of natural enemies on this pest earlier in India. A survey was conducted on a number of coffee estates infested with mealy bugs in Wayanad for these natural enemies during January to May 2005. Three species of indigenous natural enemies viz. Spalgis epius (Westwood) (Lepidoptera: Lycaenidae), Triommata coccidivora (Muls.) (Coleoptera: Coccinellidae) and Pullus pallidicollis (Felt) (Diptera: Cecidomyiidae) were encountered during the survey. The predators Spalgis epius and Triommata coccidivora were abundant and commonly seen in all estates. The activity of Pullus pallidicollis was comparatively less.

Introduction

The mealy bugs are the most wide spread pests occur on all land masses of the world and attack ornamentals, orchards and plantation crops including coffee. Taxonomists have identified 2 – 3 thousand species of mealy bugs injurious to plants of economic importance. In India 13 fully identified and 4 partly identified coccoids are recorded on coffee (Anonymous, 1984; Chacko, 1979; Chacko and Bhat, 1976; Chacko et al., 1979; Le Pelly, 1968; and Rao and Chacko, 1977).The mealy bugs (*Homoptera: Pseudococcidae*) occur on above ground parts of coffee plant and also on roots; no coffee growing area in the world is free from this pest (Le Pelly, 1968). *Planococcus lilacinus* (Ckll.) attacks the shoots and roots and *Planococcus citri* (Risso) the roots of arabica coffee (Sekhar, 1964). Chacko et al (1977) reported *Planococcus citri* (Risso) on shoots of robusta and arabica coffee in many localities. However, simultaneous infestation of both root and shoot portions has been reported on *Coffea arabica* L.C.V Catimor (Cauvery) in Wayanad district of Kerala (Kumar and Prakasan, 1992). Probably there is no coffee pest in India without a natural enemy. Always some degree of natural control is exercised by such enemies has been known, but its importance will be recognized by the loss of it. Several workers have reported a number of natural enemies on this pest earlier. The literature scanning revealed that 35 species of natural enemies had already been recorded on the mealy bugs of coffee in India. Many of them sparse. But some are common and reduce the mealy bug population to lower levels not to the desired levels. The most common bio agents on mealy bugs are *Triommata coccidivora* (Felt) (Anonymous, 1985), *Cacoxenus perspicax* (Knab) (Reddy *et al*, 1990), *Spalgis epius* (west wood) (Le Pelly, 1943), *Nephus sp.*, (Anonymous, 1985), *Pseudoscymnus spp.* (Anonymous, 1985) *Pullus pallidicollis* (Muls.) (Chacko *et al*., 1977) and *Horniolus sp.nr. vietnamicus* (Irulandi *et al*., 2001).

The present study was conducted to assess the occurrence and distribution of indigenous natural enemies of coffee mealy bugs in different regions of Wayanad. So far, no such studies were conducted in coffee tracts of Wayanad district of Kerala.

Materials and Method

A survey was carried out during the year 2005(January to May) to assess the occurrence of indigenous natural enemies of major mealy bug species of coffee viz., *Planococcus citri* (Risso) and *planococcus lilacinus* (Ckll.) in areas of Wayanad district of Kerala. There are seven liaison zones in Wayanad Viz., Chundale, Kalpetta, Sultan Bathery, Pulpally, Meenangadi, Panamaram and Mananthavady.A total of 35 estates were visited during the survey. Five estates were randomly selected from each liaison zone. The variety of coffee grown in these estates is S.274 (*Coffea canephora*) of 30 to 45 years old. For sampling and collection of mealy bug infested nodes the methods developed by Atwal et al (1990) was followed. The spacing maintained between the plants are 10'×10' with medium shade pattern. For sampling, an area of one hectare was selected from each estate. The area was divided into quadrants consisting of 16 plants. Five plants from the quadrant one at centre and four from each corner of the quadrants were selected for sampling. 20 such quadrants were chosen for assessing the occurrence of indigenous natural enemies of mealy bug species. From each plant one mealy bug infested node was collected for observation. A total of 100 samples were collected from each estate. The collected nodes were taken to laboratory and observed for the presence or absence of indigenous natural enemies using microscope. The number of bio agents in each node was counted. The results obtained from the studies are presented in Table.1.

Results and Discussion

In Kalpetta region, 86 specimens of *Spalgis epius*, 15 specimens of *Triommata coccidivora* and 4 specimens of *Pullus pallidicollis* were recorded. In Chundale region, 64 *Spalgis epius*, 38 *Triommata coccidivora* and 2 *Pullus pallidicollis* specimens were observed. In Meenangadi region, 116 *Spalgis epius*, 27 *Triommata coccidivora* and 3 *Pullus pallidicollis* specimens were observed. In Sulthan Bathery region, 101 *Spalgis epius*, 52 *Triommata coccidivora* and 5 *Pullus pallidicollis* specimens were collected. In pulpally zone, 120 *Spalgis epius*, 54 *Triommata coccidivora* and 10 *Pullus pallidicollis* specimens were observed. In Mananthavady region, 119 *Spalgis epius*, 38 *Triommata coccidivora* and 4 *Pullus pallidicollis* specimens were recorded. In Panamaram region, 92 *Spalgis epius*, 36 *Triommata coccidivora* and 2 *Pullus pallidicollis* specimens were recorded. A total of 698 *Spalgis epius*, 260 *Triommata coccidivora* and 30 *Pullus pallidicollis* specimens were recorded from 3500 mealy bug samples collected from Wayanad district of Kerala.

Several workers have reported a number of natural enemies on this pest earlier in India. Three species of indigenous natural enemies viz. *Spalgis epius*, *Triommata coccidivora* and *Pullus pallidicollis* were encountered during the survey. The predator *Spalgis epius* and *Triommata coccidivora* were abundant and commonly seen in all estates. The activity of *Pullus pallidicollis* was comparatively less. Le Pelly (1968) recorded *Spalgis epius* predating on *Planococcus lilacinus* (Ckll.) attacking coffee in India. This predator was observed feeding on *Planococcus lilacinus* on coffee in several localities of Chikmagalore and Kodagu district of Karnataka (Chacko et al. 1977). *Spalgis epius* was reported to be an effective bio agent in suppressing populations of *Planococcus lilacinus* attacking coffee in India (Anonymous, 1996). Abdul Rahiman et al (1998) reported 54.72 to 63.38% predation of *Planococcus lilacinus* by *Spalgis epius.* It was also reported that the caterpillars of *Spalgis epius* fed voraciously on the coffee mealy bugs and had very good searching ability (Anonymous, 2000). Radhakrishnan Nair (1993) reported that the *Planococcus lilacinus* is regulated to a certain extent by the activity of the predator *Spalgis epius*.

The predator, *Triommata coccidivora* reduced the populations of coffee mealy bugs in some coffee estates of Tamilnadu and Karnataka (Anonymous, 1988). Prakasan et al (1990) reported a 96.17% reduction of *Planococcus lilacinus* by *Triommata*

coccidivora and opined that it is effective in suppressing the mealy bug, *Planococcus lilacinus*. The predator, *Pullus pallidicollis* is also an effective indigenous bio agent on coffee mealy bugs. The earlier studies on this predator reported that the predator grubs were very effective in suppressing the coffee mealy bug, *Planococcus lilacinus* (Anonymous, 1994). The activity of these indigenous natural enemies may be one of the factors which are responsible for the reduction of *Planococcus lilacinus* populations in the coffee tracts of Wayanad district. The above survey clearly indicates the occurrence and distribution of three common indigenous natural enemies of coffee mealy bugs in Wayanad district of Kerala. It is evident that these indigenous natural enemies play an important role in the suppression of coffee mealy bugs and their conservation is vital in integrated management of this pest. The potential of these natural enemies can be exploited in the bio control programme of coffee mealy bugs.

Table1. Distribution of indigenous natural enemies of coffee mealy bugs in Wayanad district of Kerala.

SI.No.	Location	No. of samples collected	No. of indigenous natural enemies recorded		
			Spalgis epius	*Triommata coccidivora*	*Pullus pallidicollis*
1	Kalpetta	500	86	15	4
2	Chundale	500	64	38	2
3	Meenangadi	500	116	27	3
4	Sulthan Bathery	500	101	52	5
5	Pulpally	500	120	54	10
6	Mananthavady	500	119	38	4
7	Panamaram	500	92	36	2
	Total	3500	698	260	30

References

Abdul Rahiman P and Vijayalakshmi CK 1998. *Spalgis epius* (West wood) (Lepidoptera: Lycaenidae)– a potential predator of coffee mealy bugs. *J. Ent. Res*. 22(2): 192.

Anonymous 1984. Thirty seventh Annual Detailed Technical Report, Research Department, Coffee Board, India, 1983–84. p. 266.

Anonymous 1985. Annual Report for 1984-85. Coffee Board Research Department, India. p. 278.

Anonymous 1988. Forty second Detailed Annual Report, Research Department, Coffee Board, India, 1988–89. p.111.

Anonymous 1994. Fifty eighth Detailed Annual Report, Research Department, Coffee Board, India, 1994–95. p. 35.

Anonymous 1996. Fiftieth Detailed Annual Report, Research Department, Coffee Board, India, 1996–97. p. 69.

Anonymous 2000. Fifty fourth Detailed Annual Report, Research Department, Coffee Board, India. 2000–2001. p.93.

Atwal AS and Balraj Singh 1990. Pest populations and assessment of crop losses, ICAR, Pusa, New Delhi. p.131.

Chacko MJ and Bhat PK. 1976. Record of *Ferrisia virgata* and its natural enemy, *Spalgis epius* on coffee in India.

Chacko MJ 1979. Natural enemies of coffee pests. *Plant Prot. Bull.* 31: 63 – 68.

Chacko MJ, Ananda Rao LV and Singh Deepak MB 1979. Out break of the star scale, *Cerococcus ornatus* Green on coffee and studies on its control. *J. Coffee Res.* 8: 74 – 79.

Chacko, MJ, Bhat PK and Ramanarayanan EP 1977. New records of *Coccoidea* with notes on natural enemies of *Planococcus spp.* On coffee from India. *J.Coffee Res.* 7: 69 – 71.

Irulandi S, Vinodkumar PK, Seetharama HG and Sreedharan K 2001. Biology of *Horneolus sp. nr.* Vietnamicus. A newly recorded Coccinilhid predator of the coffee mealy bug, *Planococcus lilacinus* (Ckll.). *J. Coffee Res.* 29(182): 18–24.

Kumar PKV and Prakasan CB 1992. Soil application of systemic insecticides for mealy bug control. *J. Coffee Res.* 22(1): 65–68.

Le Pelly RH 1943. An oriental mealy bug, *Pseudococcus lilacinus* and its insect enemies. *Trans. R. Ent. Soc. London* 93: 73–93.

Le Pelly RH 1968. Pests of coffee. Tropical Science Series, Longmans, Green & Co. Ltd., London and Harlow. p.590.

Prakasan CB, Vinodkumar PK and Balakrishnan MM 1990. Biological suppression of the mealy bug *Planococcus lilacinus* (Ckll.) (Homoptera: Pseudococcidae) on coffee by *Triommata coccidivora* (Felt) (Diptera: Cecidomyiidae). *J. Plantation Crops* 20 (Supplement): 140–141.

Rao LV and Chacko MJ 1977. Occurrence of *Ischnaspis longirostris* on coffee in India. *J. Coffee Res.* 7: 55–57.

Reddy KB, Sreedharan K, Prakasan CB and Bhat PK 1990. Role of indigenous natural enemies in the integrated management of sucking pests of coffee. *J. Plantation Crops.* 20 (Supplement):115 – 122.

Radakrishnan Nair CP 1993. A management schedule for the cocoa mealy bug, *Planococcus lilacinus* (Ckll.) by spot application of insecticides. *J. Plantation Crops.* 21 (Supplement): 182 – 185.

Sekhar PS 1964. Pests of coffee. In 'Entomology in India': 99 – 109.

Studies on the potential role of neem kernel aquous extracts in integrated management of coffee mealy bugs

Baiju CK[1], Abdul Rahiman P[2], Vijayalakshmi CK[2] and Mohanan KV[1]
1 Centre for Plantation Development Studies, University of Calicut, Kerala- 673635.
2 Regional Coffee Research Station, Chundale, Wayanad, Kerala- 673123.

Abstract

Several species of mealy bugs damage leaves, buds and fruits of arabica coffee and robusta coffee in South India. The important ones are Planococcus citri (Risso) and Planococcus lilacinus (Cockerell) (Homoptera: Pseudococcidae). Chemical pesticides used against this pest are not only costly but are often harmful to the ecosystem. Neem products, being natural in origin, have been studied for their efficacy against a large number of insect pests. In this context, laboratory and field trials were conducted at RCRS, Chundale during 2005 to study the efficacy of different concentrations of neem kernal aquous extracts against coffee mealy bugs. In the laboratory, the treatments, 5 kg NKAE and 2.5 kg NKAE in 100 l of water were on par with the recommended pesticides by recording 79.39 and 70.62 percent mortality of mealy bugs respectively. In the field study, the treatment 5 kg NKAE in 100 l of water was on par with the recommended pesticides by recording 74.04 percent kills.

Introduction

Mealy bugs are small, soft bodied, plant feeding insects covered by a powdery wax from which their common name is derived. They are wide spread pests which occur on all land masses of the world. They attack ornamentals, orchards and plantation crops including coffee. They occur on both *arabica* and *robusta*, but is a major pest of *robusta*. Among the mealy bugs recorded on coffee in India *Planococcus citri* (Risso) and *Planococcus lilacinus* (Cokerell) (*Homoptera: Pseudococcidae*) are the major pests (Chacko *et al.*, 1977). The chemical pesticides used against this pest are not only costly but are often harmful to the ecosystem. The disruption of the balance between insect pests and their indigenous natural enemies due to improper pest management is a recurring phenomenon in agroecosystems. The short term effect of pesticides on natural enemies may be manifested within a single season by resurgence of pests due to the reduction of natural enemy complex, while in the long term, cumulative impact of pesticides can be more dangerous by creating an imbalance in the ecosystem and periodic uncontrollable outbreaks (Mayerdirk *et al.*, 1979). According to Barlett (1963), the residues of as many as 61 insecticides are generally toxic to hymenopteran parasitoids.

The insecticidal, phagodeterrent and other properties of the derivatives of the neem tree (*Azadiracta indica*) have been a subject of extensive research. Neem oil and other extract of the plant are effective against a wide range of pests, some times equaling even that of synthetic products and are harmless to the beneficial non – target organisms (Schoonhaven, 1980; Ketkar and Ketkar 1985; Srivastava and Paramar, 1985). Against the mealy bugs, *Planococcus spp.*, a serious pest of coffee in India, no unilateral method of control has been entirely successful. So far, no studies were conducted to find ecologically non-disruptive natural insecticides for use in integrated management of mealy bugs of coffee. The studies reported here were undertaken to asses the insecticidal efficacy of Neem Kernal Aquous Extracts against mealy bugs and to examine their suitability to fit into this gap.

Materials and Method

A laboratory study was conducted at Regional Coffee Research Station,, Chundale, Wayanad, Kerala against coffee mealy bugs with different concentrations of NKAE, Quinalphos and Kerosene oil emulsion. There were six treatments including control : 1) 5 kg NKAE in 100 litres of water + 50 ml IG Surf 2115. 2) 2.5 kg NKAE in 100 litres of water + 25 ml of IG surf 2115. 3) 1.25 kg NKAE in 100 litres of water + 12.5 ml of IG Surf 2115. 4) Quinalphos 25 EC @ 150 ml in 100 litres of water + 50 ml IG Surf 2115. 5) Kerosene oil 2 litre in 100 litres of water + 50 ml IG Surf 2115. 6) Control – Untreated. There were 5 replications for each treatment consisting of one fully mealy bug covered pumpkin with 4 marked squares for each replication. The initial population of mealy bugs was recorded from the marked square before imposition of treatment. The treatment was imposed using hand sprayer. The mortality of the bugs was recorded at the end of 8, 16 and 24 days. The percentage of mortality was calculated using the following formula.

$$\text{The percentage mortality} = \frac{\text{No. of dead mealy bug} \times 100}{\text{Total number of mealy bugs}}$$

The data were transformed into arc sine values and analysed statistically using 'F' test (analysis of variance) and presented in the Table 1.

A field trial was taken up on robusta coffee of RCRS, Chundale farm with different concentrations of Neem Kernal Aquous Extracts. The insecticides Quinalphos 25 EC and Kerosene oil emulsion were the standard check. An untreated control was also maintained. The treatment details were similar to that of laboratory study. The chemicals were sprayed using Knapsak sprayer. IG Surf was added for better spread and adhesion. There were five replications for each treatment distributed randomly. There were 3 plants for each replication. On each plant three twigs carrying good infestation of mealy bugs were labeled and 3 nodes from the growing tip were taken into account. The population of mealy bug nymphs and adults on each node was recorded before the imposition of treatment. The post treatment observations at 8th, 16th and 24th days' interval were recorded. The percentage mortality was calculated and the data were analysed statistically and presented in Table 2.

Results and Discussion

The treatment Quinalphos 25 EC recorded 74.10% mortality of mealy bugs on 8th day under laboratory test followed by the treatment Kerosene oil emulsion with a mortality of 68.29%. These are the recommended pesticides against coffee mealy bugs. The treatment 5 kg NKAE was on par with Quinalphos and Kerosene oil emulsion by recording 65.79% mortality. The treatment Quinalphos 25 EC registered 81.10% mortality of mealy bugs on the 16th day followed by Kerosene oil emulsion with a kill of 75.55%. The treatment 5 kg NKAE and 2.5 kg NKAE were on par with Quinalphos and Kerosene oil emulsion by recording 75.96% and 67.02% mortality respectively. The treatment Quinalphos 25 EC recorded a kill of 82.52% of mealy bugs on 24th day followed by Kerosene oil by recording 79.46% mortality. The treatments, 5 kg NKAE and 2.5 kg NKAE were on par with the recommended pesticides Quinalphos and Kerosene oil by registering 79.39 and 70.62% mortality respectively. All other treatments were inferior to the above mentioned treatments. The results are furnished in the Table 1.

Under field condition, the treatment Quinalphos 25 EC recorded 68.92% mortality of mealy bug on 8th day followed by Kerosene oil emulsion recording 62.41% kill. The treatment 5 kg NKAE was on par with the above mentioned recommended pesticides of mealy bugs by recording 61.90% mortality. The treatment Quinalphos 25 EC registered 78.44% mortality of mealy bugs on 16th day. The next to Quinalphos was Kerosene oil emulsion by recording 73.07% kill in the field. The treatment 5 kg NKAE was on par with Quinalphos and Kerosene oil emulsion by recording 71.63% kill. The treatment Quinalphos 25 EC recorded 80.04% mortality of mealy bugs on 24th day

followed by Kerosene oil emulsion recording 74.88% kill under field condition. The treatment 5 kg NKAE was on par with Quinalphos and Kerosene oil emulsion by recording 74.04% kills. All other treatments were inferior to the above mentioned treatments. The results are presented in the Table 2.

In the laboratory test, the treatment 5 kg NKAE and 2.5 NKAE were highly effective to mealy bugs. These treatments were on par in efficacy with the recommended pesticides like Quinalphos and Kerosene oil emulsion. From the result of field experiment, it is clear that NKAE @ 5 kg was highly effective to mealy bugs and it was on par with the recommended pesticides. It can be inferred that while the mortality caused with 8 days after application was due to the toxicity of NKAE to the bugs, the subsequent mortality at later intervals could be due to the phagodeterrency of neem. Jacobson *et al.* (1979) and Gokuldas Kumar *et al.* (1980) also reported the phagodeterrent properties of neem seed extract against mealy bugs.

It is concluded that NKAE has great potential to serve as an ecologically safe product against mealy bugs on coffee. Since these are quickly biodegradable leaving practically no toxic residues, they will be safe and hence can promote the activity of biocontrol agents. Such an environment will be more conducive to practicing IPM system against pests of coffee. They are also cheap and completely safe to the user.

Table 1. Laboratory trial with NKAE against Coffee mealy bugs

Sl. No.	Treatments	Mean Percent mortality		
		8 DAT	16 DAT	24 DAT
T1	5 kg NKAE + 50 ml IG Surf + 100 litre H_2O	54.21 (65.79)	60.67 (75.96)	63.01 (79.39)
T2	2.5 kg NKAE + 25 ml IG Surf + 100 litre H_2O	50.48 (59.53)	54.94 (67.02)	57.17 (70.62)
T3	1.25 kg NKAE + 12.5ml IG Surf +100 litre H_2O	40.40 (41.97)	46.26 (52.16)	48.50 (56.14)
T4	Quinalphos 25 EC @ 150 ml + 50 ml IG Surf + 100 litre H_2O	59.41 (74.10)	63.51 (81.10)	65.27 (82.52)
T5	Kerosene oil 2% + 50 ml IG Surf + 100 litre H_2O	55.73 (68.29)	60.40 (75.55)	63.08 (79.46)
T6	Control	1.28 (0.47)	7.49 (1.72)	7.49 (1.72)
	Significance	**	**	**
	C D at 5%	7.50	8.89	5.17
	C D at 1%	10.23	12.13	7.05

Figures in the paranthesis are original values.

Table 2. Field trial with NKAE against Coffee mealy bugs

Sl.No.	Treatments	Mean percent mortality		
		8 DAT	16 DAT	24 DAT
T1	5 kg NKAE + 50 ml IG Surf + 100 litre H_2O	51.88 (61.90)	57.80 (71.63)	59.34 (74.04)
T2	2.5 kg NKAE + 25 ml IG Surf + 100 litre H_2O	46.72 (52.97)	50.94 (60.28)	52.30 (62.64)
T3	1.25 kg NKAE + 12.5ml IG Surf +100 litre H_2O	37.52 (37.12)	40.28 (41.81)	41.67 (44.23)
T4	Quinalphos 25 EC @ 150 ml + 50 ml IG Surf + 100 litre H_2O	56.11 (68.92)	62.37 (78.44)	63.44 (80.04)
T5	Kerosene oil 2% + 50 ml IG Surf + 100 litre H_2O	52.18 (62.41)	58.76 (73.07)	59.73 (74.88)
T6	Control	5.74 (1.03)	6.55 (1.25)	7.49 (1.71)
Significance		**	**	**
C D at 5%		5.08	5.15	4.14
C D at 1%		6.90	7.03	5.65

Figures in the paranthesis are original values.

References

Barlett BR 1963. The contact toxicity of some pesticide residues to hymenopteran parasites and predators. *J. Econ. Entomol.* 56: 694–698.

Chacko MJ, Bhat PK and Ramanarayana EP 1977. New record of *cocccoidea* with notes on natural enemies of *Planococcus sp.* on coffee in India. *J.Coffee Res.* 7(3): 68–70.

Gokuldas Kumar M, Bhat PK and Ramarah PK 1989. Potential role of Kerosene and neem derivatives in integrated management of mealy bugs on coffee *J.Coffee Res.* 19(1):17–29.

Jacobson M, Reed DK, Crystal MM, Moreno DS and Sodderstorm EL 1978.Chemistry and biological activity of insect feeding deterrents from certain weeds of coffee.

Kethkar CM and Kethkar MS 1985. Potential role of neem in plant protection. In 'Behavavioral and Physiological Approaches in Pest Management. (Ed. Jayaraj S)':7–14.

Mayerdirk DE, French JV, Hart WG and Chandler LD 1979. Citrus mealy bug: Effect of pesticides residues on adult of the natural enemy complex. *J.Econ. Entomol.* 72: 893–895.

Schoonhoven LM 1980. First international neem conference: After word. Proc. First Neem. Conf. 1980, Rottach – Egern, Germany: 291–298.

High density planting in sapota

Balakrishnan S
Agricultural College and Research Institute, Madurai, Tamil Nadu- 625 104.

Abstract

Sapota is an important fruit crop of the tropics. It is normally planted at wide spacing of 8m x 8m and grows very slow. As a result it takes 10-12 years to occupy the allotted full space depending on the level of management, climate and edaphic conditions. High density planting in sapota offers scope to maximize land and space use efficiency to get high fruit yield and net income. In South Tamil Nadu, Periyakulam-1 variety is predominantly cultivated. Hence a study on high density planting in sapota cv. Periyakulam 1 was conducted. The treatment consisted of four spacings 10m x 10m, 10m x 5m, 8m x 8m and 8m x 4m. The highest estimated yield of 18.01 t/ha was recorded in the spacing of 8m x 4m with 312 plants/ha. followed by 11.68 t/ha. In the spacing of 8m x 8m with 156 plants per ha. Hence it is concluded that 8m x 4m spacing is the best for high density planting of sapota cv. Periyakulam 1.

Introduction

Sapota is normally planted at wide spacing and grows very slow that it takes 10-12 years to occupy the allotted full space depending on the level of management, climate and edaphic conditions. High density planting offers scope to maximize land and space use efficiency to generate more yield and income in the perennial fruit crops particularly during the initial bearing periods in mango (Ram and Sirohi, 1989; Majumdar and Sharma, 1990). However, no information is available on the possibility of having HDP in Sapota which prompted us to take up this present investigation.

Materials and Method

This trial was laid out with PKM 1 Sapota trees of 13 years old at Horticultural College and Research Institute, Periyakulam during 2003. The treatments consisted of four spacing viz., 10 x 10 M (100 plant/ha) 10 x 5 M (200 plants/ha), 8 x 8 M (156 plants/ha) and 8 x 4 M (312 plants/ha). Observations were recorded on tree height, number of fruits / tree, yield of fruits (kg) / tree.

Results and Discussion

Vegetative growth character viz., tree height exhibited no significant differences among the treatments (Table 1). However, yield characters exhibited differences. During the year 2002-2003, a maximum of 1206.7 fruits weighting 74.93 kg per tree was recorded in spacing 8 x 8 M and the highest estimated yield of 18.01 tons / ha was recorded in spacing 8 x 4 M with 312 sapota population in one hectare. Thus, it is evident that the maximum fruit yield obtained per unit area at 8 x 4 M high density planting system was due to increased number of plants per unit area rather than increased fruit yield per tree. Increase in total yield under HDP was due to only increase in the number of plants per unit area in other perennial crops like Mango (Ram and Sirohi, 1989).

Summary

In sapota cv. PKM1, the highest projected yield of 18.01 tons/ha was recorded in the spacing of 8 x 4 M with 312 number of plants / ha. This was followed by 11.68 tons / ha in the spacing of 8 x 8 M with 156 number of trees / ha.

Table 1. High density planting in PKM 1 Sapota (Age 13 years)

S.No.	Spacing	No. of plants / ha	Tree height (cm)	No. of fruits / tree	Yield of fruits (kg) / tree	Estimated yield (ton/ha)
1.	10 x 10	10	404.5	129.2	67.18	6.71
2.	10 x 5	200	419.6	1015.1	58.06	11.61
3.	8 x 8	156	416.3	1206.7	74.93	11.68
4.	8 x 4	312	359.2	1007.6	57.72	18.01
CD (0.05)			NS	35.6	2.10	

References

Majumdar PK and Sharma DK 1990. Mango. In 'Fruits – Tropical and Subtropical (Eds. T.K. Bose and S.K. Mitra)', Naya Prakash, Calcutta: 1-62.

Ram S and Sirohi SC 1989. Feasibility of high density of orcharding with Dashehari mango. *Acta Horticulture* 191: 207-12.

Effect of graded levels of Zinc on tomato yield, quality and uptake in red sandy soil

Rathinasamy A, Anbu S, Balakrishnan K and Durairaj Muthiah N
Horticultural College and Research Institute, Periyakulam, Tamil Nadu- 625 604

Abstract

An experiment was carried out at Horticultural College and Research Institute, Periyakulam during the period between 1996 and 2000 to study the response of tomato to zinc in a red sandy soil as on farm trial in a farmer's field near Thevaram, Uthamapalayam Taluk, Theni District. The experiment was conducted in a completely randomised block design with five replications using tomato variety PKM -1 as the test crop. The following were the treatments viz., Control (Zn_0), 5.6 Kg Zinc ha^{-1} (Zn_1), 11.2 Kg Zinc ha^{-1} (Zn_2) and 16.8 Kg Zinc ha^{-1} (Zn_3). A common dose of N, P_2O_5 and K_2O @ 150: 100: 50 Kg ha^{-1} respectively were added to each plot. Out of which half of N and full dose of P_2O_5 and K_2O were basally applied and thoroughly mixed with the soil. The fertilizers used in this experiment were commercial grade urea, single super phosphate and potassium chloride. Zinc was applied in the form of Zn $S0_4$ $7H_2O$. The zinc content of the plant was estimated at different stages. The results indicated that at flowering stage the tomato recorded maximum zinc content (17.96 ppm) when compared to vegetative and harvest stages. Regarding Zn treatments, the level 16.8 Kg zinc ha^{-1} recorded the maximum Zn content (19.42 ppm), Zn uptake (0.0438 Kg ha^{-1}) and fruit yield (27.12 t ha^{-1}). The quality characters viz., total soluble solids, titrable acidity, reducing sugars, ascorbic acid, lycopene and minerals were also assessed. In that titrable acidity decreases and reducing sugars increased with Zn rates.

Introduction

In recent years, identification of wide spread Zn deficiency in some Indian soils and its consequent manifestations on several crops have put Zn on the national map of our fertilizer programme. After the first report of occurrence of khaira disease in wetland rice, nutritional problems relating to Zn deficiencies have been reported in a number of crops on a variety of soils. Analysis of more than 2,25,000 soil samples from 16 states and two Union Territories for available Zn indicated that the deficiency of this trace element was the most serious constraints to sustainable productivity in 11 states, thus leading to occurrence of Zn deficiency on a wider scale. The soils need to be catalogued for their total and available Zn reserves with a view to ascertain the inherent Zn supplying power of soils and to study the response of the crop varieties besides formulating a suitable fertilizer schedule for the crops in a particular region.

No systematic work on the aspects stated above was carried out in Theni district in Tamilnadu for vegetable crops and tomato in particular. Hence in the present study, an attempt was made to study the response of tomato to added Zn in soils of Theni district, besides optimizing the Zn requirements for tomato.

Materials and Method

A field experiment was conducted in a red sandy soil (Typic Haplustalfs) representing the Somayyanur series as on-farm trial in a farmer's field near Thevaram, Uthamapalayam Taluk, Theni district, Tamil Nadu.

The experiment was conducted in a completely randomized block design with five replications using tomato variety PKM-1 as the test crop during summer 1998.

There were four levels of Zinc viz.,Control (Zn_0); 5.6 kg ha^{-1} Zinc(Zn_1); 11.2 kg ha^{-1} Zinc(Zn_2); 16.8 kg ha^{-1} Zinc(Zn_3). A common dose of N, P_2O_5 and K_2O @ 150: 100: 50 kg

ha^{-1} respectively were added to each plot, out of which half of N and full dose of P_2O_5 and K_2O were basally applied and thoroughly mixed with the soil. The fertilizers used in this experiment were commercial grade fertilizers viz., urea, single super phosphate and potassium chloride. Zinc was applied in the form of $ZnSO_47H_2O$. Both soil and plant samples were collected at vegetative (20 DAP, ST_1), 50 per cent flowering (45 DAP, ST_2) and at harvest stages (85 DAP, ST_3) in each treatment. Fresh fruits at maturity stage were used for qualitative analysis. The soil samples were air dried in shade, gently powdered with a clean wooden mallet and sieved through a 2mm plastic sieve. This portion of soil was used for analysis. Plant samples were washed with 0.1M HCl, rinsed with distilled water air dried and then oven dried at 65^0C. The leaf and stem samples were powdered with stainless steel scissors and mixed thoroughly. The fruits were also washed with 0.1 M HCl rinsed with distilled water, air dried and then used for quality analysis. The data obtained were subjected to statistical scrutiny according to Panse and Sukhatme, (1967) and Snedecor and Cochran, (1967), wherever necessary, for interpretation and discussion.

Results and discussion

EFFECT OF GRADED LEVELS OF Zn ON DTPA - Zn (Table 1)

AVAILABLE ZINC

Application of graded levels of Zn promoted the available zinc in soil at all stages of crop growth. The values of available Zn significantly varied from 0.13 to 0.27 ppm at Zn_o and Zn_3 levels respectively indicating that there was a two fold increase in Zn availability at Zn_3 level. Regarding the stages, 50 per cent flowering compared to the control registered the highest value of 0.23 ppm and the lowest availability was associated in ST_3 stage (0.19ppm). The interaction effects displayed between the Zn levels and stages of crop growth were not significant. Such enrichment of available Zn in soil solution on addition of fertilizer may be an expected phenomenon as soil is the sink.

EFFECT OF GRADED LEVELS OF Zn ON DRY MATTER ACCUMULATION (Table 2)

Addition of increasing levels of Zn favoured the dry matter accumulation at all stages. The values of dry matter accumulation improved from 976.88 kg ha^{-1} (Zn_0) to 1375.36 kg ha^{-1} (Zn_3). Regarding the stages the values increased from ST_1 (84.96 kg ha^{-1}) to ST_3 (2530.57 kg ha^{-1}) stage. The interaction effects between the Zn levels and stages of tomato followed a similar trend as in main effects. The dry matter accumulation increased substantially at different stages of crop growth and this might be due to the increased and balanced utilization of available N and Zn at increasing levels of Zn application.

EFFECT OF GRADED LEVELS OF Zn ON Zn CONTENT OF TOMATO (Table 3)

ZINC CONTENT

Application of increasing levels of Zn led to significant increase in Zn content of plant at all growth stages. The values markedly increased from 15.50 ppm (Zn_0) to 19.42 ppm (Zn_3). With regard to stages the Zn content of tomato plant increased from ST_1 (17.34 ppm) to ST_2 (17.96 ppm) stage and then it declined at harvest stage. The interaction effects displayed between the zinc levels and stages were found to be insignificant.

Increasing levels of Zn led to appreciable increase in Zn content of plant at all stages and this might be due to the increased available Zn in the soil with graded levels of Zn application, as the plant is the best indicator of how well nutrients are supplied from the soil. The Zn content in plant increased from vegetative to flowering stage and declined in the harvest stage and this might be due to the increased crop uptake or biological translocation of nutrients at well defined critical stages of crop varieties is unique and reported by Sujatha (1997).

EFFECT OF GRADED LEVELS OF Zn ON Zn UPTAKE OF TOMATO (Table 4)

ZINC UPTAKE

Increasing levels of Zn was found to promote significantly the Zn uptake by tomato irrespective of stages. The uptake values progressively increased from 0.0151 kg ha^{-1} (Zn_0) to 0.0194 (Zn_1) and then 0.0227 at Zn_2 followed by 0.0266 at Zn_3. Regarding the stages also the Zn uptake increased significantly from ST_1 (0.0015 kg ha^{-1}) to ST_3 (0.0438 kg ha^{-1}) stage. The interaction effect displayed between the Zn levels and stages were also significant.

FRUIT YIELD (Table 5)

The data pertaining to the fruit yield of tomato variety PKM-1 are presented in Table 5. The influence of different Zn levels on the fruit yield of tomato was found to be highly significant. The highest fruit yield was recorded at Zn_3 (27.12 t ha^{-1}) level followed by Zn_2 (24.23 t ha^{-1}) level. The lowest fruit yield was observed at control treatment (14.84 t ha^{-1})

Application of Zn has increased the yield of tomato fruit upto the highest level (16.8Kg ha^{-1}) tried in this experiment implying the deficiency of Zn in the soil. When the response function fitted with the yield of tomato and Zn levels reveals a linear model. Such response behaviour could be ascribed due to a low level of Zn saturation of the soil (0.22ppm) coupled with moderate Zn fixation intensity. Further the release of Zn from native source is also adequate as revealed from a very poor 'a' co-efficient value (1.16) from Cobb Douglas equation fitted for the release pattern. It follows from the above revelation that the larger requirement for Zn has been only met from the added Zn fertilizers rather than from the native source and this could be a very congenial reason for the above manifestation of response. Calibration of the added Zn with yield data could not be possible in the present study (to deduce optimum and economic doses of Zn) since the response continues to be linear. It is also inferred from the linear response that there is more possibility of enchancing the levels of Zn addition for obtaining higher responses of tomato in these soil.

EFFECT OF GRADED LEVELS OF ZINC ON THE FRUIT QUALITY PARAMETERS (Table 6)

The increase in TSS values might be due to the increased uptake of major and minor nutrients at all stages of crop growth which in turn led to increased photosynthetic efficiency and promotion of sugar transport. Similar observations were also made by Dube and Saxena (1971) in tomato.

The fruits for processing industry require low pH in the pulp as opined by Lower and Thompson (1967). In the current study tomato fruits grown at higher Zn level registered a low pH in the fruit pulp and *vice versa*. Sujatha (1997) has also obtained similar results in tomato without explaining the exact mechanism for the above phenomenon.

The low titrable acidity, a characteristic factor for quality fruits was favoured by nutrient applications. Low acidity in quality fruits was explained by Ribreau- Gayon (1968), that the conversion of organic acids into sugars is one of the reasons for the reduction in acidity during fruit maturity.

The increase in reducing sugars might be possible because of the indirect role of Zn in regulating the synthesis of reducing sugars probably the activated enzyme enhances the photosynthesis resulting in synthesis and accumulation of monosaccharides particularly the glucose. Sujatha (1997) also reported similar results.

The biosynthesis of ascorbic acid is controlled by nutrients present in the plant. The enhancement in ascorbic acid content was observed due to Zn application. The reason for increased ascorbic acid content might be due to its fresh synthesis or reduction of dehydroascorbic acid into ascorbic acid by the influence of Zn application. The results of present study were in line with Suryanarayana Reddy et al. (1985) and Rani Perumal and Subbiah (1994).

The important quality attribute of tomato fruit is the colour contributed by the lycopene pigment. The colour change starts from persimon orange to capsicum red. The increased lycopene content in the tomato fruit might be due to the combined effect of Zn with other nutrients at fruit maturity. Sujatha (1997) also reported similar results.

EFFECT OF GRADED LEVELS OF Zn ON THE MINERALS CONTENT OF FRUIT (Table 7)

Addition of graded levels of Zn had increased substantially the mineral nutrition of the tomato fruit. It increased the N, K, Ca, Mg and Zn content in the fruit at all levels of Zn application. This establishes the role of Zn in the improvement of the quality characters of tomato fruit. The improvement in the mineral content in tomato as zinc application promotes the absorption of N, K, Ca, Mg etc.

Conclusion

Added Zn caused a conspicuous increase in available Zn during the crop period and it was the highest at flowering stage. The Zn content in tomato increased markedly with increasing level of Zn addition. Graded levels of Zn led to spectacular increase in Zn uptake at all stages of crop growth and improved the quality of tomato fruits. The yield data of the field experiment followed a linear response indicating that there is more possibility of enhancing the levels of Zn beyond 16.8 kg ha^{-1} for obtaining higher responses of tomato in this soil.

Table 1. Influence of graded levels of Zn on DTPA-Zn in soil at different stages of tomato (kg ha^{-1}) (mean of five replications)

TREATMENTS (Kg/Ha)	Stages			
	Vegetative	Flowering	At Harvest	Mean
$Zn_{0.0}$	0.14	0.13	0.13	0.13
$Zn_{5.6}$	0.19	0.23	0.16	0.19
$Zn_{11.2}$	0.25	0.26	0.21	0.24
$Zn_{16.8}$	0.28	0.28	0.25	0.27
Mean	0.22	0.23	0.19	

DTPA-Zn:

SE(d)	CD(P=0.05)	
		Zn
0.010	0.020	
		ST
0.008	0.017	
		Zn X ST
0.017	0.034	

Table 2. Influence of graded levels of Zn on dry matter accumulation at different stages of tomato(kg ha^{-1}) (mean of five replications)

TREATMENTS (Kg/Ha)	Stages			
	Vegetative	Flowering	At Hatvest	Mean
$Zn_{0.0}$	75.42	753.64	2101.58	976.88
$Zn_{5.6}$	81.75	963.72	2453.56	1166.34
$Zn_{11.2}$	81.52	1003.28	2683.00	1255.93
$Zn_{16.8}$	101.15	1140.79	2884.14	1375.36
Mean	84.96	965.36	2530.57	

SE(d)	CD(P=0.05)	
		Zn -
20.092	40.747	
		ST
19.943	45.989	
		Zn X ST
34.801	70.576	

Table 3. Influence of graded levels of Zn on Zn content at different stages of tomato (PPM) (mean of five replications)

TREATMENTS (Kg/Ha)	Stages			
	Vegetative	Flowering	At Harvest	Mean (PPM)
$Zn_{0.0}$	15.10	16.20	15.19	15.50
$Zn_{5.6}$	16.50	17.16	16.38	16.68
$Zn_{11.2}$	18.50	18.60	17.82	18.31
$Zn_{16.8}$	19.26	19.86	19.14	19.42
Mean	17.34	17.96	17.13	

SE(d)	CD(P=0.05)	
		Zn
0.271	0.546	
		ST
0.235	0.473	
		Zn X ST
0.469	0.945	

Table 4. Influence of graded levels of Zn on Zn uptake by tomato plant at different stages of tomato (kg ha^{-1}) (mean of five replications)

TREATMENTS (Kg/Ha)	Stages			
	Vegetative	Flowering	At Harvest	Mean
$Zn_{0.0}$	0.0011	0.0123	0.0319	0.0151
$Zn_{5.6}$	0.0013	0.0166	0.0402	0.0194
$Zn_{11.2}$	0.0015	0.0187	0.0478	0.0227
$Zn_{16.8}$	0.0019	0.0227	0.0552	0.0266
Mean	0.0015	0.0176	0.0438	

Zn-UPTAKE

SE(d)	CD(P=0.05)	
		Zn -
0.0005	0.0010	
		ST
0.0004	0.0009	
		Zn X ST
0.0009	0.0018	

Table 5. Influence of graded levels of Zn on tomato yield (t ha^{-1})

Sl. No.	Treatments	Replications					Total	Mean
		R-I	R-II	R-III	R-IV	R-V		
1.	Zn_o	13.70	12.50	15.70	15.50	16.80	74.20	14.84
2.	Zn_1	16.50	19.80	16.40	16.60	19.20	88.50	17.70
3.	Zn_2	23.16	25.40	24.20	23.60	24.80	121.15	24.23
4.	Zn_3	26.60	25.60	28.90	27.80	26.70	135.60	27.12
5.	Total	79.96	83.30	85.20	83.50	87.50		
6.	Mean	19.99	20.82	21.30	20.88	21.88		

SE(d) : 0.908 CD(P=0.05) : 1.979

Table 6. Influence of graded levels of Zn on the quality parameters of tomato fruit (mean of five replications)

Parameters / Treatments	TSS (^{0}Brix)	pH	Titrable Acidity (%)	Reducing Sugars (%)	Ascorbic Acid (mg $100g^{-1}$)	Lycopene (mg $100g^{-1}$)
Zn_o	4.08	4.628	0.622	0.150	9.06	1.18
Zn_1	4.32	4.664	0.550	0.176	9.85	1.46
Zn_2	4.52	4.524	0.440	0.224	10.92	2.60
Zn_3	4.84	4.434	0.378	0.294	11.58	2.68
Mean	4.44	4.562	0.498	0.211	10.35	1.98

	TSS	pH	T.Acidity	Red.Sugars	A.acid	Lycopene
SE(d)	0.08	0.037	0.028	0.015	2.98	0.152
CD(P=0.05)	0.18	0.082	0.062	0.033	6.50	0.331

Table 7. Influence of graded levels of Zn on the mineral content of tomato fruit (Mean of five replications)

Treatments	Minerals content				
	Zn (ppm)	P	K (%)	Ca	Mg
$Zn_{0.0}$	39.72	1.09	2.23	0.91	0.06
$Zn_{5.6}$	48.06	1.06	2.49	1.53	0.19
$Zn_{11.2}$	52.38	0.99	3.59	1.80	0.58
$Zn_{16.8}$	58.44	0.91	3.34	1.62	0.42
Mean	49.65	0.94	2.91	1.46	0.31

	Zn	P	K	Ca	Mg
SE(d)	3.25	0.041	0.2240.068	0.043	
CD(P=0.05)	7.08	0.088	0.4880.148	0.094	

References

Dube SD and Saxena HK, 1971. Effectiveness of zinc chelate (Zn EDTA) vs zinc sulphate ($ZnSO_4$) in orange (*Citrus sinensis* L. Osbeek). *Punjab Hort. J.* 9(3-4): 246-249.

Lower RL and Thompson AE, 1967. Inheritance of acidity and solid content of small fruited tomatoes. *Proc. Am. Soc. Hort. Sci.*. 91: 486-494.

Panse VG and Sukhatme PV 1967. Statistical Methods for Agricultural Workers. ICAR, New Delhi.

Rani Perumal and Subbiah K, 1994. Pectin and ascorbic acid contents in tomatoes as influenced by the graded doses of N, K and $CaCl_2$ sprays. *Madras Agri. J.* 81(4): 227-229.

Ribereau– Gayon G 1968. Etudes mechanisms, synthetics transformation del doid malique, del acidic tartaric etd 1 acid citreque, ches *Vitis vinitfra* (L.) Phytochem. 7: 1471-1482.

Snedecor GW and Cochran WG, 1967. Statistical Methods (Sixth edition). Oxford and IBH Publishing Co., Calcutta. p.593.

Sujatha A 1997. Physiology of nutrient sprays for higher yield and quality in tomato cultivars and hybrids (*Lycopersicon esculentum* Mill.). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Suryanarayana Reddy P, Ramakrishna Reddy MG, Subrahmanyam K and Satyanarayana Reddy D, 1985. Response of tomato to micronutrients.

Biochemical changes in vanilla beans as influenced by different sweating and drying processes

Bindumol GP, Sreekumar G, Priya P. Menon and Thomas J
Indian Cardamom Research Institute, Myladumpara, Kerala- 685 553.

Abstract

An experiment was conducted at the Indian Cardamom Research Institute, Myladumpara to evaluate the effect of different types of sweating and drying process on the quality as well as biochemical changes of vanilla beans during curing. The different methods of sweating and oven drying technique at different temperatures and covering the beans with or with out woolen blanket were evaluated against the standard Bourbon method. The study revealed that sweating of beans by wrapping in woolen blanket and keeping in oven at 40^0C for 24hrs or keeping the beans wrapped in woolen blanket in oven at 40^0C for 22hrs followed by drying the bean unwrapped from the blanket and keeping at 55^0C for 2hrs had significant influence on the vanillin content. Maintenance of optimum temperature of 40^0C throughout the sweating process resulted in higher vanillin production. A positive significant correlation was obtained between vanillin content and total phenol content as well as vanillin content and reducing sugar content.

Key words: Vanilla, biochemical changes, total phenol and vanillin

Introduction

Vanilla is one of the most complex tastes in the world used for flavouring ingredients in food. It is obtained from the beans of *Vanilla* p*lanifolia* Andrews. The characteristic flavour and aroma of vanilla developed in properly cured beans, is the result of a number of biochemical and chemical transformations. Over 170 volatile components that contribute to flavour have been identified in cured beans (Klimes and Lamparsky, 1976; Ranadive, 1992). Of these, vanillin is the most abundant.

Green vanilla beans contain aroma precursors, primarily vanillin β-D glucoside (Glucovanillin) and minor glucosides of *p*-hydroxybenzaldehyde, *p*-hydroxybenzoic acid, vanillic acid (Leong *et al.,* 1989*)* and *p*-hydroxybenzyl alcohol (Kanisawa 1993). These precursors are hydrolysed by the enzyme β-D glucosidase upon ripening in the vine or during the initial thermal step of the traditional curing process (Arana, 1943; Hanum 1997; Odoux 2000) resulting in the release of aromatic agycons and the generation of aroma and flavour.

Even though a number of curing processes have been developed, they are all characterized by the four phases namely: killing, sweating/drying, slow drying and conditioning. At the usual harvesting time of mature beans both glucovanillin and β-D glucosidase coexist in the bean without hydrolysis taking place and hence these beans do not possess the characteristic vanilla flavour (Arana, 1943; Wild Altamirano, 1969; Kanisawa, 1993). The enzymatic hydrolysis is of major importance to the final aromatic quality of the finished product. Information is available on the biochemical changes in different types of sweating and drying process is very meager. In this context an attempt was made to evaluate effect of different sweating and drying process on the quality as well as the biochemical changes of vanilla beans during curing.

Materials and Method

Mature vanilla beans were collected from the Indian Cardamom Research Institute Myladumpara, Idukki and thoroughly washed before use. The beans were killed by dipping in hot water at 63-65°C for three minutes. After killing process, the beans were divided into five portions and subjected to sweating and drying process according to the following treatments.

T_1- Beans kept in hot air oven at 40°C on stainless steel racks.
T_2- Beans wrapped in woolen blankets and kept at 40°C in hot air oven.
T_3- Beans wrapped in woolen blankets and kept in wooden box followed by 2 hrs heating at 55°C in oven
T_4 -Beans wrapped in woolen blankets and kept in wooden box followed by 2 hrs heating under sunlight (check).
T_5 - Beans wrapped in woolen blankets and kept at 40°C in oven followed by 2 hrs heating at 55°C .

After completing each sweating and drying process samples were taken and analysed for moisture content (Odoux 2000). Reducing sugar release was determined by the 3,5- dinitrosalicylic acid method and total phenol content was estimated using Folin -Ciocalteu reagent (Thimmiah,1999).

HPLC Analysis

Samples were shaken with 40% ethanol and filtered through #5 Whatman filter paper. The HPLC system used for the analysis of vanillin content was a Water's system comprising of Water-TM 600 controller, Water-TM 486 tunable UV detector, Water-TM 746 Data module and Water U6K injector. Vanillin was fractionated on a C_8 reversed- phase (5µm Water Symmetry TM 4.6 X250 mm) steel column. Solvent A was water acidified with 1.25 % acetic acid and solvent B was methanol at a flow rate of 1mL /m. Standard curve was obtained using vanillin (Sigma).

Results and Discussion

Effect of different methods of sweating & drying on moisture content

The moisture content in vanilla beans as affected by different methods of sweating and drying as given in Table 1.The result indicated that the moisture content of the bean reduced from the initial content of 85-90% to around 55% at the end of the sweating and drying process. There was a loss of 3-10% moisture per day depending on the temperature and humidity condition. The fastest rate of moisture depletion was noticed in beans kept under constant temperature of 40°C in hot air oven on stainless steel racks. The rate of moisture depletion was similar in the beans wrapped with woolen blanket and kept at 40°C to that of check, but comparatively the beans retained 5-7% more moisture mainly because of the beans were wrapped in woolen blanket. Because of drastic depletion of moisture in the treatments T_1 and T_2, the acceptable physical texture and lustre were not obtained in these treatments. The loss of moisture in beans kept under wooden box was almost similar and the beans retained higher moisture content during the entire period of sweating and drying.

In the vanilla curing process, the stage of drying and sweating is the second phase of the Bourbon method of vanilla curing. The indication of the completion of second phase is the time when the moisture content of the bean is reduced to around 50%. It is assumed that a steady and slow rate of moisture depletion is desirable during this phase of curing. The treatments T_1, T_2 and T_5 behaved almost similar. In all these treatments constant temperature were maintained throughout this curing phase in the

electric oven while in treatment T_3 and T_4 could not be maintained the higher temperature inside the vanilla curing wooden box.

Effect of different methods of sweating & drying on reducing sugar content

The reducing sugar in the vanilla bean is a resultant production of glucose mainly from different glucosides in the beans. The major glucoside is glucovanillin and consequent enzymatic reaction with *β*-glucosidase, vanillin and glucose are produced. The reducing sugar content of vanilla beans was positively influenced by different sweating and drying methods (Table 2). Here also the higher content of reducing sugars was noticed during each sweating and drying process in the treatments where constant temperature was provided in the electric oven. All the enzymes involved in sugars would have been more active in comparison with other treatments when constant temperature could not be maintained. In treatments T_3 and T_4 gradual reduction of the temperature is likely to occur while remaining in the wooden box.

Effect of different methods of sweating & drying methods total phenol content

The beans kept under constant temperature of 40°C for 24 hrs on steel racks (T_1) had registered maximum total phenol content (2.93%) presented in Table 2. The increased total phenol content may be due to the increased enzymatic activity when a constant temperature (40°C) was provided. The minimum total phenol content was obtained in beans which were kept in wooden box for 22 hrs and drying at 55°C for 2 hrs in oven (T_3) .The treatments which received sweating and drying at 40°C in woolen blanket (T_2) and sweating at 40°C and drying at 55°C for 2 hrs (T_5) registered average total phenol content of 2.2% and 2.4 % respectively.

There is a progressive increase in the total phenol content in vanilla beans during sweating and drying period (figure 1). This indicates that enzymatic activity is in progress and releasing various phenolic compounds such as vanillin in the beans. Here also relatively higher phenol content was noticed in the treatments were constant temperature could be maintained. In general, there is a initial peaking of phenol content around 4th day of sweating and drying process indicating that the enzyme phenolic oxidase is active during the initial period of sweating and drying. Earlier observation in the laboratory also indicated that the maximum activity of *β*-glucosidase was during the second day of the sweating and drying process.

Effect of different methods of sweating & drying methods on vanillin content

The average vanillin content in vanilla beans was affected by different sweating and drying as in the Table 2. As in the case of all other parameters, the treatments where constant temperature were provided like T_1, T_2 and T_5 recorded higher vanillin content each day of sweating and drying phase. The peaking of vanillin content was observed between 4th and 5th day of process and there after the content drastically declined (figure 2). However a similar peaking of vanillin content was not observed in treatments T_3 and T_4 where a gradual increase in vanillin content was noticed during the entire period of sweating and drying process. The data indicated that the temperature during the curing process had significant influence on the vanillin production in the beans (Theodose 1973).

The traditional method of sweating and drying (Bourbon method-T_4) and beans kept in wooden box and drying at 55^{0}C (T_3) in oven registered the lowest content of vanillin. The reason behind for this lower vanillin content may be due to the lack of constant temperature and presence of lower temperature in the wooden box, which reduced the *β*-glucosidase enzyme activity.

In general, a positive correlation was noticed between vanillin content and total phenol content as well as vanillin content and reducing sugar content irrespective of treatments. The correlation was also significant at 1% level..

Comparing the treatments T_1, T_2 and T_5 it is observed that when a constant temperature of 40^0C is given, total phenol, reducing sugar and vanillin content are comparatively higher. In the treatment T_1 the beans are kept opened in oven the loss of moisture from the beans is at a faster rate and this moisture reduction would have adversely affected the activity of the major enzyme *β*-glucosidase, there by recording a lower vanillin content than T_2. Though the total phenol, reducing sugar and vanillin contents are comparable in T_2 and T_5, the treatment T_5 produced better quality beans when the physical parameters such as uniform chocolate brown colour, oily appearance, lustre and flexibility are also taken into account. The above desirable physical parameters were attained in the treatment T5 because it was kept unwrapped and subject to a higher temperature of 55^0C for 2 hrs. This process was essential for attainment of the desired black to chocolate brown colour, oily appearance and lustre. In the treatment Bourbon method, T_4 and treatment T_3 the total phenol, reducing sugar and vanillin content were lower, mainly because of a constant temperature could not be provided during the sweating period. In another study, it was observed that during the sweating and drying process using the conventional method, the temperature of the beans reaches the prevailing ambient temperature within a period of 8 to 10 hrs. thus lowing down the enzymatic activity. However the physical parameters like colour, texture, oily appearance and lustre were found to be good. This shows that for attaining the correct physical qualities the beans have to be subjected to higher temperature for a period of 2 hrs. The study indicates that if a constant temperature around 40^0C could be maintained during the sweating process even in conventional curing system higher vanillin content could be obtained.

Table 1. Effect of sweating on moisture content (%) of vanilla beans

Treatments	Days after Killing								
	1	2	3	4	5	6	7	8	9
Hot air oven at 40°C	79.83	74.00	75.5	70.20	62.80	57.40	50.50	40.00	--
Wrapped in woolen blanket + oven at 40°C	83.48	80.19	76.90	74.08	66.53	55.20	54.02	45.00	--
22hrs in wooden box + 2 hrs in oven at 55 °C	86.16	80.40	79.90	77.90	72.10	70.20	67.60	62.10	56.16
Bourbon method	90.20	82.30	80.90	77.90	76.90	69.00	63.00	58.00	55.29
22hrs at 40°C + 2hrs at 55°C in oven	87.67	76.60	70.17	72.34	64.71	57.30	57.29	54.80	53.90

Table 2. Effect of sweating and drying on biochemical parameters of vanilla beans (% dry wt basis)

Treatments	Total phenol (%)	Reducing sugar (%)	Vanillin (%)
T1- Hot air oven at 40°C	2.93	8.22	2.0
T2- Wrapped in woolen blanket + oven at 40°C	2.2	6.9	2.56
T3- 22hrswooden box + 2 hrs in oven at 55 °C	1.67	4.0	1.83
T4- Bourbon method	2.0	5.09	1.88
T5- 22hrs at 40 °C + 2hrs at 55°C in oven	2.4	6.5	2.4

Figure1.

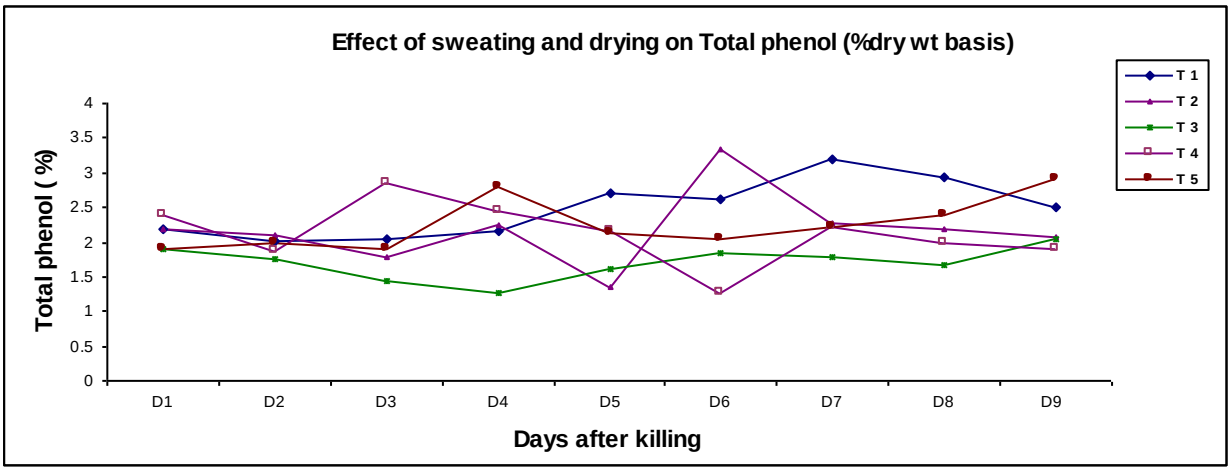
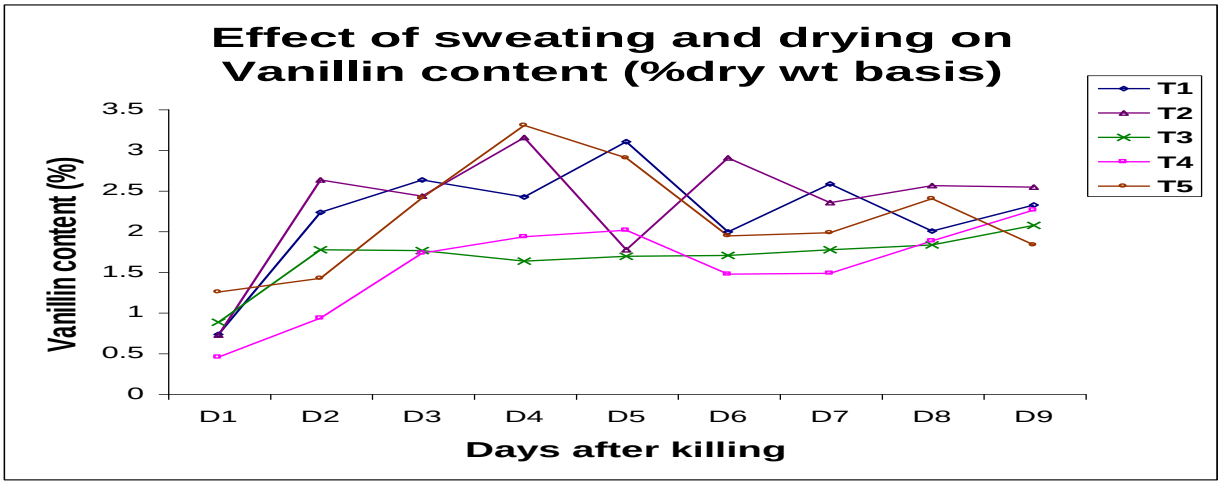


Figure 2



References

AOAC 1996. Official Methods of Analysis 16 th Ed, AOAC, Washington, D.C.: Vol II, Sec. 990- 25.

Arana F 1943. Action of a *β*-Glucosidase in the curing of vanilla. *Food Res***.** 8: 343-351.

Hanum T 1997. Changes in vanillin and activity of *β*-Glucosidase and oxidases during post harvest processing of vanilla beans (*Vanilla planifolia*) .*Bull Telnol Ind Pangan* 8:46-52.

Kanisawa T 1993. Flavour development in vanilla beans. *Kouryou* 180:113-123.

Klimes I and Lamparsky D 1976. 'Vanilla volatiles- A comprehensive analysis', *Int. Flav. Food Additives*, Nov/Dec, 1976: 272-291.

Leong G, Uzio R and Derbesy M 1989. Synthesis,identification and determination of glucosides present in green vanilla beans (*Vanilla fragrance* Andrews). *Flavour Fragrance J.* 4: 163-167.

Odoux E 2000. Changes in vanillin and glucovanillin concentrations during the various stages of the process traditionally used for curing *Vanilla fragrance* beans in Reunion. *Fruits* 55: 119-125.

Ranadive AS 1992. Vanillin and related flavour compounds in vanilla extracts made from beans of various global origins. *J. Agric. Food Chem.* 40: 1922-1924.

Theodose R 1973. Trop.Sci. 5(1): 47-57.

Thimmaiah SK 1999. Standard methods of biochemical analysis. Kalyani Publishers, Noida, U.P.: 53- 95.

Wild Altamirano C 1969. Enzymatic activity during growth of vanilla fruit.1. Proteinase, glucosidase, peroxidase and polyphonoloxidase. *Journal of Food Science* 34:235-238.

Influence of irrigation and agronomic manipulations on seed set and yield of Hybrid Sunflower

Sakthivel S, Balasubramanian R and Murali Krishnasamy S
Agricultural College & Research Institute, Tamil Nadu Agricultural University,
Madurai, Tamil Nadu- 625 104.

Abstract

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during kharif and summer season to study the influence of irrigation and agronomic manipulations on seed set and yield of hybrid sunflower. The experiments were laid out in split plot design with three replications. The main plot consisted of three level of irrigation, IW/CPE ratio of 0.75 (I_1), 0.60 (I_2) and 0.45(I_3). The sub plot consisted of agronomic manipulations (hand pollination (A_1), DAP 2% spray at ray floret opening stage (A_2) and borax dusting (2 kg ha^{-1}) to capitulum at ray floret opening stage (A_3). Sunflower hybrid MSFH-8 was chosen for the study and the recommended dose of fertilizers were applied for the crop. The yield components and yield were recorded. The results revealed that irrigation at IW/CPE ratio of 0.75 (I_1) registered significantly higher yield components (head diameter, total number of seeds $head^{-1}$, filled seeds $head^{-1}$, percentage of filled seeds) and also seed yield of sunflower. The seed yield recorded under I_1 was 1608 kg ha^{-1} and 1885 kg ha^{-1} for kharif and summer respectively. The increase in seed yield was 6.70 and 13.80 per cent for kharif and 6.53 and 13.51 per cent for summer season than the subsequent lower levels of irrigation I_2 and I_3, respectively. Dusting of borax to capitulum at ray floret opening stage (A_3) increased the seed yield of sunflower by significantly improving the number of filled seeds $head^{-1}$. The seed filling percentage was significantly higher with borax dusting (86.31 % in kharif and 85.93 % in summer seasons) comparer to other agronomic manipulations. Hence irrigation at IW/CPE ratio of 0.75 along with dusting of borax @ 2 Kg ha^{-1} to capitulum at ray floret opening stage can be recommended to increase the yield of sunflower.

Key words : sunflower, irrigation regimes, boron, DAP, seed set, yield

Introduction

Sunflower is an important oilseed crop of the world and ranks third next only to cotton seed and groundnut in the total world production of oilseeds. The adaptability of sunflower to wider soil and climatic conditions coupled with its day neutrality, short duration, suitability for late sown conditions, low seed rate, high seed multiplication ratio and high oil content puts it in a competitive position with groundnut, the fore runner of India's oilseed crop. Sunflower is better adapted to water stress conditions than other oilseed crops. Although sunflower is drought resistant than many other crops, it responds well to irrigation. Information on response of sunflower to moisture levels may go a long way in contributing to the knowledge of the total water requirement of the crop and scheduling of irrigation water.

The problem of poor seed set and filling has been one of the most commonly encountered problems in sunflower cultivation. Even under favourable conditions, the average per cent seed set is around 60 per cent and it may reduce to 20 per cent in certain seasons and locations (Seetharam, 1976). Poor seed filling is reflected in terms of higher per cent of hollow seeds and lower test weight. This problem demands greater attention due to its adverse effect on seed yield. 'Boron and the quality of crops' is now an important subject area for research in several crops particularly in sunflower. Boron increased the pollen viability, fertilizing capacity of the pollen and decreased the

number of wilted achenes and the percentage of empty achenes in sunflower (Shatilov and Ikonnikov, 1970). Studies conducted in India and elsewhere indicated that even though with no visible boron deficiency symptoms, sunflower responds well to boron fertilization as soil application or as foliar spray in terms of improved seed filling and yield. But information on the effect of dusting of boron on sunflower heads at the time of flowering is scanty. Studies on the internal P requirement of sunflower revealed that 41 to 70 per cent of P is taken up during grain filling and ripening stages. Increasing the P availability during these stages will have a favourable impact on sunflower productivity. Not much work has been done to find out the response of sunflower to increased P availability by foliar application of P during the reproductive phase of the crop. Hence the study was under taken to find out the influence of irrigation, and agronomic manipulations namely, DAP spray and borax dusting at ray floret opening stage on seed set & yield of sunflower.

Materials and Method

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* and summer season to study the influence of irrigation and agronomic manipulations on seed set and yield of hybrid sunflower. Sunflower hybrid MSFH-8 was chosen for the study and the recommended dose of fertilizers 60:30:30 kg NPK ha^{-1} were applied for the crop. The sowing sunflower hybrid was taken up in ridges in furrows at 60 cm x 30 cm. spacing. The experiments were laid out in split plot design with three replications. The main plot consisted of three level of irrigation, IW/CPE ratio of 0.75 (I_1), 0.60 (I_2) and 0.45(I_3). The sub plot consisted of agronomic manipulations (hand pollination (A_1), DAP 2% spray at ray floret opening stage (A_2) and borax dusting (2 kg ha^{-1}) to capitulum at ray floret opening stage (A_3)). The yield components and yield of sunflower were recorded and statistically analysed.

Results and Discussion

Yield components

The yield components viz., head diameter, number of total seeds $head^{-1}$, number of filled seeds $head^{-1}$ and hundred seed weight are given in Tables 1 and 2. Irrespective of season, the yield components were significantly higher with irrigation at IW/CPE ratio of 0.75 (I_1) over irrigation at IW/CPE ratio of 0.60 (I_2) and 0.45 (I_3). Similarly the percentage of filled seeds was higher at higher level of irrigation (I_1) than at lower levels (I_2 and I_3). Udayakumar *et al.* (1976) found that transport of ^{14}C metaboliltes from the source to sink under moisture stress was more towards the outer zone of the head indicating that the moisture stress reduced the efflux of photosynthates from the leaves resulting in poor seed filling. At higher level of irrigation (I_1) the plant did not experience any moisture stress and the translocation of assimilates from stem and leaves might have been distributed throughout the head resulting in increased number of seeds $head^{-1}$. Agronomic manipulations also had a pronounced effect on number of filled seeds $head^{-1}$ and per cent seed filling. DAP two per cent spray at ray floret opening stage increased the number of filled seeds $head^{-1}$ over hand pollination (A_1). Raman and Dhingra (1981) in their field studies in the pattern of P uptake and its distribution in sunflower showed that 41 to 70 per cent of the P was taken up during grain filling and ripening stages. DAP two per cent spray at ray floret opening stage increased the P content in plants. As P is very essential for seed development, plentiful supply of P during the reproductive phase of the crop resulted in proper seed development and filling and thus increased the number of filled seed $head^{-1}$ and per cent seed filling. Borax dusting at ray floret opening stage (A_3) explicitly increased the number of filled seeds $head^{-1}$ over control (A_1). Shatilov and

Ikonnikov (1970) found that boron increased the pollen viability and fertilizing capacity of pollen. Thus the increased number of filled seeds head^{-1} and per cent seed filling observed with borax dusting might be due to better pollen germination, increased pollen viability and fertilizing capacity of pollen.

Yield

Irrigation at IW/CPE ratio of 0.75 (I_1) explicitly boosted the seed yield over irrigation at IW/CPE ratio of 0.60 (I_2) and 0.45 (I_3). The seed yield recorded under I_1 was 1608 kg ha^{-1} and 1885 kg ha^{-1} for *kharif* and summer respectively. The increase in seed yield was 6.70 and 13.80 per cent for *kharif* and 6.53 and 13.51 per cent for summer season than the subsequent lower levels of irrigation I_2 and I_3, respectively. This variation in seed yield with varying levels of irrigation can be related to variation in number of filled seeds head^{-1}. These yield components were highest in I_1 and lowest in I_3. Similarly the percentage of filled seeds was higher at higher level of irrigation than at lower levels. The seed yield was significantly higher in DAP two per cent spray (A_2) and borax dusting (A_3) at ray floret opening stage compared to control (A_1). The superiority of these two treatments could be examined based on the increase in seed setting percentage. The higher number of filled seeds head^{-1} may be due to the higher P content in plants during the reproductive phase with DAP spray which in turn resulted in proper seed development and filling and thus increased the seed yield. This corroborated the findings of Kene *et al.* (1990) that foliar application of P at flowering stage increased the seed yield of sunflower. The higher seed set with borax dusting might be due to better pollen germination, increased pollen viability and the fertilising capacity of the pollen as reported by Shatilov and Ikonnikov (1970) The increased seed yield with DAP two per cent spray and borax dusting was mainly due to the significant increase in number of filled seeds head^{-1} and seed filling percentage, since there was no variation in head diameter, number of total seeds head^{-1} and hundred seed weight due to agronomic manipulations.

From the above study conducted during *kharif* and summer season, It is concluded that the yield potential of sunflower hybrid can be exploited with irrigation at IW/CPE ratio of 0.75 and dusting of borax @ two kg.ha^{-1} to capitulum at ray floret opening stage (I1A3) and this can be recommended as a suitable management practice to get higher yield in sunflower.

Table 1. Effect of irrigation regimes and agronomic manipulations on head diameter and total number of seeds head^{-1} in sunflower

Treatments	Head diameter (cm)		Total Number of seeds head^{-1}	
	kharif	summer	*kharif*	summer
Irrigation at IW/CPE ratio of 0.75 (I_1)	13.8	15.5	551.6	617.8
Irrigation at IW/CPE ratio of 0.60 (I_2)	12.6	13.8	515.8	579.1
Irrigation at IW/CPE ratio of 0.75 (I_3)	11.6	12.7	485.5	544.6
SE_d	0.09	0.03	1.69	3.77
CD (0.05)	0.25	0.08	4.70	10.47
Hand pollination (A_1)	12.7	13.9	513.9	578.1
DAP 2% spray (A_2)	12.7	14.1	521.6	583.6
Borax dusting (A_3)	12.6	14.0	517.5	579.8
SE_d	0.09	0.09	5.29	5.89
CD (0.05)	NS	NS	NS	NS

Table 2. Effect of irrigation regimes and agronomic manipulations on filled seeds head^{-1} and percentage of filled seeds in sunflower

Treatments	Filled seeds head^{-1}		Percentage of filled seeds	
	kharif	summer	*kharif*	summer
Irrigation at IW/CPE ratio of 0.75 (I_1)	464.8	523.2	84.13	84.57
Irrigation at IW/CPE ratio of 0.60 (I_2)	417.9	474.4	81.05	81.80
Irrigation at IW/CPE ratio of 0.75 (I_3)	383.4	434.3	78.84	79.63
SE_d	3.07	6.26	0.33	0.55
CD (0.05)	8.52	17.39	0.92	1.51
Hand pollination (A_1)	392.4	449.0	76.17	77.48
DAP 2% spray (A_2)	426.5	483.3	81.54	82.60
Borax dusting (A_3)	447.2	499.7	86.31	85.93
SE_d	8.66	9.71	0.82	0.84
CD (0.05)	18.06	19.54	1.65	1.68

Table 3. Effect of irrigation regimes and agronomic manipulations on seed yield of sunflower

Treatments	Seed yield (kg ha^{-1})	
	kharif	summer
Irrigation at IW/CPE ratio of 0.75 (I_1)	1608	1885
Irrigation at IW/CPE ratio of 0.60 (I_2)	1507	1770
Irrigation at IW/CPE ratio of 0.75 (I_3)	1413	1661
SE_d	11.0	5.38
CD (0.05)	30.55	14.93
Hand pollination (A_1)	1441	1698
DAP 2% spray (A_2)	1522	1790
Borax dusting (A_3)	1565	1827
SE_d	14.55	11.21
CD (0.05)	29.26	22.55

References

Kene HK, Wankhade ST and Sagare BN 1990. Influence of nutrients spray on yield and oil content of sunflower. *Ann. Plant Physiol.* 4: 246-248.

Raman SS and Dhingra R 1981. Uptake of nitrogen and phosphorus by sunflower (*Helianthus annuus* L.). *Indian J. For.* 4: 141-148.

Seetharam A 1976. Performance of sunflower varieties and the role of various factors affecting seed yield. Paper presented at subject matter seminar on sunflower production technology, University of Agricultural Sciences, Bangalore.

Shatilov FV and Ikonnikov PA 1970. Effect of soil drought on reproductive capacity of sunflower top dressed with phosphorus and boron. *Soil Fert.* 33(3): 302.

Udayakumar M, Rama Rao S, Prasad TG and Krishna Sastry KS 1976. Translocation of ^{14}C metabolites to the head in sunflower. *Indian J. Expt. Biol.* 14: 302-304.

Gregor Mendel Foundation Proceedings 2006

Scope of navara cultivation

Yasmin SH, Gipson Makil, Nandakumar PM and Anil Kumar N
Community Agrobiodiversity Centre, M.S. Swaminathan Research Foundation, Puthurvayal, Kalpetta, Wayanad, Kerala.

Introduction

Rice- the most important food grain of the world is endowed with a wide genetic diversity as evidenced by the existence of thousands of its landraces and improved cultivars. Rice is food – and more than a food. It is society, culture, politics, business, the beauty of the landscape, people in their communities. In short, *rice is life.* It is the staple food of Keralites and its cultivation had been the main occupation for generations. Making rice cultivation remunerative and profitable is the challenge of the season. The area under rice cultivation has been declining in the Indian state of Kerala in recent years at a rate of 52 ha/day state-wide. The paddy field area in Wayanad has witnessed a tremendous decrease from 17304 (1999-2000) to 12988 ha in 2002-2003 (Agricultural Statistics, 2002-2003). Reports today quote that the area has got reduced to 10000 ha. Failures of the monsoon in recent years, non-availability and high cost of labour and higher input prices are factors responsible for the decline.

Kerala is bestowed with rich rice biodiversity and biodiversity and traditional knowledge. Wayanad district of Kerala harbored about 75 odd traditional rice varieties. It is reckoned that about 1,20,000 genetically distinct varieties of rice exist in the world today and in India the collection exceeds about 30,000 (M.S. Swaminathan, 1984). The rice genetic diversity of Wayanad is known for its wide range of uniqueness and special features from aromatic to medicinal flood resistant to drought to long duration and so on that have been carefully conserved by the farmers over thousands of years. The rice genetic base of Wayanad has now narrowed down to around 15-20 rice varieties.

Erumakkari, Jatthusugi, Jeerachembavu, Kammal, Marutha Chembavu, Kolaran, Kunjinellu, Nallachenellu, Navara (purple & golden), Gandakasala, Kalladiyaran, Zeerakasala, Mullachanna, Chenthadi, Vadakkan and Vatton are some of the traditional rice verities of Kerala and all are very rare in cultivation Various literature shows different varieties of rice have been used in many forms against diverse ailments (Kirtikar & Basu, 1935, bentley & Trimen 1880; Omkar & Ghosal, 1995). Some of the Indian classic literature like Jatakas, Puranas and Ayurveda describes the medicinal properties of rice. According to Duke and Ayensu (1984), the flowers are dried as cosmetic and dentifrice in China; awns are used for jaundice in China. The stem is used for bilious conditions; ash for discharges and wounds, sapraemia in Malaya; infusion of straw for dysentery, gout, and rheumatism. The husk is used for dysentery and considered tonic in China, rice cakes are fried in camel's fat for hemorrhoids, rice water is used for fluxes and ulcers and applied externally for gout with pepper in Malaya (James A. Duke. 1983).

Navara is widely known among the traditional healers and is used as "health rice" during sick conditions. Being an early duration variety (60-120 days) it is cultivated in restricted agro-climatic zones of Kerala. Low yield, lodging, slender stems, weeds, low seed viability are a few conservation issues of Navara. The demand for this variety is increasing nowadays with the increase in the popularity of Ayurvedic medicines. The productivity of this speciality rice is comparatively less (Gopalakrishnan, 2003). Though Navara is a low yielding crop it entails a fairly good market price compared to other rice varieties. Yield enhancement technique namely SRI will solve the

problem of yield of Navara. A well-planned approach for developing a niche market for Navara and its value added products would help to boost the cultivation.

To sustain self-sufficiency in the coming decades rice production has to increase in India every year by almost two million tons (Mishra, 2003). This can be made possible by adopting yield enhancement techniques and concentrating on Specially Rice varieties. The Protection of Plant Varieties and Farmers' Rights Act is a major step in conservation of any plant variety. Crop improvement through participatory genetic purification and plant breeding as well as the revitalization of the conservation traditions of tribal and rural farming communities will make an accelerated progress in Plant conservation if the provisions of the Act are implemented in an effective, transparent and speedy manner.

Methodology

The present study has been conducted in different Navara rice grown regions of the Kerala from (January 2004–December, 2005). Survey, Direct one to one interactions and interviews with farmers, traditional healers and ayurvedic physicians and field trials are some of the used to elicit the results. Commercialization to gain economic importance, public conscientisation for conservation, collection of different strains of Navara, cultivation, networking with micro level institutions and awareness generation are some of the approaches undertaken to attain the projected results. The study focuses the conservation issues of Navara, the scope for conservation of Navara and the approach to be followed in Nnavara cultivation.

Results and Discussion

Rice cultivation not only fulfils the food needs of a country but also contributes to the ecological, health, economic and employment security of the community. Negative returns from paddy cultivation, higher inclination of interest of the present generation towards conversation of paddy fields to cash crop cultivation, land filling, lack of promotion and encouragement from the government, poor market price, low productivity, climatic fluctuations, cheaper availability of rice from alternative sources, resurgence of pests and diseases are some of the reasons for the decline of paddy cultivation. The society at large and the Government in particular are not paying desired heed to promote rice cultivation. The invaluable services that the paddy fields serve to the environment are aplenty. Some of the visible impacts of the contribution of paddy fields to the environment range from maintenance of ground water table to supplementing leafy and fleshy foodstuffs to the tribals, medicinal plants for home remedies to logical physicians etc. The priceless service that are embedded with rice cultivation draws the immediate attention of the all to revitalize paddy cultivation for ecological and food security of the public at large and employment security of the womenfolk particularly tribal women.

Conservation issues and the scope of conservation of Navara

Navara, a unique rice cultivar of Kerala from time immemorial is bestowed with extra short duration (60-105 days). Two Ecotypes viz., black (awned and awnless) and yellow (awned and awnless) exist in Navara. It is known as Shashtikam, Shashtikasali or Snighdathandulam in Ayurveda. Shastikam denotes sixty days and this peculiar rice variety has a life span of sixty days. In Ashtangahridayam, Navara is quoted as the best among the Vrihi (grains having red kernel) grains. Ashtangahridayam, quotes the yellow one as superior to black but many practicing physicians use black glumed Navara. Interviews reveal that the yellow ecotype of Navara is cultivated in the southern regions of Kerala whereas the farmers and healers of the northern region of Kerala cultivate and use the black ecotype. Herbal healers quote Navara as "gold having aroma" and readily marketable at any season. Therefore it is being conserved with great sanctity and care though the grain yield is very low.

The farmers of Wayanad opine that Punja (summer) season is the apt one for Navara cultivation though they cultivate it in the Nancha season also to compensate for any financial loss that occurs in other ordinary rice varieties that is being cultivated along with Navara. It was interesting to note that the crop duration in the Southern parts of the state is 60-90 days, whereas it extends to 105 days in the district of Wayanad. In Punja direct sowing is generally preferred while in Nanja transplanting is carried out. In Punja sprouted seeds are broadcasted in the field in late January-December. Tillering starts within twenty days of sowing. 55-65 (Days After Sowing) DAS panicle formation begins which is followed by the milky stage in 70-75 DAS. Harvesting presumes within 105 DAS. In Nanja nursery is prepared by late July and the seedlings of 20-25 days old are transplanted to the main field. Tillering is completed within 14 days after transplanting (DAT). Panicle Initiation takes place within 60 DAT which is followed by the Milky stage in 75 DAT. 90 DAT the maturing stage begins that is followed by the harvesting stage in 110 DAT.

The plant generally grows upto 1 m tall with very weak tillers and is a low yielder. The present yield of Navara per acre is 7 quintal (1:18) whereas other ordinary rice is 24 (1:60) quintal. If Navara has to be economically sustainable with the current price rate, the production has to be doubled ie. at least 15 quintal per acre which can be achieved by adopting yield enhancing technologies like System of Rice Intensification (SRI). Another major constraint that is being faced by the Navara cultivators is the absence of a niche market for Navara. Though the farmers necessarily cultivate Navara every year they are able to sell their produces only when any pharmaceutical companies place a demand, where the farmers otherwise use it for their needs to ward of ailments. Interactions revealed that Navara is at present used as medicine more widely and the crop is yet to accomplish the title Navara for food.

(a) Navara in traditional therapeutic practices and food

All parts of Navara – the **grains, roots** and **straw** of Navara are medicinal in one way or the other. In Wayanad, Navara is widely used as in *Navarakizhi* – a warm sweating treatment, *Navaratheppu* – paste of Navara rice applied on the body of the patietns and in *Shastikathailam* – oil prepared from Navara bran and is used in nervous diseases, body aches, numbness, spondilitis, and wasted muscles due to polio myletes, myopathies and motor neuron diseases. It is used as a cure of haemorrhoides, urinary complaints, stomach ulcer, polio, muscle builder, an aphrodisiac, for snakebites, for quick healing of small burns and cuts, for premature hair fall in treatment of musclar dystrophy, diabetes, blood pressure and so on. A local ayurvedic physician of Wayanad reveals that Navara massage treatments can be broadly classified into two (**viz**) ***Paalkizhi*** – Navara rice is tied in cloth bags and boiled in milk for about 45 minutes and is used as kizhi (sweating by formentation-used against rheumatic disorders) and *Adakkizhi / Elakkizhi* where Navara is boiled in a decoction of medicinal leaves (*Parppadakappullu, Eshangu, Vellakunni, Murivuperundi, Kaishalamaaran* that is used for muscle wasting bruises / *kshathangal*). *Elakkizhi* can also be orally consumed to ward of muscle wasting bruises. He also points out that a juice extracted from the Navara roots (the roots are removed from the germinated grass on the 5th day) is effectively used for curing *Panchapoothavipraanthi* (Mental illness and Epilepsy), diabetes, strangury and bilious fever. The healer also pines that the formentation by *Paalkizhi* is given for a period of one hour from 7-14 days depending on the condition of the patient. Jsutifying the Black strain as the genuine Navara strain he quotes that Black green leaves / seeds absorb more sunlight and this accounts for the medicinal property of this strain. Navara unlike other rice's can retain heat until 3 minutes and does not create scars to the applied area that might be the reason for its inclusion in Ayurvedic treatments. He quotes that Navara is used in treating rheumatism, spondilitis and arthritis, increases the circulation of blood, strengthens nerves and is a good energizer. It was also observed that it is an aphrodisiac and increases milk

secretion in recently delivered mothers. *Navaratheppu* cures itching (*Karinjchori*). Navara straw along with the straw of *Ramacham* is used in making beds that helps in controlling rheumatism. It is also used as a veterinary medicine. It is used against *Agiduveekam* in cows and also for post delivery care.

Navara is highly nutritional and increases the weight of babies. *Marunnukanji* prepared to Navara rice gruel mixed with various medicinal plants like *Kadaladi* (*Cyathula prostrata)*, *Vishnukranthi Mukkutti, ilappana (Curculigo orchiods)* is used in the *Karikada* season toward off various diseases escorted with the monsoon. It is with *Brihmana* (nourishing) quality, which increases the growth of muscles and stimulates the nerve endings. Navara rice is recommended as a safe food for diabetic patients. Newborn babies are fed with a safe and nutritious dish named "*angri*" made of Navara flour and dried powder of *Kunnan* banana. Some of the value added products of Navara that is frequently used by the Wayanadan people include *Navadhanyapodi/Nutrivita* – a protein rich food recommended for pregnant women, babies and diabetic patients, *Baby Vita* –a nutritious baby food, *Paalkanji, Payasam, Navara Pappad, Navara Puttu, Navara Dosa* and *Navara Uniappam*.

(b) Navara in traditional cultural practices

According to Hindu beliefs Navara represents Aditya the Sun God interactions reveal the cultural significance of Njavara as being is used in *Prathishta vaykkal* and *Sahasra kalasham. Prathishta vaykkal* a Hindu ritual in which the idol is installed at the sanctum sanctorum. Prior to the installation of the idol *Navadhanyangal* (grains) are spread on the floor and the idol is placed on the grains. Navara is one among the nine grains. This is followed by the *Sahasra Kalasham*, a ritual in which the thousand pots are used of which three hundred are golden pots and the rest are silver and earthen pots. Twelve *Mulam paalika* (earthern pots) are taken and seeds of twelve rains namely *Yavom (Barley), Green gram, Mustard, Horse gram. Thina, Black gram, Red gram, Navara (Sun God), Sesamum, Vanpayar (Cow pea), Amara* and *Chama* are solely sown in each of the pots known as *Mulayidal samprathayam*. They are watered three times a day for seven days. Slokas and Hymns are enchanted during watering. Ashwagandha and Turmeric are added to the irrigating water. Before sowing Cow dung and manures are added to the pots to initiate growth. On the eighth day a main ritual is performed by the thanthri, the chief priest of the temple where al the earthen pots are placed around the idol.

Approach of Navara cultivation

The crop cycle of Navara includes 60-105 days and is a photo insensitive crop. Navara is highly vulnerable to extinction owing to its short seed viability. Unlike other rice varieties the seed viability stands only for six months and it warrants the cultivation in every season. The high susceptibility to lodging adds further to its vulnerability during monsoon crops. The yield pattern of Navara, *ie.* 1:18 can be increased two fold by adopting the technique of System of Rice Intensification (1:36) that increases rice production and raises the productivity of land, labour, water and capital through different practices of management. Rice grown in this way has to undergo earlier transplantation (8-12 days) with an espacement of 30 cm x 30 cm and meticulous weeding. Results of our preliminary field trials reveal that the rice grown in this way requires 4 kg of seeds unlike the 40 kg/acre, 30-40% of less water, has larger root system and the yield is 2 times higher the traditional methods of cultivation namely – direct sowing and ordinary transplanting (22 days). There is a tremendous increase in the number of tillers in the SRI technique (25-30 tillers) when compared the ordinary method of cultivation (7-8 tillers). Though the productivity of Navara in general is low, the cost benefit analysis reveals the fact that Navara fetches a comparatively reasonable and consistently 3-4 times higher price than any other ordinary rice variety. The current market value of 1 kg of Navara rice is Rs.25-30 and rice grain is Rs.45-50

whereas an ordinary rice fetches a mere value of Rs.5-6 and 12-20 rupees respectively. If the SRI method of cultivation in Navara is followed in the Southern parts of Kerala where there are three seasons (Punja, Mundakkan and Viripppu) outstanding results can be obtained and can beat the profit generating from banana cultivation.

Traditional knowledge and Navara

There is a saying in Malayalam "*Kurukkan maranhal pathu maeni*" that stats that if Njavara grows to a height which can hide a fox on the paddy field we can expect high results from the present cultivation. Another saying is that "*vithu gunam pathu gunam*" that means that the harvest will be ten times better if good quality seeds are used. The farmers opine that Navara is to be harvested in the "*Paathivila stage*" (when the straw colour changes from green to black or dark yellow for food to prevent breaking down of grains. When Paddy is harvested during the "*Moothavila stage*" (when the straw colour changes from golden yellow to brownish yellow) rice will break down easily and this is used in preparing gruel. The Navara grains have to be dried for seven subsequent days (night and day) before storing the seed stock for the next year. Transplanting when carried out before *Karkidagam 15th* (July-August) control bird attack. Seeds are sown only on Sunday, Tuesday or Friday after conducting certain *Poojas*. Organic manures are generally used in Navara cultivation. Chemical fertilizers, pesticides and fungicides are not used, as the farmers believe that chemicals may decrease the medicinal property of Navara. Few farmers allot a particular area of the paddy fields for cultivating Navara solely to get rid of contamination of this special rice. Navara cannot withstand water logging and water requirement of 2-4 cm is generally preferred. Some Integrated Pest and Disease Management methods like Yellow sticky cards and rotten fish spray (1 kg fish/acre) are used for pest control. Though the pest and disease attack are minimal in Navara, *Pacha Karpooram (Artemesia vulgaris*) stems are planted in between the paddy fields to get rid of pests on invasion.

Traditional knowledge associated with plant genetic resources is an important element in registering a variety under Protection of Plant Varieties and Farmers' Rights Act (PPVFR). According to the PPVFR Act, Farmers variety is one that is developed by an individual or a community of farmers through the process of cultivation, conservation and selection to suit to peculiar agro-climatic production and utilization requirements. Navara can be registered under the PPVFR Act as this variety has been traditionally cultivated by the farmers and evolved by them who possess common knowledge about the cultivation and utilization aspects of Navara. The Protection of Plant Varieties and Farmers' Rights Act is a significant step in conservation of plant genetic resources and will help a great deal in the conservation of Navara. The National Community Gene Fund, constituted under PPV&FR Act, is an innovative approach to recognize, reward, revive in-situ conservation traditions and compensate for loss of yield. Recognition and protection of Navara and other native rice varieties of Wayanad under this Act will enhance conservation effort of local communities and it is one of the best possible methods to check the erosion of diversity of crop plants from one of the biodiversity hotspots of India.

Conclusion

The growing population of the state exemplifies the need for further production of rice every year. The current rice production of India is 190-200 million tones/yr. By 2020 the production has to reach 240-million tons/yr to keep pace with the growing population rate and with the current consumption rate. The area of paddy fields of Wayanad that was once 30000 ha has reduced to 10000 ha. According to the Department of Economics and Statistics the area has reduced from 17304 ha (1999-2000) to 12988 ha (2002-2003). At this juncture, revitalization of paddy fields by ensuring reasonable remunerative returns from the crop shall fulfill the food security of the country and restore the ecological decadence. The results of the study highlight the

nutritional importance of Navara and its medicinal properties. In this wake there arises a need to popularize Navara, a remunerative crop than any ordinary rice variety as a food rather than medicine. Adoption of technologies like SRI and the registration of the unique rice variety in the PPVFR Act can help promoting the rice variety. The active principles that attributes to the medicinal quality of Navara are yet to be unveiled. The results will be a major breakthrough in the large scale promotion of Navara along with a well-developed niche market. Landraces and local varieties specific to sites or niches are generally considered potential sources of valuable and rare genes (Arunachalam, 2000). With the growing upsurge of interest in Ayurveda, Navara based treatments have received wide recognition. Hence utmost diligence is to be imparted to cultivate this unique rice cultivar of Keala to enhance the cultivation on a wider scale not only to conserve this miracle rice but also to get rid of all health problems and for the ecological and economical advancement of the farming community.

References

Anonymous 2002-2003. Agricultural Statistics, 2002-2003. Economics and Statistics Department, Kerala.

Arunachalam A 2000. Participatory conservation: A means of encouraging community biodiversity. *Plant Genetic Resources Newsletter* 122: 1-6.

Duke JA 1983. Handbook of Energy Crops, Unpublished.

Duke JA and Ayensu ES 1985 Medicinal Plants of China. Reference Publications Inc., Algonac, MI.

Gopalakrishnan R 2002. Status of rice breeding in Kerala. In 'Priorities and Strategies for Rice Research in High rainfall Tropics. Proc. National Symposium Organized during the Platinum Jubilee of Regional Agricultural Research Station, Pattambi, Kerala, 10-11 October, 2002: 63-77.

Kirtikar KR & Basu BD 1935. Indian Medicinal Plants. Ed. 2, Lalit Mohan Basu, Allahabad.

Mishra B 2002. Present Status and Future Prospects of Hybrid Rice in India, Priorities and Strategies for Rice Research in High rainfall Tropics, Proc. National Symposium Organized duringthe Platinum Jubilee of Regional Research Station, Pattambi 10-11 October, 2002 (17-32).

Omkar Krishnan & Anjali Ghosal. 1995. Rice *Navadhanya*. The Resource Foundation for Science. Technology and Natural Resource Policy, New Delhi.

Robert Bentley & Henry Trimen. 1880. Medicinal Plants. Vol. IV J & A. Churchill New Burlington Street, London.

Studies on evaluation of various clones of tea [*Camellia sinensis* (L.) O. Kuntze] under low temperature conditions

Netto Leonard Allen and Jayaram KM
Department of Botany, University of Calicut, Kerala- 673635, India.

Abstract

Low temperature is one of the major environmental factors determining the growth rate of [Camellia sinensis (L.) O. Kuntze]. As tea is grown in areas where frost can occur it is necessary to select clones of tea, which are better suited to the low temperature conditions. Fluorescence studies were carried out to study the effect of low temperature stress effects on tea plants. The Fv/Fm values at 6.30 am (300-400 µmol m^{-2} s^{-1}), did not vary much between the clones. Further, when the light incidence increased at mid noon hours (1700-1800 µmol m^{-2} s^{-1}), the Fv/Fm values recorded a decline, irrespective of the clones. Of the 10 clones under investigation, 3 clones, namely CRA-6017, TTL-6 and SMP-1, respectively, recorded a sharp decrease in the Fv/Fm ratio by 2 pm. The observation made on TTL-1, TTL-4 and UPASI-9 gave an indication of low temperature tolerance with regard to chlorophyll a fluorescence response. The results indicate that in TTL-6, SMP-1 and SM/OM/54, the toxic oxygen species scavenging mechanisms may be less functional as compared to other clones.

Abbreviations: PAR: photosynthetically active radiation, Fo: original fluorescence, Fv: varaible fluorescence, Fm: maximal fluorescence, PS: photosystem.

Introduction

Tea [*Camellia sinensis* (L.) O. Kuntze] is an important plantation crop of India, which is grown in varied agro-climatic conditions. At present the tea industry is facing a challenge and the best option would be to use high-yielding clones with maximum quality potential and to select clones which will be suitable to specific climatic regions (Joshy and Palani, 1998; Vyas et al., 1998).

Low temperature is one of the major environmental factors determining the growth rate of tea. It has been shown that temperatures below 13°C are not optimal for the growth of tea (Barua, 1989; Hudson and Muraleedharan, 1996) and they adversely affect the biosynthetic activities in tea plant. Tea bushes are susceptible to winter desiccation and frost damage (Fuchinoue, 1985). Frost damage results in visual symptoms such as scorching of flush shoots and maintenance foliage in the event of light incidence as well as defoliation of the bush near the plucking table under moderate occurrence of frost, and die back of branches and splitting of bark if it is severe (Hudson and Muraleedharan, 1996).

Most of the high yielding tea clones are taken up widely for plantations in high altitudes, where considerable seasonal and diurnal lowering in temperature is noticed. In south India an area of 2816 hectares is affected by low temperature and frost, which corresponds to 15.6% of the area under tea cultivation in the Nilgris and 16% in the high ranges (Hudson and Muraleedharan, 1996). Concerning these major problems, in order to achieve success in terms of calculated yields, it would be appropriate to select clones of tea, which are better suited to the low temperature conditions.

Photosynthesis is one of the metabolic processes to be affected greatly by any stress and it is commonly used as a tool for identifying low temperature stress effects on plants (Berry and Björkman, 1980; Larcher, 1994). This particular physiological

process is considered primarily for the rapid selection of plants most suitable for different climatic conditions. As photosynthesis and yield are closely related, photosynthetic performance of plant species are counted as a direct relation to yield of a particular clone (Zelitch, 1982). Although clonal variations in photosynthetic features and other associated physiological functions in relation to low temperature stress have been reported in other plant species (Janssen et al., 1995), such information is lacking for tea clones (Joshi and Palani, 1998). Therefore the present investigation was undertaken to determine the clonal variations in various physiological functions of tea with relation to low temperature.

Materials and Method

Ten different clones were selected for the present study -TTL-1, TTL-2, TTL-4, TTL-5, TTL-6, SMP-1, SM-OM-54 (released by Tata Tea Limited, Munnar, Kerala, India), UPASI-9, CR-6017 (released by United Planters' Association of South India – UPASI, Valparai, Tamil Nadu, India) and TRI-2025 (released by Tea Research Institute of SriLanka). All the plants were in their 3rd year from planting and were planted at a spacing of 4 x 2.5 feet along a single hedge at Tata Tea experimental plots, Madupetty, Kerala, India. The study was carried out in the winter months (December to February) of 2001, 2002 &2003 during which the temperatures varied between 3-12^{o}C. During the winter months maximum damage to tea was recorded for the past 20 consecutive years in Madupetty region (Kerala, India). The observations related to plant response against low temperature were recorded at 6.30 am (300-400 μmol m^{-2} s^{-1} & 3^{o}C), 9 am (1500-1700 μmol m^{-2} s^{-1} & 7^{o}C), 11.30 am (1700-1800 μmol m^{-2} s^{-1}& 12^{o}C), 2 pm (1700-1800 μmol m^{-2} s^{-1} & 10^{o}C, 4.30 pm (900-1100 μmol m^{-2} s^{-1} & 5^{o}C and 7 pm (5-10 μmol m^{-2} s^{-1} & 3^{o}C). The values given in the brackets represent photosynthetically active radiation (PAR) and temperature corresponding to the hour of data recording, respectively. The following observations were repeated for twelve different days in the months of December to February.

Chlorophyll fluorescence was monitored with a portable Fluorescence induction monitor, FIM 1500 (Analytical Development Company Ltd. England). The photosynthetic plant parts were dark-adapted for 30 min prior to fluorescence measurements. Original (Fo) and maximal (Fm) fluorescence yields were measured with weak modulated red light (<0.5 μmol $m^{-2}s^{-1}$) with a 0.8 s pulse of saturating light (>6.8 mmol $m^{-2}s^{-1}$ PAR).

Results and Discussion

In both forest and plantation crop nurseries, frost or low temperature tolerant varieties are assessed by various traditional methods (Ritchie, 1991), such as visual assessment of damage (Vyas *et al.*, 1998). In the present study, damage caused by low temperature and frost was assessed by physiological responses of plants as evaluated by monitoring chlorophyll a fluorescence.

Chlorophyll a fluorescence is non-destructive, easy, and fast and is more reliable method for assessing frost and low temperature tolerance in plants (Mohammad et al., 1995). It is well known that the ratio of Fv/Fm is a quantitative measure of photochemical efficiency (Kitajiima and Butler, 1975) or optimal quantum yield of photosystem (PS) II (Schreiber and Bilger, 1993; Bolhar-Norden-kampf and Öquist, 1993). The Fv/Fm of the tea clones were recorded on each day of the study separately. The measurements were taken at 2.5 hour interval, starting from 6.30 am to 7 pm (Table1).

Fv/Fm values at 6.30 am did not vary much between the clones and the approximate Fv/Fm ratio was in the range of 0.770 to 0.800. With increase in light

incidence at 11.30 am and 2 pm, the Fv/Fm values recorded a decline, irrespective of the clones. Of the 10 clones under investigation, 3 clones, namely CRA-6017, TTL-6 and SMP-1 recorded a sharp decrease in the Fv/Fm ratio by 11.30 am to the extent of 0.565, 0.539, and 0.481, respectively. The observation suggested that the functioning of the photosynthetic apparatus is severely affected by the cumulative effects of low temperature and high light. Readings at 4.30 pm and 7 pm showed that the changes in the values of Fv/Fm ratio developed a reversing trend and tendency to recover. By 7 pm, in all the clones the Fv/Fm values were almost restored to the extent of the initial values recorded at 6.30 am.

It is a well-known phenomenon that capacity of plants to utilize the light absorbed declines significantly upon exposure to environmental stresses such as drought, salt and low temperature (He et al., 1995; Dubey, 1997; Giardi et al., 1997). This condition wherein the plants are unable to utilize the light absorbed by them for photochemistry results in the phenomenon called photoinhibition (Puthur, 2000).

Photoinhibition is caused largely due to the production of toxic oxygen species (Scandalios, 1993; Asada, 1994, Alam and Jacob, 2002). The increase in the generation of toxic oxygen species leads to a substantial inactivation/destruction of lipids, proteins and nucleic acids (Halliwell and Gutteridge, 1986; Scandalios, 1993). An important target for the action of toxic oxygen species is PS II (Powles, 1984; Krause, 1988) and as a result a significant decline in PS II activity was noted in a wide variety of plants exposed to photoinhibitory conditions (Constant et al, 1997; Keren et al, 1997). Photoinhibition is more prominent in the conditions of high light and low temperature (Björkman and Powles, 1984; Huner, et al., 1993; Wise, 1995).

The faster recovery in terms of Fv/Fm values observed in clones such as TTL-1, TTL-4 and UPASI-9 shows that there may be an effective damage negating operation such as free radical scavenging mechanism functioning within them, enabling them to take care of the damage caused as a result of toxic oxygen species because of which there was an indication of low temperature tolerance with regard to chlorophyll a fluorescence response.

Bisht *et al.*, (1996) have reported that the clone UPASI-9 showed minimum photoinhibition due to low temperature and frost. Joshi and Palni (1998) have also confirmed the high thermo-tolerance of the clone UPASI-9 when compared to other clones in a study where measurement of photosynthetic rates at different temperatures was done. UPASI-9 happens to be one of the parents of TTL-1 and there are more chances of the trait of frost tolerance to pass on to the progeny.

Conclusion

The identification of various tea clones such as TTL-1, TTL-4 and UPASI-9, as more low temperature and frost tolerant as compared to other clones which were subjected to study, would be of outmost importance for identifying clones suitable for a region frequented with low temperature conditions. Promotion of such low temperature and frost tolerant clones in such areas will ensure the production of estimated yield and quality of tea, throughout the season.

Table 1. Fv/Fm measurements recorded in leaves of tea plants growing in low temperature conditions at various time intervals. The data is an average of recordings from three independent experiments each with three replicates (i.e. n=9). The data represent mean± standard error.

CLONE	6.30 AM	9:00 AM	11.30 AM	2:00 PM	4.30 PM	7.00 PM
TTL-1	0.784±.06	0.750±.05	0.651±.05	0.660±.05	0.738±.07	0.796±.07
TTL-2	0.786±.05	0.758±.06	0.613±.06	0.645±.05	0.723±.07	0.788±.05
TTL-4	0.787±.06	0.770±.06	0.644±.06	0.673±.06	0.739±.05	0.796±.05
TTL-5	0.783±.04	0.756±.07	0.649±.05	0.634±.06	0.712±.04	0.791±.06
TTL-6	0.770±.05	0.713±.07	0.539±.05	0.573±.06	0.701±.05	0.725±.04
U-9	0.775±.05	0.729±.05	0.612±.06	0.651±.05	0.723±.06	0.781±.06
CRA-6017	0.785±.06	0.714±.05	0.565±.05	0.556±.04	0.689±.06	0.749±.05
TRI-2025	0.787±.07	0.732±.04	0.608±.06	0.605±.04	0.699±.06	0.765±.05
SMP-1	0.780±.05	0.670±.05	0.481±.04	0.562±.05	0.651±.05	0.739±.07
SM-OM-54	0.778±.04	0.737±.06	0.584±.04	0.673±.06	0.735±.07	0.793±.07

References

Alam B and Jacob J 2002. Overproduction of photosynthetic electrons is associated with chilling injury in green leaves. *Photosyn* 40(1): 91-95.

Asada K 1994. Production and action of active oxygen species in photosynthetic tissues, In CH Foyer, PM Mullineaux (Eds), Causes of Photooxidative stress and amelioration of defense systems in plants, CRC Press, Boaca Raton. FL: 77-104.

Barua DN 1989. Science and practice in tea culture. Tea Research Association, Calcutta, Jorhat.

Berry J and Björkman O 1980. Photosynthetic response and adaptation to temperature in higher plants. *Ann. Rev. Plant Physiol.* 31: 491-543.

Bisht MS, Vyas P, Bag N, Nandi SK and Palni LMS 1996. Chlorophyll fluorescence: A tool to assess plant stress. Screening of tea clones for frost tolerance. National Symposium on Modern Trends in Plant Physiology, Pantnagar, India: 50-55.

Björkman O and Powles SB 1984. Inhibition of photosynthetic reactions under water stress: interaction with light level. *Planta.* 161: 490-504.

Bolhar-Norden-kampf HR and Öquist G 1993. Chlorophyll fluorescence as a tool in photosynthesis research. In: PO Hall, JMO Schurlak, HR Bolhar-Nordenkampf, RC Leegood and SP Long (Eds), Photosynthesis and production in a changing environment: A field and laboratory manual. Chapman and Hall, London: 193-206.

Constant S, Perewoska I, Alfonso M and Kirilovsky D 1997. Expression of the *psbA* during photoinhibition and recovery in *Synechocystis* PCC 6714: inhibition and damage of transcriptional and translational machinery prevent the restoration of photosystem II activity. *Plant Mol. Biol.* 34: 1-13.

Dubey RS 1997. Photosynthesis in plants under stressful conditions, In M Pessarakli (Ed), Handbook of Photosynthesis. Marcel Dekker Inc., New York: 859-876.

Fuchinoue H 1985. Time course of cold injury of tea plants related to the climate. In: H Fuchinoue (Ed), Special report on cold injury in tea plant. Saitama Prefectural Tea Experimental Station, Japan: 24-28.

Giardi MT, Masojidek J and Godde D 1997. Effects of abiotic stresses on the turnover of the D_1 reaction centre II protein. *Physiol. Plant.* 101: 635-642.

Halliwell B and Gutteridge JMC 1986. Iron and free radical reactions: Two aspects of antioxidant protection. *Trends Biochem. Sci.* 11: 372-375.

He JX, Wang J and Liang HG 1995. Effects of water stress on photochemical function and protein metabolism of photosystem II in wheat leaves. *Physiol. Plant.* 93: 771-777.

Hudson JB and Muraleedharan N 1996. Frost damage to tea. *Planters' Chronicle* 91: 571-575.

Huner NPA, Oquist G, Hurry VM, Krol M, Falk S and Griffith M 1993. Photosynthesis, photoinhibition and low temperature acclimation in cold tolerant plants. *Photosyn. Res.* 37:19-39.

Janssen LHJ, VanOeveren JC, Van Hasselt PR and Kuiper PJC 1995 Genotypic variation in chlorophyll fluorescence parameters, photosynthesis and growth of tomato grown at low temperature and low irradience. *Photosynthetica* 31: 301-314.

Joshi SC, Palni LMS (1998) Clonal variation in temperature response of photosynthesis in tea. *Plant Sci.* 137(2): 225-232.

Keren N, Berg A, van Kan PJM, Levanon H and Ohad I 1997. Mechanism of Photosystem II photoinactivation and D1 protein degradation at low light: the role of back electron flow. *Proc Nat Acad Sci.* USA 94: 1579-1584.

Kitajiima M and Butler WL 1975. Quenching of chlorophyll fluorescence and primary photochemistry in chloroplast by dibromothymoquinone. *Biochem. Biophys. Acta* 376: 105-115.

Krause GH 1988. Photoinhibition of photosynthesis. An evaluation of damaging and protective mechanisms. *Physiol. Plant.* 74: 566-574.

Larcher W 1994. Photosynthesis as a tool for indicating temperature stress events, In ED Schulze, MM Caldwell (Eds), Ecophysiology of photosynthesis. Springer-Verlag, Berlin: 261-277.

Mohammed GH, Binder WD and Gillies SL 1995. Chlorophyll fluorescence: A review of its practical forestry applications and instrumentation. *J. For. Res.* 10: 383-410.
Powles SB 1984 Photoinhibition of photosynthesis induced by visible light. *Ann. Rev. Plant Physiol.* 35: 15-44.

Puthur JT 2000. Photosynthetic events in *Sesbania sesban* L. Merril in relation to osmotic stress under various developmental stages. Ph. D. Thesis. Jamia Millia Islamia, New Delhi, India.

Ritchie GA 1991. Measuring cold hardiness. In: JP Lassoie and TM Hinckley (Eds), Techniques and Approaches in Forest Tree Ecophysiology, CRC Press Inc., Boca Raton Ann Arbor, Boston: 557-582.

Scandalios JG 1993. Oxygen stress and superoxide dismutase. *Plant Physiol*. 101: 7-12.

Schreiber U and Bilger W 1993. Progress in chlorophyll fluorescence research: Major developments during the past years in retrospect. *Progress in Botany* 54: 151-173.

Siefermann-Harms D 1987. The light-harvesting and protective functions of carotenoids in photosynthetic membranes. *Physiol. Plant*. 69: 561-568.

Vyas P, Bisht MS, Palni LMS 1998. Chlorophyll A fluorescence: A tool for screening tea clones for frost tolerance. *Dev. Plantation Crops Res.* 22: 98-102.

Wise RR 1995. Chilling-enhanced photooxidation: The production, action and study of reactive oxygen species produced during chilling in the light. *Photosyn. Res*. 45: 79-97.

Young AJ, Orset S, Tsavlos AJ (1997) Carotenoid in higher plant photosynthesis In: M Pessarakli (Ed), Handbook of Photosynthesis. Marcel Dekker Inc., New York: 859-876.

Zelitch I 1982. The close relationship between net photosynthesis and crop yield. *Bioscience* 32: 796-802.

Drip irrigation with fertigation on productivity and water use efficiency of onion (*Allium cepa*)

Sakthivel S, Veerabadran V, Balasubramanian R, Murali Krishnasamy S and Kumar V
Agricultural College & Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu- 625 104.

Abstract

Field experiment was conducted during July to September, 2005 at Irrigation Technology Park at Agricultural College and Research Institute, TNAU, Madurai to study the effect of drip irrigation with fertigation on growth, yield and economics of aggregatum onion cultivation. The crop was raised under broad bed furrow (BBF) of 80 / 40 cm for easy laying out of drip irrigation system. The treatment consisted of surface irrigation at IW/CPE ratio of 1.0 (I_1), drip irrigation at 100% PE (I_2) and drip irrigation at 75% PE (I_3). Drip irrigation was given once in three days for treatments I_2 and I_3 to supply 100% and 75% of PE respectively. For I_1, surface irrigation was given when the cumulative pan evaporation reached 50 mm. Recommended dose of fertilizer (60:60:30 kg NPK/ ha) was adopted. For all the treatments, phosphorus was given as basal. For surface irrigation treatment, half dose of N and K as basal and remaining half was top dressed on 30 DAS. For drip irrigation treatments, entire dose of N and K was given as fertigation in four equal splits on 10, 20, 30 and 40 DAS. The growth, yield attributes and yield of onion were recorded. The water use efficiency and economics were worked out. The results revealed that drip irrigation with fertigation performed better than surface method of irrigation. Drip irrigation at 100 % PE (I_2) improved growth of onion and registered significantly higher bulb yield of 11,290 kg/ha with a WUE of 34.53 kg ha mm^{-1}. Drip irrigation at 75 % PE (I_3) recorded a bulb yield of 10,160 kg/ha with higher WUE of 39.65 kg ha mm^{-1}. The yield increase was 44.0 and 29.8 per cent in I_2 and I_3 respectively over surface method of irrigation (I_1). The drip irrigation at 100% PE (I_2) registered higher net return of Rs. 49,740 and B:C ratio of 3.76. It can be concluded that drip irrigation at 100% PE with fertigation can be adopted to get higher productivity and profit for onion cultivation.

Key words: Onion, micro irrigation, fertigation, water use efficiency

Introduction

Onion (*Allium cepa*) is a popular commercial crop and is cultivated in 28,644 ha in Tamil Nadu with a production and productivity of 2.79 lakh tonnes and 9.75 t ha^{-1} respectively. The crop comes up very well under sandy loam soil conditions. The crop is preferred by farmers as it can be easily fit into any cropping system as the duration of the crop is only 70 – 80 days. There is a wide scope to cultivate this crop under micro irrigation system. Not much work has been done on the performance of onion under micro irrigation and with fertigation. With this back ground a study was undertaken to study the effect of drip irrigation with fertigation on growth, yield and economics of aggregatum onion cultivation. This research project forms part of the research programme of All India Co-ordinated Research Project on Water Management.

Materials and Method

Field experiment was conducted during July to September, 2005 at Irrigation Technology Park at Agricultural College and Research Institute, TNAU, Madurai to study the effect of drip irrigation with fertigation on growth, yield and economics of

aggregatum onion cultivation. The crop was raised under broad bed furrow (BBF) of 80 / 40 cm for easy laying out of drip irrigation system. Each BBF was provided with 12mm lateral line with 8 drippers each with a discharge rate of 8 lph. Four rows of onion were planted at 20 x 10 cm spacing in each BBF. The treatment consisted of surface irrigation at IW/CPE ratio of 1.0 (I_1), drip irrigation at 100% PE (I_2) and drip irrigation at 75% PE (I_3). Drip irrigation was given once in three days for treatments I_2 and I_3 to supply 100% and 75% of PE respectively. For I_1, surface irrigation was given when the cumulative pan evaporation reached 50 mm. Recommended dose of fertilizer (60:60:30 kg NPK/ ha) was adopted. For all the treatments, phosphorus was given as basal. For surface irrigation treatment, half dose of N and K as basal and remaining half was top dressed on 30 DAS. For drip irrigation treatments, entire dose of N and K was given as fertigation in four equal splits on 10, 20, 30 and 40 DAS. The growth, yield attributes and yield of onion were recorded. The water use efficiency and economics were also worked out.

Results and Discussion

Growth, yield attributes and yield: Drip irrigation with fertigation performed better than surface method of irrigation. Drip irrigation at 100 % PE (I_2) increased the number of leaves while drip irrigation at 75 % PE (I_3) recorded more leaf length (Table 1). Drip irrigation at 100 % PE (I_2) registered higher (number of bulbs / plant (11.4), shoot yield (6.60 t ha^{-1}) and bulb yield (11.29 t ha^{-1}). Drip irrigation at 75 % PE (I_3) recorded a bulb yield of 10,160 kg ha^{-1} (Table 2) The yield increase was 44.0 and 29.8 per cent in I_2 and I_3 respectively over surface method of irrigation (I_1). The higher growth, yield attributes and yield recorded under drip irrigation is due to continuous availability of moisture by drip irrigation and nutrients through drip fertigation. Similar results were reported in groundnut by Veerabadran *et.al.*(2003).

Water Use Efficiency (WUE): Drip irrigation at 75 % PE (I_3) recorded higher water use efficiency of 39.65 kg ha mm^{-1} followed by drip irrigation at 100 % PE (I_2) with a WUE of 34.53 kg ha mm^{-1} (Table 3.) Drip irrigation systems allow precise control over quantity of irrigation water applied and allows more frequent application. This enables an increase in storage and availability of applied water in the effective root zone. Shorter interval and more frequent irrigation (once in every 3 days) with drip system might have contributed to lower losses of applied irrigation water which resulted in increased bulb yield and higher water use efficiency.

Economic return: The drip irrigation at 100% PE (I_2) registered higher net return of Rs. 49,740 and B:C ratio of 3.76 (Table 4). This was followed by drip irrigation at 75% PE (I_3).

From this above study it can be concluded that drip irrigation at 100% PE with fertigation can be practiced to get higher productivity and economic return in onion cultivation.

Table 1. Effect of drip irrigation and fertigation on growth and yield attributes of onion

	Plant height (cm)	No. of leaves / plant	Leaf length (cm)	No. of bulbs /plant
I_1 - Surface Irrigation at IW/CPE ratio 1.0	31.6	35.1	24.5	7.8
I_2 – Drip irrigation at 100% PE	30.2	39.0	25.7	11.4
I_3 – Drip irrigation at 75% PE	30.9	34.4	26.9	9.9

Table 2. Effect of drip irrigation and fertigation on bulb and shoot yield of onion

	Bulb yield (t/ha)	Shoot yield (t/ha)	Shoot to bulb ratio
I_1 - Surface Irrigation at IW/CPE ratio 1.0	7.83	5.61	0.76
I_2 – Drip irrigation at 100% PE	11.29	6.60	0.58
I_3 – Drip irrigation at 75% PE	10.16	6.44	0.63

Table 3. Effect of drip irrigation and fertigation on water use efficiency (WUE) of onion

	No. of irrigations given	Total water used (mm)	WUE (kg ha mm^{-1})
I_1 - Surface Irrigation at IW/CPE ratio 1.0	5	408.45	19.17
I_2 – Drip irrigation at 100% PE	17	326.95	34.53
I_3 – Drip irrigation at 75% PE	17	256.20	39.65

Table 4 . Effect of drip irrigation and fertigation on economics of onion

	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
- Surface irrigation at IW/CPE ratio 1.0	16000	46980	30980	2.93
- Drip irrigation at 100% PE	18000	67740	49740	3.76
- Drip irrigation at 75% PE	18000	60930	42960	3.39

Value of onion produce: Rs.6.00 per kg

Reference

Veerabadran V, Shanmugasundaram K and Krishnasamy S 2003. Water productivity augmentation through microsprinkler fertigation in groundnut. Proceedings of International Symposium on Transitions in Agriculture for Enhancing Water Productivity. 23 - 25 Sep 2003, AC&RI, Killikulam, Tamilnadu, India.: 83.

Acknowledgement

The authors acknowledge the All India Co-ordinated Research Project on Water Management, (AICRP – WM) ICAR, New Delhi for providing finance for conducting the field experiment.

Effect of intercropping and weed management practices in cassava under irrigated condition

Balasubramanian R, Swaminathan V, Malarvizhi P, Sakthivel S and Murali Krishnasamy S
Agricultural College & Research Institute, Tamil Nadu Agricultural University,
Madurai, Tamil Nadu- 625 104.

Abstract

Field experiment was conducted at Agricultural College and Research Institute, TNAU, Madurai during 2004-05 to study the effect of intercropping and weed management practices on weed control and yield of cassava under irrigated condition. The experiment was carried out in split plot design replicated thrice. The main plot consisted of six various intercropping practices (groundnut, vegetable cowpea and blackgram) and sub plot comprised of six different weed management practices like use of pre emergence herbicides like pendimethalin, alachlor and fluchloralin compared with hand weeding practices. The cassava var. CO(TP) 4 was planted at 90 x 90 cm spacing during July, 2004. The results revealed that cassava intercropped with vegetable cowpea and pre emergence use of fluchloralin 0.75 kg ha^{-1} along with one hand weeding on 4th week after planting (I_2W_3) markedly reduced the total density and dry matter production of weeds and improved all the tuber characters viz., tuber length, number of tubers, tuber weight and tuber yield of cassava under irrigated condition. Double intercropping was not effective as it suppressed the growth of cassava and the second crop of pulse.

Key words: Cassava, intercropping, weed management, weed control, yield, irrigated condition

Introduction

Tuber crops are one of the most important sources of carbohydrates in the world and it ranks first in India. Wider spacing and slow initial growth rate of cassava causes severe weed competition (Srinivasan and Maheswarappa, 1993). The weed competition is observed from early crop growth upto major part of the growing season. The yield loss due to weed competition ranges from 40 to 68 per cent. Single weed management technology may not be useful. Cultural method with intercropping practice is simple and most effective in suppressing the weeds. Application of pre emergence herbicide and hand weeding are reported to be effective in most crops. Hence, the study was taken up with intercropping practices and pre emergence herbicides along with hand weeding.

Materials and Method

Field experiment was conducted at Agricultural College and Research Institute, TNAU, Madurai during 2004-05 to study the effect of intercropping and weed management practices on weed control and yield of cassava under irrigated condition. The experiment was laid out in split plot design replicated thrice. The main plot consisted of different intercropping practices like groundnut var. TMV-9 (I_1), vegetable cowpea var. Gomathi (I_2), blackgram var. Vamban-3 (I_3), groundnut fb. blackgram (I_4), cowpea fb. blackgram (I_5) and no intercrop (I_6). The sub plot comprised of different weed management practices viz., pre emergence herbicides such as pendimethalin 0.75 kg/ha (W_1), alachlor 1.5 kg/ha (W_2) and fluchloralin 0.75 kg/ha (W_3) each followed by one hoeing and weeding on 4th week and hoeing weeding (HW) twice (W_4), HW thrice (W_5) and HW four times (W_6). The cassava

var. CO(TP) 4 was planted at 90 x 90 cm spacing during July, 2004. A common fertilizer dose of 100:100:100 kg NPK ha^{-1} was adopted. The total weed density, weed dry matter production, yield attributes and yield of cassava were recorded and statistically analysed.

Results and discussion

Weed growth: The weed flora of the experimental field consisted of grasses like *Echinochloa colona, Cynodon dactylon, Dactylactenium ageptium,* sedges like *Cyperus rotundus* and broad leaved weeds like *Trinathema portulacastrum, Cleome viscosa* and *Eclipta alba*. The results showed that the various intercrops significantly reduced the weed density and dry matter production (Table 1 and 2) compared to pure crop of cassava (I_6). Among various intercrops, vegetable cowpea (I_2) more effectively checked total weed density (37.35) and total weed dry matter production (45.05 g) by greater suppression effect than other intercrops. Cassava intercropped with cowpea grain or cowpea vegetable type, groundnut and french bean effectively controlled weed growth at CTCRI, Thiruvananthapuram (Anon., 1999). The legumes grown in cassava have better coverage of soil which diminishes light penetration to the soil thus reducing the weed growth (Srinivasan and Maheswarappa, 1993). Among different weed management practices, pre-emergence application of fluchloralin 0.75 kg ha^{-1} + one hand weeding (on 4th week after planting) (W_3) significantly reduced the total weed density (27.23) and total weed dry matter production (34.63 g). This could be due the selective killing action of the herbicide from the early stage of the crop. The treatment combination of cassava intercropped with vegetable cowpea and pre-emergence application of fluchloralin 0.75 kg ha^{-1} + one hand weeding (on 4th week after planting) (I_2W_3) recorded the lowest total weed density (23.1) and total weed dry matter production (31.4 g). This was comparable with cassava intercropped with vegetable cowpea followed by blackgram and pre emergence fluchloralin 0.75 kg ha^{-1} + one hand weeding (on 4th week after planting) (I_5W_3). Greater weed control was achieved by the integration of cultural, chemical and manual methods. Pure crop of cassava with hand weeding twice on 4^{th} and 15^{th} week after planting (I_6W_4) recorded highest weed growth. This could be due to the wider spacing occupied by pure crop of cassava and greater exposure of soil surface for weed growth and delayed hand weeding practice adopted which was not effective on weed control

Yield attributes: Intercropping practices influenced the tuber characters of cassava (Table 3 to 5). Tuber length was higher in intercropping with groundnut fb. blackgram (35.2 cm) (I_4) and vegetable cowpea (34.9 cm) (I_2). Number of tubers / plant was greater in pure crop of cassava (10.3) (I_6) and intercropping with vegetable cowpea fb. blackgram (10.0) (I_5). But the tuber weight was higher (447.7 g) in pure crop of cassava (I_6). Intercrops smothered weeds effectively and added nitrogen to the soil which could have enhanced the growth characters resulting in improvement in yield attributes of cassava. Among weed management practices, pre emergence use of fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (W_3) significantly improved all the tuber characters like tuber length (36.4 cm), number of tubers (13.8) and tuber weight (450.1 g). This could be due to selective killing and effective control of weeds. Among different combinations of treatments, pure crop of cassava and fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (I_6W_3) and intercropping with vegetable cowpea and fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (I_2W_3) were comparable in improving the tuber characters of cassava. This could be due to effective and early control of weeds by pre emergence herbicides and physical removal of all weeds by hand weeding practices.

Cassava yield: Among different intercropping systems, sole crop of cassava (I_6) registered higher tuber yield of 21.0 t ha^{-1} (Table 6). But it was found comparable with double intercropping with vegetable cowpea and blackgram (I_5) (20.71 t ha^{-1}) and single

intercropping with vegetable cowpea (I_2) (20.07 t ha^{-1}). The leguminous intercrops especially vegetable cowpea controlled weeds effectively. Due to the better weed control and greater availability of nitrogenous nutrient by vegetable cowpea, all the yield attributes and tuber yield of cassava were increased. This is due to better uptake of nutrients and greater growth achieved in cassava. Prabhakar *et al.* (1983) reported that cassava + french bean association resulted in higher tuber yield of cassava. In case of weed management practices, fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (W_3) recorded significantly higher tuber yield of 24.45 t ha^{-1}. This was followed by pendimethalin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (W_1) (20.84 t ha^{-1}) and alachlor 1.5 kg ha^{-1} + one hand weeding on 4th week after planting (W_2) (20.00 t ha^{-1}). This could be due to the selective action of these herbicides which effectively controlled weeds in the early crop growth. Among various treatment combinations, sole crop of cassava and fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (I_6W_3) registered higher tuber yield of 26.87 t ha^{-1}. But this was found to be comparable with double intercropping of cowpea and blackgram along with fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (I_5W_3) and single intercropping of vegetable cowpea along with fluchloralin 0.75 kg ha^{-1} + one hand weeding on 4th week after planting (I_2W_3) with tuber yield of 26.45 and 26.33 t ha^{-1}, respectively. This could be due to the fact that greater weed control was achieved by the integration of cultural, chemical and manual methods. The vegetable cowpea smothered weeds, pre emergence herbicides selectively killed weeds from germination onwards in the early stages of crop growth and manual weeding removed all the remaining unaffected weeds thereby greater weed control was achieved. This could have resulted in better crop growth, improved tuber characters and higher tuber yield.

It is concluded that cassava intercropped with vegetable cowpea and pre emergence use of fluchloralin 0.75 kg ha^{-1} along with one hand weeding on 4th week after planting (I_2W_3) can be recommended as an integrated weed management for effectively controlling weed growth and getting higher tuber yield of cassava.

Table 1. Effect of intercropping and weed management practices on total weed density* (No./m^2) at 90 DAP

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	40.5 (6.36)	31.5 (5.61)	26.3 (5.13)	42.5 (6.52)	53.2 (7.30)	50.5 (7.11)	40.75 (6.34)
I_2 -Cowpea	36.2 (6.02)	24.8 (4.98)	23.1 (4.81)	40.0 (6.32)	51.5 (7.18)	48.5 (6.96)	37.35 (6.04)
I_3-Blackgram	43.0 (6.56)	32.5 (5.70)	28.4 (5.33)	48.5 (6.96)	55.3 (7.44)	52.1 (7.22)	43.30 (6.53)
I_4-Groundnut fb Blackgram	41.7 (6.46)	30.5 (5.52)	29.5 (5.43)	46.5 (6.82)	53.0 (7.28)	51.2 (7.16)	42.07 (6.44)
I_5- Cowpea fb Blackgram	38.4 (6.20)	27.5 (5.24)	25.7 (5.07)	46.0 (6.78)	52.2 (6.86)	49.9 (7.06)	39.95 (6.20)
I_6 -Pure crop	42.4 (6.51)	35.3 (5.51)	30.4 (5.94)	50.7 (7.12)	57.5 (7.58)	53.5 (7.31)	44.97 (6.66)
Mean	40.37 (6.35)	30.35 (5.43)	27.23 (5.28)	45.70 (6.75)	53.78 (7.27)	50.95 (7.14)	41.40 (6.37)
	I	W	I x W				
SEd	0.05	0.50	0.13				
CD (0.05)	0.13	0.11	0.27				

* Figures in parenthesis are square root transformed values

Table 2. Effect of intercropping and weed management practices on total weed dry matter production* (g/m²) at 90 DAP

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	45.3 (6.73)	39.9 (6.32)	34.2 (5.85)	51.7 (7.19)	59.1 (7.69)	56.2 (7.50)	47.73 (6.88)
I_2 -Cowpea	42.8 (6.54)	36.8 (6.07)	31.4 (5.60)	48.4 (6.96)	57.7 (7.60)	53.2 (7.29)	45.05 (6.68)
I_3-Blackgram	49.5 (7.04)	41.0 (6.40)	36.8 (6.06)	54.2 (7.36)	61.2 (7.82)	57.1 (7.56)	49.97 (7.04)
I_4-Groundnut fb Blackgram	46.8 (6.84)	39.2 (6.26)	34.7 (5.89)	52.5 (6.47)	59.4 (7.71)	56.4 (7.51)	48.17 (6.78)
I_5- Cowpea fb Blackgram	43.3 (6.58)	37.4 (6.12)	32.8 (5.73)	49.2 (7.01)	58.2 (7.63)	54.4 (7.38)	45.88 (6.74)
I_6 –Pure crop	47.2 (6.87)	42.7 (6.53)	37.9 (6.16)	56.7 (7.53)	63.0 (7.94)	59.0 (7.68)	51.08 (7.12)
Mean	45.82 (6.77)	39.50 (6.28)	34.63 (5.88)	52.12 (7.09)	59.77 (7.73)	56.05 (7.49)	47.98 (6.87)
	I	W	I x W				
SEd	0.07	0.08	0.19				
CD (0.05)	0.17	0.16	0.40				

* Figures in parenthesis are square root transformed values

Table 3. Effect of intercropping and weed management practices on tuber length (cm) of cassava

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	34.8	33.1	35.8	31.2	32.4	33.6	33.5
I_2 -Cowpea	35.6	36.2	37.8	32.4	33.2	34.2	34.9
I_3-Blackgram	34.3	35.1	36.4	31.2	32.1	34.8	34.0
I_4-Groundnut fb Blackgram	33.8	32.0	35.2	25.6	26.3	32.6	35.2
I_5- Cowpea fb Blackgram	35.1	35.1	36.1	31.2	33.1	34.8	34.2
I_6 -Pure crop	35.0	36.3	37.1	32.8	33.9	34.2	34.9
Mean	34.8	34.6	36.4	30.7	31.8	34.0	
	I	W	I x W				
SEd	0.36	0.46	1.13				
CD (0.05)	0.80	0.92	2.26				

Table 4. Effect of intercropping and weed management practices on number of tubers of cassava

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	10.8	10.1	11.7	8.6	9.1	8.7	9.8
I_2 -Cowpea	10.9	10.4	12.8	7.9	8.8	8.4	9.9
I_3-Blackgram	9.6	9.9	10.7	8.8	8.9	8.7	9.4
I_4-Groundnut fb Blackgram	8.0	9.5	11.0	6.8	7.1	7.5	8.3
I_5- Cowpea fb Blackgram	11.5	10.4	11.8	8.9	8.9	8.5	10.0
I_6 -Pure crop	10.9	10.6	13.1	8.8	8.6	9.9	10.3
Mean	10.3	10.2	13.8	8.3	8.6	8.6	

	I	W	I x W				
SEd	0.16	0.20	0.49				
CD (0.05)	0.36	0.40	0.98				

Table 5. Effect of intercropping and weed management practices on tuber weight (g) of cassava

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	445.2	436.2	446.2	420.9	428.2	434.9	435.3
I_2 -Cowpea	438.2	434.8	457.2	415.9	424.0	435.2	434.2
I_3-Blackgram	439.4	436.2	443.8	418.3	427.3	433.9	433.2
I_4-Groundnut fb Blackgram	434.8	435.2	449.2	421.5	425.9	432.6	433.2
I_5- Cowpea fb Blackgram	446.2	435.3	448.2	427.9	428.3	437.8	437.3
I_6 -Pure crop	452.2	451.2	455.8	434.3	440.3	450.4	447.7
Mean	443.0	438.5	450.1	423.1	429.0	437.5	
	I	W	I x W				
SEd	4.56	5.79	14.2				
CD (0.05)	10.17	11.58	28.38				

Table 6. Effect of intercropping and weed management practices on tuber yield (t ha^{-1}) of cassava

Inter-cropping	Weed management practices						
	W_1	W_2	W_3	W_4	W_5	W_6	Mean
I_1-Groundnut	21.60	19.80	23.49	17.38	18.72	18.14	19.86
I_2 -Cowpea	21.47	20.34	26.33	16.79	17.90	17.57	20.07
I_3-Blackgram	18.95	19.40	21.33	17.66	17.10	18.10	18.76
I_4-Groundnut fb Blackgram	17.62	18.59	22.23	17.20	17.00	17.10	18.29
I_5- Cowpea fb Blackgram	23.09	20.34	26.45	18.29	18.20	17.86	20.71
I_6 -Pure crop	22.28	21.51	26.87	18.19	17.06	20.07	21.00
Mean	20.84	20.00	24.45	17.59	17.66	18.14	
	I	W	I x W				
SEd	0.54	0.68	1.67				
CD (0.05)	1.22	1.35	3.38				

References

Anonymous 1999. Package of practices for cassava. Leaflet published from Central Tuber Crops Research Institute, Sreekariyam, Thiruvanthapuram.

Prabhakar M, Mohankumar CR and Nair GM 1983. Intercropping vegetables with cassava. *J. Root Crops* 9(1-2): 21-26.

Srinivasan G and Maheswarappa HP 1993. Weed control in tropical tuber crops: A review. J. Root Crops 19(2): 104-112.

Acknowledgement:

The authors acknowledge the Indian Council of Agricultural Research, New Delhi (ICAR-Adhoc cassava scheme) for providing finance for conducting the field experiment

Effect of Nitrogen, Phosphorus, Azospirillum, Phosphobacteria and VAM on growth and yield of medicinal coleus

Swaminathan V, Ravi P, Sadasakthi A and Balasubramanian R
Agricultural College & Research Institute, Tamil Nadu Agricultural University,
Madurai, Tamil Nadu- 625 104.

Abstract

Medicinal coleus (Coleus forskohli) is an important medicinal plant cultivated through out India. The tuber contains forskholin and is used in drugs for hypertension, glaucoma, asthma and heart diseases. Field trial has been laid out with twenty seven treatment combinations consists of three levels of nitrogen viz., 30, 40 and 50 kg ha^{-1}, three levels of phosphorus viz., 45, 60 and 75 kg ha^{-1} and each 2 kg ha-1 of Azospirillum, phosphobacteria and VascularArbuscularMycorhizae(VAM) were replicated thrice under factorial randomized block design. A uniform dose of potassium @ 50 kg ha^{-1} was applied. Results revealed that the application of VAM @ 2kg ha^{-1} along with 50 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} significantly increased the dry tuber yield by 1662 kg ha^{-1}. The highest yield achieved in the elite treatment is due to the accelerated physiological activity as evidenced from higher plant height (52.4cm), more number of laterals (29.1) and more number of leaves (348).

Introduction

Medicinal coleus (*Coleus forskohlii* brig.) is one of the most important medicinal crops of the future as its pharmacopical properties have been discovered only recently. It belongs to the family labiataceae and it is known to have originated in Indian subcontinent. In Tamil Nadu it is predominantly grown in salem, Dharmapuri, Erode, Coimbatore and Trichy districts with an area of 4500 acres. It is naturally grown in 600 – 1800 M elevation with 6.4 to 7.9 pH containing loamy or sandy loam soils. The tuberous root extract of Coleus forskohlii were found to contain a diterpene, forskohlin, Which is exclusive to this species, pharmacological and biochemical investigation established that forskohlin possesses multifaceted biological activities such as positive inotropic, antihypertensive, bronchospasmolytic, antithrombotic platelet aggregation inhibiting antiglaucoma and adenylate cyclass stimulation (Krishnan, 2001) In Ayurveda, the tuberous roots are used as drug for heart diseases, abdominal colic, respiratory disorder and convulsions (Ammon and Muller, 1985) The tuberous roots are prescribed for burning sensation, skin infection and eczema and used as treatment of glaucoma, congestive, cardiomyopathy, asthma and certain cancers (De Souza and Sha, 1988). It is also used for pharmaceutical preparation prescribed for glaucoma and low blood pressure (Veeraragavathatham *et al.*, 1985). There is an ample scope for cultivation of medicinal coleus under wide range of soil and ecological condition in Tamil Nadu. So for no systematic work has been done to study the efficacy of integrated nutrient management (INM) of the crop. Hence the present study was taken up with the following objectives: To find out the effect of Nitrogen, Phosphorus and Biofertilizers on growth and physiology of Medicinal coleus. To find out the combined effect of Nitrogen, Phosphorus and Biofertilizers on yield and yield components of medicinal coleus.

Materials and Method

The experiment was carried out during November 2003 to April 2004 in the block E of the college orchard, Department of Horticulture, Agricultural College and Research Institute, Madurai. The terminal cuttings of local cultivar were obtained from a farmer in Nagalapuram village of Natham, The following treatments were applied in a Factorial Randomized Block Design with twenty seven treatments combination with one

control, involving three levels in three factors viz. Nitrogen, Phosphorous and biofertilizers, Urea (46% N), Super phosphate (16% P_2O_5) and Muriate of potash (60%K_2O) were the sources of Nitrogen, Phosphorus and Potassium.

The main treatments are given below:

N1: 100 per cent of N (50 kg/ha) N2: 75 per cent of N (40 kg /ha)
N3: 50 per cent of N (30 kg/ha) P1: 100 per cent of P (75 kg/ha)
P2: 75 per cent of P (60 kg/ha) P3: 50 per cent of P (45 kg/ha)
B1: Azospirillum (2 kg/ha) B2: Phosphobacteria (2 kg/ha)
B3: VAM (2 kg/ha)
A uniform dose of potassium (50 kg/ha) was applied.

Biometrical Observations: Plant Height, Plant Spread, Number of Laterals, Number of Leaves, Diameter of the Tuberous Roots, Dry tuber weight /Plant at final harvest and Crop Growth Rate

Results and Discussion

Increase in plant height (52.40 cms) was obtained by the application of 50kg ha^{-1} N+ 60 kg $ha^{-1}P_2O_5$ + VAM at 150 days after planting (Table 1.). Nitrogen greatly influenced the increase of the shoot length (Gupta. *etal,* 2000). Phosphorus enhances the root proliferation through photosynthesis and respiration (Das, 1999). The increased in plant height due to VAM inoculation might be attributed to increase production of growth hormones viz., auxin, gibberellins, cytokinins, vitamins and antibiotics. The response of biofertilizer was superior over with sub optimal levels of N, P and K and is conformity with the study of Farooqi *etal (*1991) in davana, yamgar *etal* (2001) in turmeric vijayabharathi (2002) in ashwagandha, poongodi (2003) in mucuna.

The application of 50 kg ha^{-1} N + 60 kg ha^{-1} P 20 kg VAM reported highest number of laterals(29.10) at 150 days after planting (Table 3.) This increase in laterals was due to enhanced vegetative growth because of increased cell division and cell elongation in turn triggered the activity and increased the supply of photosynthates. This study is in agreement with the earlier findings of Torry (1950), Dhanalakshmi and Pappiah (1995) in tomato, Vijayabharathi (2002) in ashwagandha, Tiwari *etal* (2000) in acorus calamus. The highest number of leaves(341) were obtained in the treatment combination of 50 kg ha^{-1} N + 60 kg $ha^{-1}P_2O_5$ + VAM(Table 4.). The increased number of leaves is highly influenced by the VAM when compared with Azospirillum and Phosphobacteria. This might be due to synthesis of organic compounds that necessitates the formation of leaves. The present findings are in line with Rameshbabu (1996) and Vijayabharathi (2002) in ashwagandha, Poongodi (2003) in Mucuna.

The highest root diameter of 4.18 cm was recorded with the application of 50 kg/ha N + 60 kg/ha P_2O_5 along with VAM (Table 5.). VAM might have resulted in altered permeability and increase in root surface area, resulting in better uptake which ultimately increased photosynthates accumulation. The present finding was supported by Ramesh babu (1996) and Vijayabarathi (2002) in ashwagandha, Paturde *et al.* (2002)in Safed musli.

Application of Nitrogen, phosphorus along with Biofertilizers was found to have significant effect in enhancing the dry tuber yield per plant at final harvest. $N_1P_2B_3$(50 kg ha^{-1} N+60 kg ha^{-1} P_2O_5 + VAM)(Table 7.) treatment registered the highest yield as 63.2 g at final harvest. The inoculation of VAM is responsible for higher nutrition uptake, besides mobilization of Phosphorus and uptake of Phosphorus, Nitrogen and several micronutrients which would have increased the tuber weight. The similar

results were obtained by Rameshbabu (1996) and Vijayabharathi(2002) in ashwaghandha

Crop growth rate is a function of dry mater production as reported by watson (1985). 5.36 g m^2 day^{-1} recorded with the application of 50 kg ha^{-1} N + 75 kg ha^{-1} P_2O_5 along with VAM during 150 days after planting (Table 8). The application of inorganic nutrients along with biofertilizers increased the CGR. This might be due to higher uptake of nutrients which lead to higher photosynthetic efficiency. Thus leading to the accumulation of photosynthates in plants which recorded higher dry matter production. (Vijayabharathi, 2002) in ashwaghandha and Poongodi (2003) in mucuna.

Conclusion

Field trial has been laid out with twenty seven treatment combinations consists of three levels of nitrogen viz., 30, 40 and 50 kg ha-1, three levels of phosphorus viz., 45, 60 and 75 kg ha_{-1} and each 2 kg ha-1 of Azospirillum, phosphobacteria and VAM were replicated thrice under factorial randomized block design. A uniform dose of potassium @ 50 kg ha-1 was applied. Results revealed that the application of VAM @ 2kg ha^{-1} along with 50 kg N ha-1 + 60 kg P_2O_5 ha^{-1} significantly increased the dry tuber yield by 1662 kg ha^{-1}. The highest yield achieved in the elite treatment is due to the accelerated physiological activity as evidenced from higher plant height (52.4cm), more number of laterals (29.1) and more number of leaves (348).

Table 1.Effect of Nitrogen and Phosphorus along with Biofertilizers on plant height (cms)

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	47.26	48.20	49.15	48.20	N	0.130	0.267
N2	40.96	42.80	44.96	42.91	P	0.130	0.267
N3	33.53	35.18	39.60	36.10	B	0.130	0.267
P1	40.78	41.86	44.31	42.32	NP	0.225	0.463
P2	42.65	44.48	47.38	44.83	PB	0.225	0.463
P3	38.33	39.83	42.01	40.06	NB	0.225	0.463
N1P1	47.15	48.00	49.15	48.10	NPB	0.390	0.802
N1P2	50.95	51.55	**52.40**	51.63			
N1P3	43.70	45.05	45.90	44.88			
N2P1	40.85	41.50	44.40	42.25			
N2P2	43.60	46.60	47.65	45.95			
N2P3	38.45	40.30	42.85	40.53			
N3P1	34.35	36.10	39.40	36.61			
N3P2	33.40	35.30	42.10	36.93			
N3P3	32.85	34.15	37.30	34.76			
Mean	40.58	42.06	44.57	42.40			

Table 2. Effect of Nitrogen and Phosphorus along with biofertilizers on plant spread (cms)

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	67.28	69.51	70.88	69.22	N	0.182	0.375
N2	58.38	60.93	64.51	61.27	P	0.182	0.375
N3	49.60	51.76	56.45	52.60	B	0.182	0.375
P1	58.98	60.61	63.60	61.06	NP	0.316	0.649
P2	61.43	64.16	68.21	64.60	PB	0.316	0.649
P3	54.85	57.43	60.03	57.43	NB	0.316	0.649
N1P1	67.95	70.15	71.20	69.76	NPB	0.547	1.125
N1P2	72.35	73.60	**75.70**	73.88			
N1P3	61.55	64.80	65.75	64.03			
N2P1	58.05	58.90	63.75	60.23			
N2P2	62.50	66.80	69.20	66.16			
N2P3	54.60	57.10	60.60	57.43			
N3P1	50.95	52.80	55.85	53.20			
N3P2	49.45	52.10	59.75	53.76			
N3P3	48.40	50.40	53.75	50.85			
Mean	58.42	60.73	63.95	61.03			

Table 3. Effect of Nitrogen and Phosphorus along with Biofertilizers on number of laterals

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	25.41	26.53	27.00	26.31	N	0.096	0.198
N2	20.65	21.91	23.98	22.18	P	0.096	0.198
N3	16.00	16.91	19.51	17.47	B	0.096	0.198
P1	20.93	21.71	23.38	22.01	NP	0.167	0.344
P2	22.26	23.55	25.51	23.77	PB	0.167	0.344
P3	18.86	20.10	21.60	20.18	NB	0.167	0.344
N1P1	25.95	26.90	27.30	26.71	NPB	0.289	0.595
N1P2	27.85	28.90	**29.10**	28.60			
N1P3	22.45	24.35	24.80	23.86			
N2P1	20.25	20.80	23.65	21.56			
N2P2	23.10	25.30	26.35	24.91			
N2P3	18.60	19.65	21.95	20.06			
N3P1	16.60	17.45	19.20	17.75			
N3P2	15.85	17.00	21.30	18.05			
N3P3	15.55	16.30	18.05	16.63			
Mean	20.68	21.78	23.50	21.99			

Table 4. Effect of Nitrogen and Phosphorus along with Biofertilizers on number of leaves

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	307.75	318.95	325.10	317.26	N	0.999	2.055
N2	262.30	374.10	293.16	276.52	P	0.999	2.055
N3	200.16	224.88	252.46	225.83	B	0.999	2.055
P1	259.15	272.38	288.90	273.47	NP	1.731	3.559
P2	273.11	290.35	310.95	291.47	PB	1.731	3.559
P3	237.95	255.20	270.88	254.67	NB	1.731	3.559
N1P1	309.10	321.10	327.10	319.10	NPB	2.999	6.165
N1P2	334.65	341.65	**348.40**	341.56			
N1P3	279.50	294.10	299.80	291.13			
N2P1	258.85	264.30	289.90	271.01			
N2P2	285.10	304.40	314.70	301.40			
N2P3	242.95	253.60	274.90	257.15			
N3P1	209.50	231.75	249.70	230.31			
N3P2	199.60	225.00	269.75	231.45			
N3P3	191.40	217.90	237.95	215.75			
Mean	256.73	272.64	290.24	273.20			

Table 5.Effect of Nitrogen and Phosphorus along with Biofertilizers on diameter of tuberous roots (cms)

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	3.51	3.69	3.80	3.67	N	0.017	0.036
N2	2.70	2.91	3.28	2.96	P	0.017	0.036
N3	1.68	1.98	2.48	2.04	B	0.017	0.036
P1	2.66	2.86	3.14	2.89	NP	0.030	0.063
P2	2.92	3.16	3.56	3.22	PB	0.030	0.063
P3	2.30	2.56	2.85	2.57	NB	0.030	0.063
N1P1	3.55	3.77	3.82	3.71	NPB	0.053	0.109
N1P2	3.96	4.04	**4.18**	4.06			
N1P3	3.03	3.28	3.41	3.24			
N2P1	2.66	2.73	3.22	2.87			
N2P2	3.12	3.47	3.69	3.42			
N2P3	2.31	2.52	2.94	2.59			
N3P1	1.78	2.08	2.40	2.08			
N3P2	1.68	1.99	2.83	2.16			
N3P3	1.58	1.87	2.21	1.88			
Mean	2.63	2.86	3.19	2.89			

Table 6. Effect of Nitrogen and Phosphorus along with biofertilizers on dry tuber weight (g)

Treatments	150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	24.55	42.00	44.40	36.98	N	0.329	0.677
N2	29.71	33.73	46.01	36.48	P	0.329	0.677
N3	15.36	23.98	22.75	20.70	B	0.329	0.677
P1	25.95	45.63	45.20	38.92	NP	0.570	1.173
P2	24.46	29.58	36.33	30.12	PB	0.570	1.173
P3	19.21	24.50	31.63	25.11	NB	0.570	1.173
N1P1	16.60	53.75	56.05	42.13	NPB	0.988	2.032
N1P2	38.65	36.80	**52.10**	42.53			
N1P3	18.40	20.15	40.30	26.28			
N2P1	33.40	35.05	49.75	39.40			
N2P2	24.05	22.05	46.10	30.73			
N2P3	31.70	44.10	42.20	39.33			
N3P1	27.85	48.10	29.80	35.25			
N3P2	10.70	14.60	26.05	17.11			
N3P3	7.55	9.25	12.40	9.73			
Mean	23.21	33.23	37.72	31.39			

Table 7.Effect of Nitrogen and Phosphorus along with Biofertilizers on dry tuber weight per plant at final harvest (g)

Treatments	FINAL HARVEST						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	49.00	53.06	55.11	52.39	N	0.356	0.732
N2	31.68	36.05	43.96	37.23	P	0.356	0.732
N3	12.50	18.20	27.96	19.55	B	0.356	0.732
P1	31.75	35.35	41.58	36.22	NP	0.617	1.269
P2	36.86	42.56	50.28	43.23	PB	0.617	1.269
P3	24.56	29.40	35.18	29.71	NB	0.617	1.269
N1P1	50.60	54.40	55.95	53.65	NPB	1.069	2.198
N1P2	57.45	60.40	**63.20**	60.35			
N1P3	38.95	44.40	46.20	43.18			
N2P1	30.15	31.70	42.55	34.80			
N2P2	40.65	48.60	52.60	47.28			
N2P3	24.25	27.85	36.75	29.61			
N3P1	14.50	19.95	26.25	20.23			
N3P2	12.50	18.70	35.05	22.08			
N3P3	10.50	15.95	22.60	16.35			
Mean	31.06	35.77	42.35	36.39			

Table 8.Effect of Nitrogen and Phosphorus along with Biofertilizers on Crop growth rate (CGR) (g m2 day-1)

Treatments	120 -150 DAP						
	B1	B2	**B3**	Mean		SED	CD (0.05)
N1	4.15	4.79	4.82	4.58	N	0.010	0.020
N2	4.29	4.37	4.82	4.49	P	0.010	0.020
N3	4.07	4.31	4.15	4.17	B	0.010	0.020
P1	4.23	4.88	4.88	4.66	NP	0.017	0.035
P2	4.16	4.39	4.51	4.35	PB	0.017	0.035
P3	4.11	4.19	4.39	4.23	NB	0.017	0.035
N1P1	4.54	5.25	4.50	4.76	NPB	0.030	0.061
N1P2	4.00	5.28	**5.36**	4.88			
N1P3	3.90	3.86	4.59	4.12			
N2P1	4.43	4.45	4.97	4.61			
N2P2	4.07	3.94	4.85	4.28			
N2P3	4.37	4.72	4.64	4.57			
N3P1	4.27	4.93	4.31	4.50			
N3P2	3.88	4.00	4.18	4.02			
N3P3	4.06	4.00	3.96	4.0			
Mean	4.17	4.49	4.59	4.42			

Table 9. Effect of nitrogen and phosphorus along with biofertilizers on the cost Economics of medicinal coleus

Treatment combination	Dry root yield (Kg/ha)	Gross income (Rs.)	Gross cost (Rs.)	Net income (Rs.)	Benefit cost ratio
N1P1B1	1375.0	55000.0	15337.0	39663.0	1: 3.59
N1P1B2	1437.5	57500.0	15327.0	42173.0	1: 3.75
N1P1B3	1487.5	59500.0	15677.0	43823.0	1: 3.80
N1P2B1	1537.5	61500.0	15249.3	46250.8	1: 4.03
N1P2B2	1587.5	63500.0	15239.3	48260.8	1: 4.17
N1P2B3	**1662.5**	**66500.0**	**15589.3**	**50910.8**	**1: 4.27**
N1P3B1	1037.5	41500.0	15186.7	26313.3	1: 2.73
N1P3B2	1200.0	48000.0	15176.7	32823.3	1: 3.16
N1P3B3	1250.0	50000.0	15526.7	34473.3	1: 3.22
N2P1B1	825.0	33000.0	15237.8	17762.3	1: 2.17
N2P1B2	887.5	35500.0	15227.8	20272.3	1: 2.33

N2P1B3	1150.0	46000.0	15577.8	30422.3	1: 2.95
N2P2B1	1087.5	43500.0	15150.3	28349.8	1: 2.87
N2P2B2	1300.0	52000.0	15140.3	36859.8	1: 3.43
N2P2B3	1387.5	55500.0	15490.3	40009.8	1: 3.58
N2P3B1	675.0	27000.0	14727.7	12272.3	1: 1.83
N2P3B2	775.0	31000.0	14717.7	16282.3	1: 2.11
N2P3B3	987.5	39500.0	15067.7	24432.3	1: 2.62
N3P1B1	462.5	18500.0	15139.0	3361.0	1: 1.22
N3P1B2	575.0	23000.0	15129.0	7871.0	1: 1.52
N3P1B3	725.0	29000.0	15479.0	13521.0	1: 1.87
N3P2B1	437.5	17500.0	15051.3	2448.8	1: 1.16
N3P2B2	537.5	21500.0	15041.3	6458.8	1: 1.43
N3P2B3	937.5	37500.0	15391.3	22108.8	1: 2.44
N3P3B1	412.5	16500.0	14988.7	1511.3	1: 1.10
N3P3B2	500.0	20000.0	14978.7	5021.3	1: 1.34
N3P3B3	625.0	25000.0	15328.7	9671.3	1: 1.63

Reference

Ammon HPT and Muller AB 1985. Forskolin: from an ayurvedic remedy to a modern agent. Planta Medica 46: 473-477.

Das P.L. 1999. Fertilizers, Kalyani publishers, New Delhi: 98-109.

De Souza, N.J. and Shah V 1988. Forskolin- an adenylate cyclase activating drug from an Indian herb. *Economic Medicinal Plant Research* 2:1-16.

Dhanalakshmi K and Pappiah CM 1995. Effect of *Azospirillum* inoculation on tomato nursery (*Lycopetrucan esculentum L.*) National symposium on organic farming, Oct 27-28, Agricultural College and Research Institute, Madurai.

Farooqi AA, Devaiah KA, Dhasartha Rao ND, Vasundhara M and Raj B 1991. Effect of nutrients on growth, yield and essential oil content in Davana. J. MAPS April-May 1991: 75-87.

Gupta MM, Verma RK, Srivastava S, Singh DV, Pandey R and Sushil kumar 2000. Use of HPLC in the rapid analysis of some important plant drugs using photodiode array detector. J. Medicinal Sciences 22: 1-3.

Krishnan R 2001. Cultivation and utilization of *Coleus forskohlii* Briq. Nationl seminar on transfer of technology of medicinal and aromatic crops. IIHR, Banglore, 2001.

Laxminaryan Hedge, 2001. Crop improvement in *Coleus forkohlii* Briq. Department of medicinal and aromatic plants, K.R.C.college of Horticulture, Arabhavi.

Paturde JT, Wankhade SG, Khode PP, Chatol PU, Deoand DD and Huyar SA 2002. Effect of organic manures and plant population on yield of safed musli, *Cholorophytum borivallianum. Agric. Sci. Digest* 22(1): 51-52.

Poongodi M 2003. Integrated nutrient management in Mucuna pruiensis for growth and yield. M.Sc. (Hort.) Thesis, TNAU, Coimbatore.

Ramesh Babu TI, 1996. Nutrutional studies in Ashwahandha. M.Sc (Ag) Thesis, TNAU, Coimbatoe.

Tiwari JP, Tiwari AB and Tiwarei G 2000. Effect of nitrogen application on growth and yield of *Acorus calamus. J. MAPS* 22(8): 636-638.

Torry TC 1950. The induction of lateral shoots by IAA and decapitation. *Amercian J. Botany* 37: 257-264.

Veeraraghavathatham, Venkatachalam DR and Sundararajan S 1985. Performance of two varieties of *Coleus forskoglii* under different spacing levels. *South Indian Hort.* 33(6): 389-392.

Vijayabharathi, 2002. Efficacy of integrated nutrient management in Ashwagandha. M.Sc (Hort) Thesis, TNAU, Madurai.

Yamgar VJ, Kathmale DK, Belhevar PS, Patil RC and Patil PS, 2001. Effect of diferent levels of nitrogen, phosphorus and potassium and split application of nitrogen on growth and yield of turmeric. *Indian J. Agron.* 46(20): 372-374.

Fixation of critical limit for Zinc in red sandy soil with reference to tomato

Rathinasamy A, Anbu S, Balakrishnan K and Durairaj Muthiah N
Horticultural College and Research Institute, Periyakulam, Tamil Nadu- 625 604

Abstract

A pot culture experiment was conducted at Horticultural College and Research Institute, Periyakulam during the period between 1996 and 2000 to study the response of tomato to Zn and to fix the critical level of Zn simultaneously in 21 soils representing seven major soil series viz., Palaviduthi (Pvd), Somayyanur (Smy), Irugur (Igr), Vylogam (Vyg), Palathurai (Pth), Thulukkanur (Tlk), and Pilamedu (Plm) of Theni district. The experiment was conducted in a completely randomized design (factorial) with two replications using tomato variety PKM-1 as the test crop. The following were the treatments viz., control (Zn_0); 2.5ppm Zn ha^{-1}(Zn_1); 5.0ppm Zn ha^{-1} (Zn_2); and 7.5 ppm Zn ha^{-1} (Zn_3). The results indicated that out of 21 soils tested, 12 soils showed quadratic pattern of response to added Zn and the physical optimum dose of Zn for these soils ranged from 6.25 to 15.41 kg ha^{-1} and the economic optimum dose ranged from 4.59 to 14.72 kg ha^{-1}. A critical level of 0.77ppm DTPA extractable Zn was determined by graphical as well as statistical method for soils of Theni District in two-way classification method. Based on the critical value the soils are classified in relation to the expected crop responses as responsive soils and non- responsive soils. Finer division was again made to classify and group the responsive soils into highly and moderately responsive. Eventually soils with the Zn status above 0.8ppm might not respond to Zn application. But in soils with values ranging from 0.62 to 0.79ppm the probability of obtaining response is moderate and soil possessing less than 0.61ppm the probability of profitable response would be of greater magnitude.

Introduction

In areas where no detailed soil fertility vis-à-vis fertilizer experimental results are available, a reconnaissance study can be undertaken to group the soils broadly into responsive and non-responsive ones. In this context critical level concept is considered as a cheaper resource inventory method. In an agriculturally prominent district like Theni in Tamilnadu where such basic fertility information is not available, the above approach seems to be very appropriate and justifiable. Once such information is made available then it could follow with fertilizer experiments to pitch upon and calibrate the fertilizer responses with more exactness. Viewing from the above contemplation a two-way and three-way delineation of the soils of Theni was first attempted to.

Materials and Method

A pot culture experiment was conducted in a completely randomized design(F) to study the response of tomato to Zn and to fix the critical level of Zn in soils simultaneously. All the seven major soil series viz. Palaviduthi (Pvd); Somayyanur (Smy); Irugur (Igr); Vylogam (Vyg); Palathurai (Pth);Thulukkanur (Tlk); Pilamedu (Plm) were used in the pot culture experiment. The test crop was tomato and variety was PKM – 1.Soils from twenty-one major tomato growing areas of Theni district were used in the study. The treatments imposed at four levels of Zinc were Control (Zn_0); 2.5ppm Zinc (Zn_1)5.0ppm Zinc (Zn_2)7.5ppm Zinc (Zn_3).

Fifteen kilograms capacity earthen pots were chosen well cleaned and the interior of the pots were lined with polythene sheets to prevent contamination and also to avoid leaching of Zn. Ten kilograms in each of air dried soil sample were transferred to the pots. A common dose of N, P_2O_5 and K_2O @ 150: 100: 50 kg ha^{-1} respectively were

added to each pot, out of which half of N and full dose of P_2O_5 and K_2O were basally applied and thoroughly mixed with the soil. The fertilizers used in this experiment were commercial grade fertilizers viz., urea, single super phosphate and potassium chloride. Each soil received four levels of Zn viz., 0.0, 2.5, 5.0 and 7.5ppm of Zn as $ZnSO_4.7H_2O$ and these treatments were superimposed before planting.

Twenty-five days old tomato seedlings (PKM-1) grown in acid washed and rinsed sand, were transplanted in the pots at the rate of two seedlings per pot at equal distance. The remaining 50 per cent of N were applied as top dressing on 30^{th} day after planting. At maturity, fruits were harvested and the yield was recorded. Plant samples were collected dried and their dry weights were recorded. A uniform quantum of soil samples from each pot was collected at harvest, processed and used for analysis.

Response functions

To evaluate the performance of tomato PKM-1 under different soils for added Zinc levels, response curves along with response equations were worked. In each soil series, the yield responses to added Zn were tested by using different response functions viz., linear: $Y = a + bx$, quadratic: $Y= a + bx – cx^2$ and cubic: $Y= a - bx +cx^2 - dx^3$ in orthogonal polynomial model (Snedecor and Cochran, 1967). For each response function, R^2 value was calculated and the function for which the largest R^2 value obtained was chosen as the best fit. The best-fit response equations are profitably used to predict the fruit yield of tomato for a particular level of applied Zn.

Quadratic function model of $Y = a + bx – cx^2$ was fitted to the fruit yield from pot experiment to arrive at the physical and economic optimal doses of Zn, for applicability and practical utility. The physical and economic optimum doses were worked out from the response equations.

Critical limit

The critical limit of Zn for the soil series of Theni district was worked out by adopting Cate and Nelson procedures.

Results and discussion

RESPONSE FUNCTIONS (TABLEs 1, 2)

Quadratic response function $Y=a+bx-cx^2$ was fitted to the mean fruit yield of soils. The physical as well as economic doses were deduced employing the response equation. Out of 21 soils, actual yields of 12 soils (S_1, S_2, S_4, S_6, S_7, S_{10}, S_{12}, S_{13}, S_{15}, S_{16}, S_{20} and S_{21}) were found to correlate significantly with predicted yields and hence the regression model was found to be adequate and best fitting. In the response function, quadratic co-efficient exhibited negative sign indicating the feasibility of working out the maximum. Accordingly the highest level (7.5ppm or 16.8Kg ha^{-1}) was found to be adequate enough to cover the full range of response functions in these soils. The soils S_3,S_5,S_8,S_{11},S_{14},S_{17} and S_{18} manifested linear response to added Zn.

Among the soils the physical optimum of Zn ranged from 6.25 (S_{20}) to 15.41 Kg ha^{-1} (S_4) and the economic optimum was found to be 4.59 (S_{20}) to 14.72 Kg ha^{-1} (S_1).

Response is a measure of the ability of the crop to yield more by foraging the added nutrient besides the native forms. So in measuring the response or otherwise, both soil and plant parameters are to be considered together. Among the soil factors the mineralogical composition, the fixation intensity operating against the Zn release power of the soil, the initial Zn saturation and among the plant characteristics, nature of crops, its rooting pattern, CEC etc. decide largely on the response characteristics. In the current study, the first group of soils (S_1, S_2, S_4, S_6, S_7, S_{10}, S_{12}, S_{13}, S_{15}, S_{16}, S_{20} and S_{21}) manifesting quadratic type of responses for the added Zn might be possibly due to

low initial Zn saturation, slow release of native Zn coupled with low intensity and less magnitude of Zn fixation in these soils. Moreover quadratic type responses could also be due to the operation of the Bray's nutrient sufficiency concept.

The second group comprising 7 soils displayed a linear response, such a response behavior could also be anticipated as the levels of Zn tried in these soils might be insufficient and well below response plateau of the soil and it might need more fertilizer inputs to manifest the end condition of response. It also led to the possibility of enhancing from the present level of 7.5ppm of Zn to a higher level, for attaining higher responses. The linear response could be further attributed to low initial Zn and low cumulative Zn release.

On the other hand, the soils belonging to third group viz., S_9 and S_{19} exhibited no response to the added Zn. These soils possessed greater initial available Zn which could satisfy the entire requirement of Zn by tomato crop. Further a higher magnitude of Zn fixing intensities coupled with poor buffering capacities of these soils to replenish the depleted Zn ions by crop removal might be a upright reason for the non responsiveness of added Zn. The physical and economic optimum dose of Zn worked out for first group of soils highlighted the feasibility of arriving a common fertilizer strategy through fertilizer calibration, which helps us to judiciously use the Zn fertilizers in tomato. From the response function it is well established that the optimum dose for obtaining the maximum yield and economic dose for highest profit of Zn recommendable for the soils are given below:

Soil	**Optimum dose (Kg ha^{-1})** (Maximum yield)	**Economic dose (Kg ha^{-1})** (Highest net profit)
S_1 Shanmugasundarapuram (Pth)	15.2	14.7
S_2 Allinagaram (Smy)	10.2	9.8
S_4 Pulikuthi (Vyg)	15.4	13.1
S_6 Silvarpatti (Igr)	13.7	12.5
S_7 T.Renganathapuram (Smy)	12.6	11.6
S_{10} A.Renganathapuram(Plm)	12.5	11.3
S_{12} Kombai (Smy)	10.2	9.9
S_{13} Appipatti (Pvd)	10.9	10.4
S_{15} Koduvilarpatti (Vyg)	11.6	11.0
S_{16} Sathakovilpatti (Igr)	11.3	10.8
S_{20} Vaigai Dam (Pth)	6.3	4.6
S_{21}Ramasamynaickenpatti (Pvd)	13.4	12.5

CRITICAL LIMIT OF ZINC IN SOILS OF THENI DISTRICT
PARTITIONING SOIL TEST YIELD VARIABLE INTO TWO CLASSES (TABLE 3)

Among 21 soils tested in the present study, 7 soils (S_1 to S_7) were found to fall below critical level of Zn whereas, the remaining 14 soils (S_8 to S_{21}) fell above critical level. The results generated on the critical level of Zn from a small representative sample size of 21 soils could now be profitably employed to delineate and broadly classify the larger areas of soils of Theni district. Based on the critical level established from 21 soils used in the pot culture studies, the soils could be classified into 2 broader groups as potentially responsive soils and non-responsive soils.

In this way for the entire soils of Theni district a critical level of 0.77ppm of Zn was calibrated by adopting a pot culture experiment employing 21 representative soil samples. From this it is possible to extrapolate this critical value of 0.77ppm for other soils within this district to make predictions on the probabilities of responses of tomato

to added Zn based on the initial soil test values of Zn as suggested and elaborated by Cate and Nelson (1965). Based on the critical value of 0.77ppm of Zn the following are the classification of soils in relation to the expected crop responses.

Responsive soils: Shanmugasundarapuram (S_1), Allinagaram (S_2), Mottanoottu (S_3), Pulikuthi (S_4), Annanji (S_5), Silvarpatti (S_6), T.Renganathapuram (S_7),

Non responsive soils: Jayamangalam (S_8), D.Vadipatti (S_9), A.Renganathapuram (S_{10}), Devadanapatti (S_{11}), Kombai (S_{12}), Appipatti (Erasai) (S_{13}), Govindanagaram (S_{14}), Koduvilarpatti (S_{15}), Sathakoilpatti (S_{16}), A.Mallingapuram (S_{17}), Pannaipuram (S_{18}), Karkodai (S_{19}), Vaigai Dam (S_{20}), Ramasamynaickenpatty (S_{21}).

PARTITIONING SOIL TEST ZINC RESPONSE DATA INTO THREE CLASSES (TABLE 4)

A three way partitioning of Zn soil test data was also attempted to subdivide the responsive soils falling below critical level value of Zn into highly responsive and moderately responsive ones to Zn addition to enhance the precision of response. Accordingly the above calibration procedure yielded a critical value of Zn (0.80ppm) to divide the soils of Theni district into responsive and non-responsive soils. Further a finer partition was made to classify and group the responsive soils into highly and moderately responsive ones by extrapolating another partition line (Critical level of 0.61ppm) which coincides with the highest range of class sum square in 3 class model.

Thus in the present study the soil with a Zn soil test value above 0.80ppm might not respond to Zn application whereas in soils with Zn soil test values ranging from 0.62 to 0.79 ppm, the probability of obtaining response is moderate. However the soils with Zn soil test values less than 0.61 ppm, the probability of profitable response would be of greater magnitude.

Realising the seriousness of the present state of escalation of cost of fertilizer inputs, a well planned and meticulous use of fertilizer to achieve maximum profits is the need of the hour. Thus emphasis was given to divide even the responsive soils into highly responsive and moderately responsive. The above venture could be possible through a three-class model approach proposed by Cate and Nelson (1971).

In consonance with the above ideas of 3 model classification, the soils of Theni district have been justifiably and profitably grouped into very high responsive soils (the soil test Zn values <0.61 ppm), moderately responsive soils (the soil test value for Zn is 0.62 to 0.79ppm), and non-responsive soils (the soil test value for Zn >0.80 ppm) for Zn application. The above 3 way instead of two way classification of the soils would definitely help the farmers of Theni district to fertilize their tomato and other solanaeceous crops to derive the maximum profits by orienting them to selectively use the fertilizer input in the highly responsive regions of tomato and other vegetable growing areas.

Accordingly the soils of Theni district could be grouped as follows based on the magnitude of response to added Zn:

1. **Highly responsive** : Shanmugasundarapuram (S_1), Allinagaram (S_2), Mottanoottu (S_3), Pulikuthi (S_4)
2. **Moderately responsive** : Annanji (S_5), Silvarpatti (S_6), T.Renganathapuram (S_7), Jayamangalam (S_8),
3. **Non responsive** : D.Vadipatti (S_9), A.Renganathapuram (S_{10}), Devadanapatti (S_{11}), Kombai

(S_{12}), Appipatti (Erasai) (S_{13}), Govindanagaram (S_{14}), Koduvilarpatti (S_{15}), Sathakoilpatti (S_{16}), A.Mallingapuram (S_{17}), Pannaipuram (S_{18}), Karkodai (S_{19}), Vaigai Dam (S_{20}), Ramasamynaickenpatty (S_{21})

It follows from above that it helps the planners to allocate and mobilize more Zn fertilizers to the areas where the response is high as a policy decision making.

Conclusion

Out of 21 soils tested, 12 soils showed quadratic pattern of response to added Zn (S_1, S_2, S_4, S_6, S_7, S_{10}, S_{12}, S_{13}, S_{15}, S_{16}, S_{20} and S_{21}) and the physical optimum dose of Zn for these soils ranged from 6.25 to 15.41 kg ha^{-1} and the economic optimum dose ranged from 4.59 to 14.72 kg ha^{-1}. The soils S_3, S_5, S_8, S_{11}, S_{14}, S_{17} and S_{18} manifested linear response to added Zn. The rest of the soils (S_9 and S_{19}) did not respond to Zn application.

A critical level of 0.77ppm DTPA extractable Zn was determined by graphical as well as statistical method for soils of Theni in two-way classification method. Based on the critical value the soils are classified in relation to the expected crop responses as responsive soils (S_1 to S_7) and non- responsive soils (S_8 to S_{21}).

Finer division was made to classify and group the responsive soils into highly and moderately responsive. Eventually soils with the Zn status above 0.8ppm might not respond to Zn application. But in soils with values ranging from 0.62 to 0.79ppm the probability of obtaining response is moderate and soil possessing less than 0.61ppm the probability of profitable response would be of greater magnitude.

Table 1. Physical and economic optimum dose of Zn for tomato in different soils of theni district.

Soils	Locations	Optimum dose (Kg ha^{-1})	Maximum Yield (t ha^{-1})	Economic dose (Kg ha^{-1})	Highest Profit (Rs)
S_1	Shanmugasundarapuram (Pth)	15.19	5.86	14.55	26,666
S_2	Allinagaram (Smy)	10.22	2.78	9.58	8,120
S_3	Mottanoottu (Pvd)	←	Linear	→	-
S_4	Pulikuthi (Vyg)	15.41	2.47	12.28	6,242
S_5	Annanji (Pth)	←	Linear	→	-
S_6	Silvarpatti (Igr)	13.71	2.60	12.10	7,076
S_7	T.Renganathapuram (Smy)	12.57	3.41	11.22	11,912
S_8	Jayamangalam (Igr)	←	Linear	→	-
S_9	D.Vadippatti (Igr)	N.S	-	-	-

S_{10}	A.Renganathapuram(Plm)	12.55	2.96	10.77	9,260
S_{11}	Devadanapatti (Pvd)	←	Linear	→	-
S_{12}	Kombai (Smy)	10.21	3.30	9.79	11,282
S_{13}	Appipatti (Pvd)	10.89	2.65	10.15	7,396
S_{14}	M.Govindanagaram (Tlk)	←	Linear	→	-
S_{15}	Koduvilarpatti (Vyg)	11.58	1.72	10.75	1,808
S_{16}	Sathakovilpatti (Igr)	11.33	2.46	10.58	6,248
S_{17}	A.Mallingapuram (Pvd)	←	Linear	→	-
S_{18}	Pannaipuram (Smy)	←	Linear	→	-
S_{19}	Karkodai (Pvd)	N.S	-	-	-
S_{20}	Vaigai Dam (Pth)	6.25	2.22	3.98	4,784
S_{21}	Ramasamynaickenpatti (Pvd)	13.45	2.93	12.08	9,032

Table 2. Response of tomato to graded levels of Zn application in different soils of theni ditrict.

Soils	Locations	Linear / Quadratic	Best fit R^2	Zn Levels (kgha^1)	Tomato yield (t ha^{-1})	
					Actual	Predicted
S_1	Shanmuga sundarapuram (Pth)	Y = 4.062 + 0.237 X - 0.0078 X^2	0.60*	0.0	4.32	4.06
				5.6	4.37	5.14
				11.2	6.15	5.74
				16.8	5.58	5.84
S_2	Allinagaram (Smy)	Y = 1.9630 + 0.1595 X - 0.0078 X^2	0.97**	0.0	1.94	1.96
				5.6	2.68	2.61
				11.2	2.70	2.77
				16.8	2.46	2.44
S_3	Mottanoottu (Pvd)	Y = 1.814 + 0.05786 X	0.91**	0.0	1.75	1.84
				5.6	2.30	2.14
				11.2	2.33	2.46
				16.8	2.82	2.79
S_4	Pulikuthi (Vyg)	Y = 2.0860 + 0.0493 X - 0.0016 X^2	0.77**	0.0	2.05	2.09
				5.6	2.42	2.31
				11.2	2.33	2.44
				16.8	2.50	2.46
S_5	Annanji (Pth)	Y = 1.175 + 0.464 X	0.95**	0.0	1.22	1.18
				5.6	1.42	1.43
				11.2	1.59	1.69

				16.8	2.03	1.95
S_6	Silvarpatti (Igr)	Y = 2.0175 + 0.085 X - 0.0031 X^2	0.96**	0.0	1.99	2.02
				5.6	2.15	2.40
				11.2	2.23	2.58
				16.8	2.78	2.57
S_7	.Renganatha-puram (Smy)	Y = 2.8215 + 0.093 X - 0.0037 X	0.66**	0.0	2.75	2.82
				5.6	3.44	3.23
				11.2	3.18	3.40
				16.8	3.40	3.34
S_8	Jayamangalam (Igr)	Y = 2.098 + 0.0907 X	0.77*	0.0	2.39	2.10
				5.6	2.42	2.61
				11.2	2.61	3.11
				16.8	4.02	3.62
S_9	D.Vadippatti (Igr)	Y = 1.8925 + 0.185 X - 0.0088 X^2	0.26	0.0	1.62	1.89
				5.6	3.47	2.65
				11.2	2.04	2.86
				16.8	2.78	2.52
S_{10}	A.Renganathapuram (Plm)	Y = 2.524 + 0.0703 X -- 0.0028 X^2	0.65*	0.0	2.58	2.52
				5.6	2.66	2.83
				11.2	3.13	2.96
				16.8	2.86	2.91
S_{11}	Devadanapatti (Pvd)	Y = 1.757 + 0.0155 X^2	0.81**	0.0	1.77	1.76
				5.6	1.79	1.84
				11.2	2.00	1.93
				16.8	1.99	2.02
S_{12}	Kombai (Smy)	Y = 2.048 + 0.245 X – 0.012 X^2	0.72**	0.0	2.18	2.05
				5.6	2.66	3.04
				11.2	3.73	3.29
				16.8	2.75	2.78
S_{13}	Appipatti (Pvd)	Y = 1.8560 + 0.146 X – 0.0067 X^2	0.97**	0.0	1.88	1.86
				5.6	2.39	2.46
				11.2	2.72	2.65
				16.8	2.39	2.49
S_{14}	M.Govindanagaram (Tlk)	Y = 1.204 + 0.07214 X	0.81**	0.0	1.39	1.20
				5.6	1.47	1.61
				11.2	1.73	2.01
				16.8	2.65	2.42
S_{15}	Koduvilarpatti (Vyg)	Y = 0.8965+ 0.1422 X- 0.00614 X^2	0.83**	0.0	0.96	0.90
				5.6	1.31	1.50
				11.2	1.91	1.72
				16.8	1.49	1.55
S_{16}	Sathakovilpatti (Igr)	Y = 1.6000 +	0.63*	0.0	1.71	1.60
				5.6	1.91	2.24

		0.1518 X –		11.2	2.79	2.46
				16.8	2.15	2.26
S_{17}	A.Mallingapuram (Pvd)	Y = 1.602 + 0.0816 X	0.62*	0.0	1.67	1.60
				5.6	2.29	2.06
				11.2	1.85	2.52
				16.8	3.34	2.97
S_{18}	Pannaipuram (Smy)	Y = 3.82 + 0.053 X	0.53*	0.0	3.62	3.87
				5.6	4.17	4.12
				11.2	4.89	4.41
				16.8	4.37	4.71
S_{19}	Karkodai (Pvd)	Y = 1.3185+ 0.088 X – 0.0041 X	0.43	0.0	1.41	1.32
				5.6	1.41	1.68
				11.2	2.07	1.79
				16.8	1.56	1.64
S_{20}	Vaigai Dam (Pth)	Y = 2.134 + 0.0275 X – 0.0022 X^2	0.99**	0.0	2.14	2.13
				5.6	2.34	2.22
				11.2	2.74	2.17
				16.8	3.22	1.98
S_{21}	Ramasamynaic kenpatti (Pvd)	Y = 2.233 + 0.103 X - 0.00383 X^2	0.77**	0.0	2.31	2.23
				5.6	2.46	2.69
				11.2	3.14	2.91
				16.8	2.81	2.88

Table 3. Partitioning soil test- Zinc response data in to two classes

Soils	Grain Yield (g pot^{-1})		Bray Percent Yield at Zn_2 (ppm) (Y)	DTPA Zn (ppm)	Postulated critical limit (X') (ppm)	Mean Bray percent yield in population	CSS 1	Mean Bray Percent yield in population II	CSS 2	R^2= TCSS-(CSS 1+CSS2) TCSS
	Zn_0	**Zn_2**								
S_1	43.02	86.05	49.99	0.24	-	-	-	-	-	-
S_2	98.13	167.83	58.47	0.46	-	-	-	-	-	-
S_3	76.94	125.73	61.19	0.56	0.510	54.23	35.96	1430.01	78.40	0.42
S_4	194.34	292.95	66.34	0.60	0.580	56.55	68.25	1117.20	79.36	0.53
S_5	84.80	122.54	69.20	0.62	0.610	61.50	140.13	937.68	80.13	0.57
S_6	63.50	92.99	68.29	0.66	0.640	61.04	223.41	810.82	80.81	0.59
S_7	87.09	121.63	71.60	0.76	0.710	62.25	267.23	643.62	81.64	0.64
S_8	162.75	219.95	73.99	0.78	0.770	63.58	342.22	535.51	82.36	0.65*
S_9	96.28	123.09	78.22	0.82	0.800	64.88	436.99	460.03	83.01	0.64
S_{10}	62.37	77.90	80.06	0.84	0.830	66.37	595.08	435.21	83.41	0.59
S_{11}	78.58	105.05	74.80	0.88	0.860	67.74	763.87	423.01	83.71	0.53
S_{12}	54.80	71.60	76.50	0.94	0.910	68.38	809.24	335.70	84.60	0.55
S_{13}	73.10	91.60	79.80	1.08	1.010	69.05	869.72	262.80	85.50	0.55
S_{14}	116.19	140.73	82.56	2.64	1.86	69.88	976.31	226.25	86.21	0.52
S_{15}	79.66	90.06	88.45	2.94	2.79	70.79	1125.59	221.00	86.73	0.47
S_{16}	104.16	141.14	73.80	3.04	2.99	71.96	1416.80	207.57	86.45	0.36
S_{17}	123.87	142.99	86.63	3.10	3.07	72.08	1419.96	15.57	88.98	0.43
S_{18}	92.08	105.07	87.64	3.40	3.25	72.93	1619.24	8.70	89.57	0.36
S_{19}	89.50	100.17	88.86	3.74	3.57	73.75	1823.47	3.76	90.21	0.28
S_{20}	75.09	83.29	90.16	6.87	5.31	74.55	2039.72	1.04	90.88	0.19
S_{21}	107.41	117.26	91.60	6.93	6.90					

Table 4. Partitioning soil test- Zinc phosphate data in to three classes.

Soils	Check yield (Y_0)	Maximum Yield (Ymax)	Actual Yield increase (Ymax-Y_0)	Zn soil Test value (X) (ppm)	Partition between soil test values (ppm)	Class sum of squares 2 class model	Range in class sum of squares 3 class model
S_1	43.02	86.05	43.03	0.24	0.46 - 0.56	1396.43	2100.96 - 5944.27
S_2	98.13	167.83	69.70	0.46	0.56 - 0.60	1788.27	2451.32 - 5791.63
S_3	76.94	125.73	48.79	0.56	0.60 - 0.62	5643.76	5885.68 - 7060.67*
S_4	194.34	292.95	98.61	0.60	0.62 - 0.66	5269.60	5482.06 - 6756.54
S_5	84.80	122.54	37.74	0.62	0.66 - 0.76	4569.60	5059.71 - 5894.77
S_6	63.50	92.99	29.49	0.66	0.76 - 0.78	4399.16	4631.72 - 5426.13
S_7	87.09	121.63	34.54	0.76	0.78 - 0.82	5781.50	5802.07 - 6269.58*
S_8	162.75	219.95	57.20	0.78	0.82 - 0.84	5279.92	5237.49 - 5717.63
S_9	96.28	123.09	26.81	0.82	0.84 - 0.88	4242.82	4268.03 - 4711.01
S_{10}	62.37	77.90	15.53	0.84	0.88 - 0.94	3975.86	3977.65 - 4385.58
S_{11}	78.58	105.05	26.47	0.88	0.94 - 1.08	3279.83	3284.40 - 3709.96
S_{12}	54.80	71.60	16.80	0.94	1.08 - 2.64	2770.72	2772.77 - 3212.14
S_{13}	73.10	91.60	18.50	1.08	2.64 - 2.94	2613.80	2803.52 - 2987.28
S_{14}	116.19	140.73	24.54	2.64	2.94 - 3.04	1873.54	2257.85 - 2424.85
S_{15}	79.66	90.06	10.40	2.94	3.04 - 3.10	2386.60	2622.61 - 2727.67
S_{16}	104.16	141.14	36.98	3.04	3.10 - 3.40	2139.54	2404.14 - 2474.35
S_{17}	123.87	142.99	19.12	3.10	3.40 - 3.74	1642.48	1642.48 - 1976.96
S_{18}	92.08	105.07	12.99	3.40	3.74 - 6.87	1090.53	1090.53
S_{19}	89.50	100.17	10.67	3.74			
S_{20}	75.09	83.29	8.20	6.87			
S_{21}	107.41	117.26	9.85	6.93			

classification	Range	Mean
	0.78 - 0.82	0.80 - Two way classification
	0.60 - 0.62	0.61 - Three way

References

Cate RB and Nelson LA 1965. A rapid method for correlation of soil test analysis with plant response data. International soil Testing Series Tech. Bull. I. North Carolina State Univ. Agric. Expt. Station, Raleigh.

Cate RB and Nelson LA 1971. A Simple statistical procedure for partitioning soil test correlation data into two classes. *Proc. Soil. Sci. Soc. Am*. 35: 658-659.

Snedecor GW and Cochran WG 1967. Statistical Methods (Sixth edition). Oxford and IBH publishing Co., Calcutta. p.593.

Olmstead PS and Tukeys JW 1947. A corner test of association. *Ann. Math. Stat*. 18: 495-513.

Studies on evaluation of different cardamom curing systems

Dileep PV[2], Hrideek TK[1], Kuruvilla KM[1] and Thomas J[1]
1 Indian Cardamom Research Institute, Myladumpara, Kailasanadu, Idukki, Kerala.
2 Centre for Food Science and Technology, University of Calicut, Kerala- 673635.

Abstract

A study has been conducted to evaluate different curing practices employed in the processing of cardamom in Idukki District of Kerala. Conventional curing chamber with firewood as fuel and improved curing systems using LPG, kerosene and diesel were evaluated with regard to their efficiency in terms of curing time duration, cost of drying, recovery ratio, etc. Results revealed that the curing systems using various sources of fuel differed in their performance in cardamom drying. This may be perhaps dued to infra structure makeup of systems and their capability of variation in maintaining the abiotic factors such as temperature and humidity. Further, the quality of the cardamom capsules with regard to moisture content, volatile oil, oleoresine, chlorophyll, total ash and acid soluble ash content were found out under different systems. Results indicated that Kardi and Zindri systems helped to maintain high value of oleoresine compared to other curing systems. All the curing systems used in this study provided export quality traits stipulated for cardamom as per the ASTA specifications.

Introduction

Cardamom, the 'queen of spices' belonging to the family *Zingiberaceae* is a native of evergreen forests of Western Ghats of India. Among the spices of India, cardamom (*Elettaria cardamomum*Maton) occupies an important position next to black pepper. It is a highly priced commodity and is valued for its very pleasant aroma and flavour. The quality of cardamom is very important in national as well as international markets as it fetches maximum price for good quality capsules.

The peak period of harvest begins in the month of August and ends in January. It takes 120 to 135 days for a flower to attain the capsule maturity ready for harvest. The harvesting of immature capsules adversely affects the quality of the produce. Harvested capsules of cardamom are almost juicy, therefore curing is essential before they are stored and marketed. The cardamom curing may be defined as the process in which the moisture content of freshly harvested cardamom capsules is reduced from 80% to 8-12% at optimum temperature of 45 to55^{o}C, so as to retain its green colour and volatile oil to a maximum extent (Pruthi, 1998).

Different methods commonly adopted for cardamom curing are, natural drying and artificial drying. The retention of flavour and aroma is possible through curing in controlled temperature, air velocity and humidity inside the curing chamber. The marketing strategy of cardamom is wholly depends on the quality of produce. In order to good produce, the best curing type is to be identified in view of the above a study is proposed with the objectives mentioned below:

1. Survey the cardamom plantations to find out the methods of different cardamom processing units
2. Evaluation of the performance of different types of curing chambers with reference to efficiency and quality of produce.
3. Biochemical analysis of the samples obtained under different modes of curing.

Materials and Method

The study was undertaken in the Indian Cardamom Research Institute, Myladumpara, Idukki, Kerala. A survey has been conducted in cardamom plantations to locate different types of curing units employed in the post harvest processing of cardamom. Details of the curing systems employed in the present study are described below.

1. Conventional drying/ kiln drying (with different roof): In this system, the heat required for curing is generated by burning firewood in an external furnace and the heat is conducted through flue pipes arranged in the lower floor of the curing chamber that in turn heats up the air in that chamber. The time required for drying varies depending upon the efficiency of curing house.

2. Liquid petroleum gas system: In this system LPG is used as fuel. Here the curing method is same as firewood but instead of flue pipes, infrared radiant burners fired with liquid petroleum gas are used.

3. Kerosene system: In this system kerosene is used as the fuel. To avoid the smell of kerosene due to the smoke coming out at the time of lightening, the stove is lighted outside the room and then placed on the floor below the trays. During the first 6 to 8 hours the ventilators are opened periodically, at that time most of the moisture escapes from the capsules.

4. Kardi drying system: This is one of the modern methods of curing system employed by the large growers, where diesel is used as fuel. Capacity of the chamber ranges from 150 - 500 kg. In Kardi drying system, a control panel controls all operation.

5. Multi fuel system (LPG with fire wood system): The fuel used is a combined form of LPG and firewood. To control the temperature during processing, an automatic temperature control stetted before both the burners and firewood are lightened.

6. Zindry system: This is a most modern type of cardamom drier. Here, firewood and diesel are used as fuel source or it can also be used with diesel alone. In combined system, the heat is generated from the outer furnace. Following analysis were done by using the samples collected during the survey.

Estimation of chlorophyll content, volatile oil, determination of oleoresin- (MDC), moisture distillation method, total ash, acid insoluble ash was done by the procedures described in Anonymous (2000).

Results and Discussion

The cardamom of commerce is the dried fruits obtained after post harvest processing. According to Govindarajulu (1998) about 80 percentage of the cardamom plantations of Idukki utilize conventional curing chambers. Considering the environ45mental problems caused by the deforestation, studies have been initiated in the beginning of the last decade to find out alternate fuel source for cardamom processing. As a result, LPG, Kerosene, Diesel, Electricity etc. are being popularized as fuel sources in the cardamom processing. The performances of different cardamom processing units are presented in Table-1. Results revealed that the performance of driers varied each other with regard duration of curing time, cost of drying etc. The kerosene used system took more time to completing the process of curing (38-40 hours). The systems in which LPG with firewood and diesel with firewood used as fuel source took less time for drying process (20-22hours).

With regard to temperature maintenance, all the systems exhibited varied performance. The temperature ranged from 30 to 85^{o}C. However in the initial 2 to 3

hours the temperature maintained at 30 to45^{o}C .The low temperatures maintained in the conventional curing chamber, where as in Kardi and Zindry type the temperature was maintained to the tune of 45 to 85^{o}C. Similar observations were also made by earlier workers (Umamaheswari *et al.*, 2001).

The long duration of processing in the conventional system is due to the maintenance of low temperature throughout the process. However in the improved types temperature is maintained at high levels and perhaps, due to this the curing process is completed in lesser time. The investment for the fabrication of Kardi and Zindry is high compared to other systems. But it provides good quality capsules.

Capsule Quality: Quality parameters taken into studies include chlorophyll content, moisture, volatile oil, oleoresin, total ash and acid insoluble ash. The results are presented in tables 2 and 3. Results revealed that the total chlorophyll content ranges from 0..404 to 0.730 and is higher in the samples obtained from Zindry (0.730) and LPG with firewood systems (0.715) (Table 2).

Oleoresin percentage also shows much variation in the cardamom capsules processed by different methods. The cardamom produced in conventional system with different roof shows highest oleoresin percentage.Among the Kardi and Sindry system the percentage of oleoresin is also good, which ranges from 2.481 to 2.595 percentage (Table.2).

With regard to volatile oil, cardamom capsules processed under conventional system with GI roof, LPG with firewood showed relatively more percentage of oil content. Zindry, kardi and conventional system with RCC and tile roof show 6 percentage volatile oil, which is low but better than the cardamom processed in kerosene and LPG systems where the oil content is low (5.5%) (Table.2). It indicates that the oil content depletes in the samples analyzed from the kardi and zindry systems. It may be due to the fact that during the processing under higher temperature, the oil from the seeds would have been oozed out. Similar findings also were reported By Zachriah (2002).

The moisture content of the processed cardamom samples varied under different systems (Table.3). The processed capsules obtained from the kerozine system showed comparatively higher moisture content (11.5 %) than kardi (7 %)and zindry (7.5 %). Low moisture level accelerates the loss of volatile flavouring compounds and excess moisture produces off flavours, fungus and mould growth. It also affects the green colour of cardamom. According to Menon (1995), the colour of the cardamom can be retained for a about 10 months storage, if the moisture level is reduced to 10% and stored in 300 gauge high density black coloured polythene lined gunny bags.

The total ash and acid insoluble ash content in the samples also had slight variation under different systems of curing. Total ash varies from 7.86 to 8.61 % in conventional curing systems. But in kardi and zindry contains 8.14 and 6.59 % respectively, while kerosene system has less ash content as 6.13 percentages. Acid insoluble ash content in all driers are in the range of 0.81 to 0.87 except kerosene and zindry, which have an acid insoluble ash content 0.72 and 0.75 respectively (Table.3).

Comparison of the quality of cardamom with 'ASTA' specifications: An important element in spice business in the United States is ASTA. ASTA was formed with the initial intent of developing some standardization in the way spices were trade in the United States. ASTA has provided many specifications and methods to monitor the possible adulteration of spices. As per the ASTA specifications the cardamom of commerce should have the qualities described below.

Specifications	**Suggested limits**
Volatile oil	3.0% minimum
Moisture	12.0%maximum
Total ash	10.0% maximum
Acid insoluble ash	2.0% maximum

In the present study different curing systems used for processing cardamom capsules were evaluated with regard to the efficiency of the systems and the quality of the capsules processed under various systems. Among the systems, in terms of moisture Kardi and Zindry are found to be most efficient and bring about high quality produce. But in the case of volatile oil content, cardamom capsules from conventional systems have high quality. On comparison with ASTA specifications the cardamom capsules processed under Zindry and Conventional systems are on par. Among the systems, conventional and zindry driers are the most ideal and can be used for producing capsules meeting the requirements of ASTA.

Table. 1. Comparison of different cardamom curing systems

Parameters	Conventional curing	LPG system	Lpg+fire wood System	Kerosene System	Kardi drier	Zindry drier
Fuel source	Fire wood	LPG	LPgas+fire wood	Kerosene	Diesel	Diesel or Diesel+fire wood
Duration of curing (hours)	27-36	24-30	20-22	38 –40	20-24	20-22
Curing temperature (^oC)	30-65	30- 70	38-70	40-60	45-85	45-80
Capacity (kg)	300	80	500	100	500	350
Curing house dimension (mtr)	7.3x3.3x5.6	0.9x0.9x 1.5	1.3x1.3x 0.12	1.05x1.0 5x1.5	1.6x1.9x 1.6	1x1x0.6
Material of construction	Bricks	GI sheet	GI sheet	Wood	GI sheet	GI sheet
Colour of the produce	Deep green	Green	Green	Green	Deep green	Deep green
Recovery percentage	20- 21	20-21	20 – 21.5	20-20.5	20 –21	20 –21
Percentage of split	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Cost of the drier	Rs 1.1 lakh	Rs 25,000	Rs 1 lakh	Rs 30,000	Rs 1.75 lakh	Rs 1.80 lakh
Fuel consumption/ kg	0.90	0.133	0.05+0.6	0.18 lit	0.128 liter	0.1 liter
Cost of drying/ kg	Rs 1.52/kg	3.45/kg	Rs 1.85/kg	Rs.3.24 per kg	Rs 3.20/kg	Rs2.60/Rs1.60/kg

Table 2. Quality parameters of cardamom from different curing systems

Method of curing		Chlorophyll a/b	Chlorophyll Total	Oleoresin%	Oil %
Fire wood	RCC roof	1.718	0.457	2.635	6
	GI roof	1.765	0.604	2.655	6.5
	Tile roof	1.761	0.541	3.061	6
Kerosene		1.693	0.404	1.985	5.5
Kardi		1.997	0.724	2.481	6
LPG		1.711	0.511	1.992	5.5
Zindry		1.961	0.730	2.595	6
LPG with Firewood		1.713	0.715	2.822	6.5

Table 3. Quality parameters of cardamom from different curing systems

Method of curing		Moisture %	Total ash %	Acid insoluble ash %
Fire wood	RCC roof	10	7.86	0.861
	GI roof	8	8.05	0.807
	Tile roof	10.5	8.61	0.864
Kerosene		11.5	6.13	0.716
Kardi		7	8.14	0.867
LPG		9	9.12	0.781
Zindry		7.5	6.59	0.747
LPG with Firewood		10.5	8.57	0.818

Table. 4. Comparison with ASTA specifications of ground cardamom

Method of curing		Oil %	Moisture %	Total ash	Acid insoluble ash
ASTA Specification		0.3 % minimum	12 % maximum	10 % maximum	2.0^% maximum
Fire wood	RCC roof	6	10	7.86	0.86
	GI roof	6.5	8	8.05	0.81
	Tile roof	6.4	10.5	8.64	0.87
Kerosene		5.5	11	6.13	0.72
Kardi		6	7	8.14	0.87
LPG		6.5	9	9.12	0.78
Zindry		6	7.5	6.58	0.74
LPG with firewood		6.5	10.5	8.57	0.81

References

Anonymous 2000. Official Analytical Methods of the Spices Board.First edition: 3-23.

Govindarajulu V 1998. Green colour- a potential indicator of cardamom capsules. Post harvest technology of cardamom: 5-7.

Menon KRK 1995. Importance of chemical analysis in spices. *Spice India* 8: 9-11.

Umamaheswari R, Potty SN and Mohanan KV 2001. Studies on curing cardamom with LPG as an alternative fuel for firewood. *Spice India* 15(5): 6-9.

Zachariah John T 2002. Chemistry of cardamom. Cardamom-The genus *Elettaria*: 69-71

Effect of varieties and date of planting on growth and yield of cassava under rice fallow situation

Balasubramanian R, Swaminathan V, Malarvizhi P, Sakthivel S and Murali Krishnasamy S.
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu– 625 104.

Abstract

Field experiment was carried out during 2003-04 at Agricultural College and Research Institute, TNAU, Madurai to study the effect of varieties and date of planting of cassava under rice fallow situation. The experiment was conducted in two factor Factorial Randomised Block Design with varieties viz., CO 2, CO 3 and CO(TP)4 as first factor and date of planting viz., September, October and November as second factor with three replication. Kharif rice was grown between June and September. Cassava setts were planted in ridges and furrows at 90 x 90 cm spacing. Growth, yield attributes and yield were recorded. The results showed that among different varieties, CO 2 recorded significantly higher plant height, number of leaves per plant, tuber length, tuber circumference, number of tubers per plant, tuber weight per plant and tuber yield per plant. It was followed by variety CO (TP) 4. But number of branches per plant was significantly higher in CO 3 followed by CO(TP) 4. Among various dates of planting, cassava planted in November recorded significantly higher plant height, number of leaves per plant, tuber length, tuber circumference, number of tubers per plant, tuber weight per plant and tuber yield per plant. Among various treatment combinations, variety CO 2 planted in November registered significantly higher plant height (265.1 cm), tuber length (37.8 cm), tuber circumference (33.97 cm), number of tubers per plant (10.17), tuber weight per plant (439 g) and tuber yield per plant (4.46 kg). This was followed by CO 2 planted in September and CO(TP) 4 planted in November. But number of branches per plant was higher in CO 3 planted in November. Number of leaves per plant was not significant.

Key words: Cassava varieties, time of planting, growth, yield, rice fallow

Introduction

Tuber crops are one of the most important sources of carbohydrates in the world. Among various tuber crops, cassava ranks first in India. It is a tropical root crop in which the adventitious roots developing from the stem are modified into tubers (Anon, 1999). Generally, cassava is cultivated under garden land conditions. In rice based cropping system alternate crops are being tried to improve the yield potential of the farm and to get higher monetary income especially when there is shortage of water for rice cultivation. Various crops like maize, sesame and sunflower are tried in rice tract during kharif season. After rice cultivation there is scope for cassava cultivation during rabi or late rabi season under rice fallow situation. Different cassava varieties viz., CO 2, CO 3 and CO(TP) 4 were released for cultivation under Tamil Nadu condition (Veeraragavathatham, 1998). Keeping this in view a study was under taken to find out the suitability of varieties and time of planting of cassava under rice fallow condition.

Materials and method

Field experiment was carried out during 2003-04 at Agricultural College and Research Institute, TNAU, Madurai to study the effect of varieties and date of planting of cassava under rice fallow situation. The experiment was conducted in two factor

Factorial Randomised Block Design with varieties viz., CO 2, CO 3 and CO(TP) 4 as first factor and date of planting viz., September, October and November as second factor with three replication. *Kharif* rice was grown between June and September. Cassava setts were planted in ridges and furrows at 90 x 90 cm spacing under rice fallow situation. Growth, yield attributes and yield were recorded and statistically analyzed.

Results and Discussion

Growth: The experimental results revealed that highly significant differences prevailed among the different varieties and time of sowing in improving plant height, number of branches and number of leaves per plant (Tables 1 and 2). Among the three varieties studied CO 2 recorded significantly higher plant height (257.7 cm) and number of leaves per plant (356) which was followed by CO(TP) 4. This could have been due to the better adaptability of the variety Co 2 over other varieties under rice fallow situation. But the variety CO 3 was found to produce the highest number of branches (9.16) compared to CO 2 and CO(TP) 4 varieties. This could be due to the heavily branching nature of the variety CO 3 (Veeraragavathatham, 1998).

With regard to the time of planting, November planting gave the best performance by improving the growth of cassava with enhancement in plant height, number of leaves per plant and number of branches per plant. During the months of September and October the field with sandy clay loam nature was too wet due to the influence of continuous rainfall and during November the field was comparatively free from the above problem and was found with better aerated condition. This might have resulted in better growth of the crop with greater uptake of nutrients.

The treatment combination CO 2 with the time of planting in November recorded the higher plant height and number of leaves per plant which was followed by Co 2 planted in the month of September. This could be due to the better adaptation of CO 2 under favourable climatic and soil conditions resulting in better growth of the cassava.

Yield attributes: CO 2 recorded significantly improved the yield attributes like tuber length, tuber circumference, number of tubers per plant and tuber weight per plant (Tables 2 to 4). It was followed by variety CO(TP) 4. This could be due to the enhanced growth put forth by CO 2 under rice fallow situation which resulted in improved tuber characters.

Among various dates of planting, cassava planted in November recorded significantly higher tuber length, tuber circumference, number of tubers per plant and tuber weight per plant. There was improvement in growth of cassava during November due to better aerated condition with rain free periods which resulted in enhanced tuber characters.

Among the different treatment combinations, planting of the variety CO 2 in the month of November improved the tuber characters viz., tuber length, tuber circumference, number of tubers per plant and tuber weight per plant. The better adaptation of CO 2 under rice fallow situation and favourable climate and soil conditions improved all the tuber characters due to the improvement in growth of the crop.

Yield: The experimental results on the trait namely tuber yield per plant clearly showed the predominant influence of the varieties and time of planting (Table 4). The tuber yield per plant ranged from 2.81 to 4.46 kg. The highest yield was obtained from the variety CO 2 (3.97 kg) as compared to CO(TP) 4 and CO 3 with the yield of 3.42 kg and 3.00 kg respectively. Planting of the setts in November was noticed to increase the yield per plant upto 3.83 kg, while planting in the month of October recorded the lowest yield of 3.12 kg per plant.

Among various treatment combinations, variety CO 2 planted in November registered significantly higher tuber yield per plant (4.46 kg). This was followed by CO 2

planted in September and CO(TP) 4 planted in November (3.73 kg). The improvement in growth with enhanced nutrient uptake considerably improved the tuber characters which increased the tuber yield per plant.

From these results, it can be concluded that cassava variety CO 2 is found to be suitable variety under rice fallow condition followed by CO(TP) 4. The variety CO 2 can be planted during November and CO(TP) 4 can also be planted in November for getting higher tuber yield under rice fallow condition.

Table 1. Effect of varieties and time of sowing on plant height (cm) and number of branches of cassava

Varieties/ time of sowing	Plant height (cm)				No. of branches per plant			
	SEP	OCT	NOV	Mean	SEP	OCT	NOV	Mean
CO 2	260.7	247.1	265.1	257.7	5.00	4.60	5.67	5.09
CO 3	206.4	195.5	217.9	206.6	9.20	8.40	9.87	9.16
CO(TP) 4	257.9	240.1	261.5	253.2	6.30	5.90	6.97	6.39
Mean	241.7	227.6	248.2	239.1	6.83	6.30	7.50	6.88
	V	S	V x S		V	S	V x S	
SEd	0.81	0.81	1.41		0.06	0.06	0.11	
CD (0.05)	1.73	1.73	2.99		0.13	0.13	0.22	

Table 2. Effect of varieties and time of sowing on number of leaves and tuber length (cm) of cassava

Varieties / time of sowing	No. of leaves per plant				Tuber length (cm)			
	SEP	OCT	NOV	Mean	SEP	OCT	NOV	Mean
CO 2	357.0	336.0	374.9	356.0	35.80	33.77	37.80	35.79
CO 3	313.5	305.5	322.2	313.7	24.73	22.73	26.97	24.81
CO(TP) 4	329.3	318.5	348.8	332.2	32.70	30.13	34.57	32.47
Mean	333.3	320.0	348.6	334.0	31.08	28.88	33.11	31.02
	V	S	V x S		V	S	V x S	
SEd	1.70	1.70	2.94		0.27	0.27	0.31	
CD (0.05)	3.60	3.60	NS		0.56	0.56	0.66	

Table 3. Effect of varieties and time of sowing on tuber circumference (cm) and number of tubers of cassava

Varieties / time of sowing	Tuber circumference (cm)				No. of tubers per plant			
	SEP	OCT	NOV	Mean	SEP	OCT	NOV	Mean
CO 2	31.50	30.13	33.97	31.87	9.40	8.23	10.17	9.27
CO 3	27.07	26.43	28.53	27.34	7.37	7.27	8.50	7.71
CO(TP) 4	28.37	26.27	30.87	28.50	8.33	7.73	9.10	8.39
Mean	31.50	30.13	33.97	31.87	8.37	7.74	9.26	8.46
	V	S	V x S		V	S	V x S	
SEd	0.22	0.22	0.38		0.13	0.13	0.22	
CD (0.05)	0.46	0.46	0.80		0.26	0.26	0.46	

Table 4. Effect of varieties and time of sowing on tuber weight (g) and tuber yield per plant (kg) of cassava

Varieties / time of sowing	Tuber weight per plant (g)				Tuber yield per plant (kg)			
	SEP	OCT	NOV	Mean	SEP	OCT	NOV	Mean
CO 2	426.7	420.3	439.0	428.7	4.01	3.46	4.46	3.97

CO 3	389.4	386.2	393.0	389.6	2.87	2.81	3.34	3.00
CO(TP) 4	408.3	403.0	410.3	407.2	3.40	3.12	3.73	3.42
Mean	408.1	403.2	414.1	408.5	3.41	3.12	3.83	3.45
	V	S	V x S		V	S	V x S	
SEd	1.46	1.46	2.53		0.09	0.09	0.12	
CD (0.05)	3.10	3.10	5.37		0.12	0.12	0.25	

References

Anonymous 1999. Package of practices for cassava. Central Tuber Crops Research Institute, Sreekariyam, Thirvanthapuram.

Veeraragavathatham D, Jawaharlal M and Seemanthini Ramdas 1998. A guide on vegetable culture. Suri Associate, Coimbatore.

Acknowledgement

The authors acknowledge the Indian Council of Agricultural Research, New Delhi (ICAR-Adhoc cassava scheme) for providing finance for conducting the field experiment.