Selection of promising lines, production of somaclones and their utilization in paprika (*Capsicum annuum* L.)

Thesis submitted to the University of Calicut
for the award of Doctor of Philosophy in Botany

by
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University of Calicut
Kerala, India.
2001.

Certificate

Certified that the Ph.D thesis entitled "Selection of promising lines, production of somaclones and their utilization in Paprika (*Capsicum annuum* L.)", is a bonafide research work carried out by Ms.Anu Augustine at the Indian Institute of Spices Research (IISR), Calicut- 673 012, under my supervision and that it has not previously formed the basis for award of any other degree or diploma. All sources of help received by her during the course of this investigation have been duly acknowledged. Certified that she has also passed the required qualifying examination.

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Declaration

I hereby declare that the thesis entitled 'Selection of promising lines, production of somaclones and their utilization in paprika (*Capsicum annuum* L.)', is a bonafide research work carried out by me at the Indian Institute of Spices Research (IISR), Calicut- 673 012, under the guidance of Dr. K.V.Peter, (Former Director, IISR), Director of Research, Kerala Agricultural University, Vellanikkara, Trichur. No part of this thesis has ever been submitted previously to any university for the award of any degree or diploma.

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Acknowledgement

I t is a matter of pleasure to glance back and recall the path traveled during the days of hard work and study. This work would be incomplete if I do not attend to the task of acknowledging the help I received during this endeavor of mine. Whatever I write here would only be a deceptive reflection of the tumult of feeling that is in my heart at this moment. I would like to recall all the people who are directly or indirectly concerned with my Ph.D studies.

I feel scanty for words to express my deep gratitude to my guide and chairman Dr. K.V.Peter, (Former Director, IISR), Director of Research, Kerala Agricultural Research, who was my supervising teacher for this study, for his valuable guidance, constant encouragement and sincere help through out the period of this investigation and preparation of the document.

I am indebted to Dr. Y.R.Sarma, Director, Indian Institute of Spices Research, Calicut, for providing the facilities in the institute to conduct my Ph.D work.

My profound thanks are due to Dr. P.N.Ravindran, Project Co-ordinator, Indian Institute of Spices Research, Calicut and Dr. Shylaja Ravindran for introducing me to this institute and for providing the facilities. Dr. Ravindran was always a source of support and guidance through out the investigation.

Dr. Nirmal Babu, Senior Scientist, Biotechnology Facitlity, IISR was indeed the person whom I approached for all practical purposes and he was the person who supervised my tissue culture work. I thank him for extending the facilities in the Biotechnology lab to carry out this work. I am deeply indebted to Dr. Nirmal Babu for all the help and guidance during the course of this study and for the valuable suggestions during the preparation of this document.

I am extremely grateful to Dr. P.A.Mathew for initiating me in to paprika research and for supplying the initial planting material.

I would always remember the help and affection provided by Dr. B.Chembakam, Sr. Scientist, Biochemistry, IISR, Calicut. I also thank Dr. John .T. Zacharia for helping me in my quality analysis.

I also thank Scientists, Ms. K.P.M.Dhamayanthi, Dr. M. Anandraj, Dr. J. Rema and Mr. B.Krishnamoorthi for their help.

Dr. Jose Abraham, Principal Scientist, Social Sciences, never let me down whenever I approached him and he patiently helped me in my statistical analysis. I also thank him for allowing me to use the computer facilities in his division. I would also like to thank Mr.

Jayaraj and Mr. Sudhakaran of computer cell for their help in the preparation of the document and photographs.

I also recall the help received from Mr. Azghar Sheriff, Mr. Augusty and Mr. Ravindran for their help in literature collection and documentation.

My colleagues and friends were always a source of strength and moral support. I would like to thank Dr. K. Shamsudeen, Ms. Sajina Adams, Ms. Minoo Divakaran, Ms. Geetha.S.Pillai, Ms. Rajalakshmy. K, Ms. A. B. Remashree, Mr. Anil Kumar, Mr. Benny Daniel, Mr. Dominic Joseph, Mr. Praveen .K, Mr.Stephan Jebakumar, Ms. Liji P, Ms. Girija. A, Ms. Sindhu B.P, Ms. Vimala Jose, Mr. Manoj .P. Das and Mr. Elango Mathavan for the help rendered by them.

I would like to thank Mr. V.P.Ramachandran, Mr. Venkitesh, Ms. Sharadha, Ms. Thankam and Mr. Sumesh for their assistance.

I thank the University Grants Commission (UGC) for funding this work.

I would also like to thank my family members, especially my son, Emil. R.Manuel for bearing with me through out my Ph.D programme.

Finally I place my effort at the feet of God – The Almighty.

ANU AUGUSTINE.

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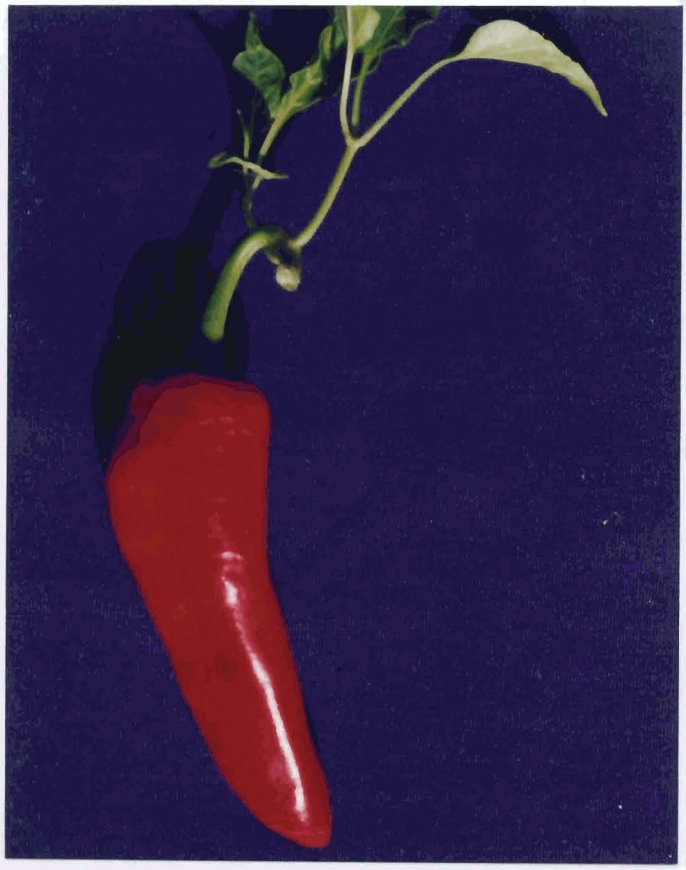
Introduction



Few could have imagined the impact of Columbus' discovery of a spice so pungent that it rivaled the better-known black pepper from the East Indies. Nonetheless, some 500 years later, after the discovery of the New World, chilli peppers (Capsicums) have come to dominate the world's hot spice trade and are grown throughout the tropics as well as in many temperate regions of the globe. Peppers, which have been found in pre historic remains in Peru, were widely grown in Central and South America in pre- Columbian times. Pepper seeds were carried to Spain in 1493 and from there spread readily throughout Europe (Anon, 1990). Not only have hot peppers come to dominate the world's spice trade but a 'recessive' non-pungent form has become an important 'green' vegetable crop on a global scale, especially in the temperate regions.

The terminology of Capsicum is confusing. It is derived from the Greek word 'Kapso'meaning to 'bite'. It is also derived from the Latin word 'Capsa' for the 'box' referring to the shape of the pod. The genus *Capsicum* belongs to the family *Solanaceae*. It is a herb or sub shrub, erect and much branched, 45-100 cm tall; it is usually early maturing and is grown as an annual. The fruit is extremely variable in size, shape, colour and degree of pungency. Chilli is basically a warm weather crop and is generally suitable for cultivation in areas with 60 – 150 cm of annual rainfall. An ideal temperature for growth and fruiting ranges from 21.1° C to 26.7° C. The crop can be grown on a variety of soils, but it should be well drained. A fertile loamy soil rich in lime is considered the most suitable. The optimum pH is 6 – 6.5 (Purseglove *et al.*, 1981). Chilli crop is raised both in southern and northern hemispheres from equator to 45°.

Plant genetic resources in chilli include the AVRDC (Asian Vegetable Research and Development Centre) collections consisting of nearly 6000 accessions and another global base collection at CATIE, Costa Rica (Engle, 1993).

The pungent principle in chilli was first isolated in a crystalline form by Thresh (1846) who named the compound capsaicin. The heat of Capsicum powder is measured in scoville heat units (Scoville, 1912). One part per million concentration of capsaicinoids is measured as 15 scoville units. The concentration of the pungent principle is greatest in the placenta.

In addition to the use of capsicum as a spice, it is also considered on par with tomato as a vegetable. Chilli and its processed products are used very effectively in Indian medicine as penetrants and counter irritants. They are used against tonsillitis, diphtheria, atonic dyspepsia, loss of appetite, flatulence, intermittent fevers, atonic gout, rheumatism, choleric cases, sore throat, swellings and hardened tumors. Long-term capsaicin treatment strengthens the defense mechanisms of the stomach and protects it from gastric irritant induced damages (De, 1992). Several painkillers are available which contain capsaicin as the active ingredient, viz. Rheumacil, Relaxil, Slogens' bomb and Iodex.

India is the largest producer of chillies in the world and shares nearly 47.11% of world cultivation (Gaddagimath, 1992). Chilly is grown over an area of 8.76 lakh hectares and annual production is 8.09 lakh tonnes (Anon, 1998). Chillies earn the highest amount of foreign exchange among the spices cultivated in India. Chillies worth 21, 013 lakhs in Indian Rupee were exported from India during 1998-1999 (Ghosh *et al.*, 1999). India, considered secondary center of Capsicum diversity, maintains a major collection of chilli germplasm at NBPGR (National Bureau of Plant Genetic Resources), New Delhi. The center under Directorate of Vegetable Research, particularly located at Katrain, Lam, Vellanikkara, Coimbatore, Pantnagar and Ludhiana maintain working collections (Peter, 1999).

Chilli crop suffers from many diseases like damping off, fruit rot (anthracnose), murda complex, leafy spots, powdery mildew and wilts.

International spice traders use the term 'paprika' for non-pungent red capsicum powder. 'Paprika' is the Hungarian word for plants in the genus *Capsicum*. This mild powder can be made from any type of *Capsicum annuum* that is non-pungent and has brilliant red colour. Dr. Szent Gyorgi, the Hungarian scientist, was awarded Nobel Prize in 1937 for isolating vitamin C from paprika fruits, showing that capsicum is one of the richest sources of this vitamin.

Paprika is valued most for its colour and mildness of flavour. The market value of paprika depends largely on its red colour, both surface hue and extractable colour. Its flavour quality is of secondary importance only. Oleoresin of paprika, extracted from the ground pods, is used to impart bright red color to meat, sausage products, sauces and to other processed foods thus making the product more acceptable and pleasing to the eye.

The pigment content of paprika varies from 0.1 – 0.8%. The pigments comprise a mixture of closely related carotenoids such as capsorubin, capsanthin, β - carotene, zeaxanthin, violaxanthin and lutene. The most important pigments responsible for red colour are capsanthin and capsorubin. The paprika colours are not metabolised in human body and hence is an ideal natural colour additive for food items. The colour value of paprika is expressed in ASTA units (American Spice Trade Association). This is the extractable colour present in paprika. Common paprika ASTA colour values preferred in the industry are 85, 100, 120 and 150 (Tainter and Grenis, 1993). According to Govindarajan (1985), the group paprika contains less than 0.1% of

capsaicinoids, the best grade of Spanish paprika having 0 – 0.0003% and for the pungent grades a maximum of 0.5%.

Paprika of commerce from different producing countries and their major characteristics are as follows

1. Hungarian paprika - It is a long, more conical pointed fruit and has a distinctive flavour and is in great demand in Europe, where it is used as a spice rather than a colouring agent. Hungarian paprika is produced in eight grades and three qualities, ranging in colour power and pungency.
2. Spanish paprika – Spain produces sweet paprika in a wide range of colour values. It is a round fruit about the size of a peach.
3. Moroccan paprika – Similar to Spanish paprika and produced as medium and high colour paprika.
4. Bulgarian paprika – Bulgaria is the one East European source that produces predominantly mild paprika. It is mainly used for food manufacturing purposes.
5. American paprika – This paprika is grown and produced in Southern California. California has become a large supplier of paprika than any other individual country.
6. Yugoslavian paprika – This is quite similar to the Hungarian variety. It is normally ground fine and contains slight heat or pungency.
7. Czechoslovakian and Chilean – These are sweet to mildly pungent paprikas.
8. Romanian, Turkish and Greek – These are slightly pungent to pungent types.
9. Portuguese – This is a sweet paprika of medium to high colour strength.

Paprika has clear price advantage over chilli. The weekly International Prices at New York Market as on January, 2000, showed the price of Indian chilli to be 0.62 dollars/pound and that of Spanish paprika (120 ASTA) to be 1.30 dollars/pound (Anon, 2000). In India, as yet, there is no spice paprika variety grown commercially. The Byadagi chillies in Dharward district in Karnataka and Tomato chillies in Warrangal district in Andhra Pradesh are near to qualities of paprika types grown in Spain or Hungary. A few selections were made from Byadagi chillies at the Indian Institute of Horticultural Research, Bangalore and the selection was released as 'Arka Abir'. In the breeding programs of the Regional Station of the Indian Agricultural Research Institute, Katrain, Kulu valley, Himachal Pradesh, germplasm from abroad were evaluated and a variety 'Kt-pl-19', having high oleoresin and high colour is released. The increasing commercial importance world over for paprika as sources of paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Today there is considerable demand for paprika powder and its oleoresin in the western world. It is desirable to extend the cultivation of paprika in India for export production for which there is immense scope. Although the trials taken up by IARI, New Delhi and CFTRI, Mysore had showed the scope for its successful cultivation, efforts are yet to begin for extensive cultivation which would facilitate to add one more spice to the exportable range of spices in the country's spice basket. At the time when there is increase in domestic demand coupled with sizeable international demand, the potential that exists in the country for paprika production is required to be exploited (John, 1989). India has the potential to produce high quality paprika and there is tremendous potential for export, which needs to be utilized.

In this context, since the variability in the material available for evaluation in India, was limited, exotic germplasm was collected from AVRDC, Taiwan, Institute of Plant Genetic Resources, Gaterslaben, Germany, Lumle Agricultural Research Station, Nepal and Belstzville, U.S.A. *In vitro* technology is a powerful tool for the induction of much-needed genetic variability; hence induction of variability through somaclonal variation was also tried.

The family Solanaceae is one of the most responsive diverse plant groups among the dicotyledons in the context of the application of tissue culture techniques. Cells tissues and organs from members of this family (tobacco, potato, tomato, and petunia) undergo morphogenesis and *in vitro* plant regeneration easily. However, tissue culture of *Capsicum* has lagged behind, mostly due to the lack of success in early attempts to regenerate plants from cultured tissues. Most of the work on *in vitro* techniques in *Capsicum* is concerned with direct organogenesis in exotic cultivars.

Taking into consideration all the above aspects the present study was taken up with the following objectives:

1. To collect and evaluate lines/ hybrids of paprika to identify suitable types.
2. To standardise protocols for callus induction, regeneration and production of somaclones.
3. Study variability among somaclones and select useful variants.

REVIEW OF LITERATURE

Anu Augustine “Selection of promising lines, production of somaclones and their utilization in paprika (Capsicum annuum L.) ” Thesis. Indian Institute of Spices Research Calicut, University of Calicut, 2001

Review of Literature

The word paprika means pepper in Hungarian language (Somos, 1984). Peppers, which were found in pre-historic remains in Peru, were widely grown in Central and South America in Pre- Columbian times. Pepper seeds were carried to Spain in 1493 and from there throughout Europe (Anon, 1990).

The genus *Capsicum* belongs to family Solanaceae. Linnaeus recognized two species, *C.annuum* and *C.frutescens* in his *Species Plantarum* of 1753 and later in 1767 he added two more. Five cultivated species are now recognized, viz. *C.annuum* var *annuum*, *C.frutescens, C.baccatum* var *pendulum*, *C.chinense* and *C.pubescens* (Purseglove *et al.*, 1981). Smith *et al.*, (1987) made a horticultural classification of peppers grown in the United States confining to only two species viz. *C.annuum* and *C.frutescens*. This classification is based exclusively on fruit characteristics like colour, shape, pungency, size, uses etc. According to this classification, there are six major groups under *C.annuum* and one group under *C.frutescens*.

Paprika is a product in the United States of America. It is defined as a sweet, dried, red capsicum powder in the United States of America. This mild powder can be made from any type of *Capsicum annuum*, which is non-pungent and has brilliant red colour. In the United States, paprika is made from the New Mexican- type chili, whereas in Europe, paprika is made from two principal fruit types: 1) a round fruit about the size of a peach and called Spanish or Moroccan paprika and 2) a longer more conical and pointed type grown in the Balkan countries called Hungarian paprika (Bosland, 1992). Colour in paprika is the principal criterion for assessing its quality value. Colour retention during storage is

influenced by light and temperature. The higher the temperature at which the product is stored, the faster, the loss of pigment in paprika. Another factor influencing colour retention is the moisture level in the spice it self. Too low a moisture content can cause the colour to fade. Optimum moisture content is considered to be 11%. The extractable colour in paprika is expressed in ASTA units. Common paprika ASTA colours available in the industry are 85, 100, 120 and 150. In paprika the chemical and physical specifications as reported by Tainter and Grenis, 1992 are as follows:

Table 1 Chemical and physical specifications of paprika

Specification	Suggested Limits
FDA DALs (6 sub samples):	
Insect fragments	Ave of 75 or more/25 g
Or	
Rodent hairs	Ave of 11 or more/25g
Or	
Howard mold count	Ave of 16 %
Volatile oil	N/A
Moisture	11.0% max
Total ash	8.0% max
Acid in soluble ash	3.0% max
Military specifications (EE-s-631 J, 1981)	
Volatile oil (ml/100g)	N/A
Moisture	12.0% max
Total ash	10.5% max
Acid insoluble ash	2.5% max
Granulation	95% min through a U.S.S. # 30
Extractable colour	110
Bulk index[1] (ml/100g)	160

1 Average bulk index- Granulation will affect number.

Paprika - Varieties

The increasing commercial importance world over for paprika as sources of paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Low yield being a limiting factor for paprika production in New Mexico, attempts were made to develop a suitable cultivar by Bosland *et al.*, (1991). As a result 'Nu Mex Conquistador', a non – pungent, high yielding cultivar with high extractable red pigment was developed by crossing 'New Mexico 6-4' with 'Nu Mex R Naky'. 'Nu Mex Conquistador' had less than 10ppm pungency. 'Nu Mex Sweet' paprika chilli was developed by Bosland *et al.*, (1993), originating as a single plant selection from an open pollinated population of 'New Mexico 6-4', followed by pedigree selection. It produced high yield, 11Kg/ha (dry weight from a single harvest) and had high extractable colour (157ASTA). Paprika variety 'Kalocsai 90' syn Fantasy Elixir was derived from a cross between an un named breeding line and selected plants from 'Horgoska S1', 'Szegedi 20' and 'Kolocsai 504'. This paprika cultivar was selected for its compact growth habit, more fruits/plant, superior yield potential, increased dry matter (19.7%), pigment content (163 ASTA), flame red reflected colour and taste typical of high quality Hungarian paprika (Red Pepper Research and Development, Ltd., 1998).

The 'Byadagi' chillies in Dharward district of Karnataka and Tomato chillies in Warrangal district of Andra Pradesh are near to qualities of paprika types grown in Spain and Hungary. A few selections were made from Byadagi chillies at the Indian Institute of Horticultural Research, Bangalore and one selection was released as 'Arka Abir'. As there is no paprika

variety grown commercially in India, breeding programmes were started at IARI, substation Katrain, Himachal Pradesh, and a large number of paprika germplasm from home and abroad were collected, evaluated and selfed. From the lines evaluated, three promising lines Kt-pl-8, Kt-pl-18 and Kt-pl-19, were identified, (Joshi *et al.*, 1993). Genotype Kt-pl-19 with colour units of 233.70 ASTA was superior to Kt-pl-18 (174.25 ASTA) and Kt-pl-8 (178.35 ASTA).

Evaluation

Iiwang and Lee (1978) studied horticultural characters influencing quality and yield in pepper. It was found that leaf length, leaf width, petiole length, plant height and main stem length of Capsicums showed high positive correlation with yield. Capsaicin content was negatively correlated with fruit weight and size and positively correlated with days to first flowering and with plant height, stem diameter and fruits/plant. Total red colour was negatively associated with stem diameter and leaf and petiole lengths. With regard to changes in the red pigment of the fruits beyond the stage of botanical ripeness, eight breeding lines were compared with four established varieties and it was found that the unfavorable tendency for pigments to break down was generally stronger in lines of determinate growth habit than others (Varga, 1982). Ten varieties of sweet peppers obtained from different sources were evaluated at Samaru, Nigeria and variation in the morphological and agronomic characters were studied. Among the characters, plant height was the least variable with a c.v. of 26.30 (Aliyu and Olerewaju, 1994). Stofella *et al.*, (1995), Meraz *et al.*, (1996), Todorov and Todorov, (1998) and Echeverri-Agudelo *et al.*, (1998) also evaluated *C.annuum* lines for various horticultural and yield related characters.

Studies on relative performance of different genotypes of sweet pepper were carried out and the variety 'Chinese Giant' gave a much higher yield (40.12%) than Dharward local (Verappa, 1984). In trials of 10 varieties during 3 *kharif* seasons under Rahuri (Maharashtra) conditions, Pant C1 and CA (P) 247 yielded significantly higher than the control, Jwala (Deore, 1986). A wide range of variability was observed for fresh fruit weight and yield /plant ranging from 55 to 180g and 104 to 266g in the first year and from 41 to189g and 160 to 240 g respectively the second year. Similar variability was found for fruits/plant, seeds/fruit and fruit dry weight (Amar-Chandra *et al.*, 1990). Thirty two geographically diverse chilli genotypes were evaluated during 1987-88 for heritability; genetic divergence and genetic advance based on data derived from 10 characters. Considerable genotypic and phenotypic variations were observed for leaf area index, fruits/plant, fruit weight and total yield indicating existence of greater diversity for these traits (Varalakshmi and Babu, 1991). Yield/plant and related 12 quantitative characters were recorded for 19 *C.annuum* cultivars (Acharya *et al.*, 1992). Analysis of the data collected indicated that improvement should be based on selection for fruits/plant, yield/plant, fruit length and circumference, seeds/fruit and leaves /plant. Thirty diverse genotypes collected from Meghalaya, Assam, Nagaland and Tripura were grown during *Kharif* 1989. An analysis of variance showed a high degree of variation among the genotypes for the eight characters studied. Geographic and genetic diversity were found unrelated (Pandey and Dobhal, 1993).

Evaluation of 73 genotypes including the standards 'Pusa Jwala' and 'G4' revealed significant differences between entries for content of capsanthin (0.126- 0.407%), ascorbic acid (58.73- 193.1 mg/100g) and capsaicin (0.056- 1.81%) in the fruits. All the three components were highest in cv. 'Ducale' (Rani, 1994). Variation for nine yield-related traits were studied in 20 chilli genotypes at Birauli and Samastipur (Bihar) over two seasons, summer and *kharif* 1989-90 with two dates of sowing in each season. Variability was greatest for weight of fresh red ripe fruits/plant. High heritability estimates were obtained for fruit length, weight of fresh ripe fruits, dry fruit weight, fruits/plant and fruit diameter (Singh *et al.,* 1996).

Genetic variability in hot pepper (*C.annuum* L.) was studied in 71 genotypes of hot pepper for plant, fruit and yield characters. The results indicated considerable amount of genetic variability for all characters with maximum being for fruit yield (Nayemma *et al.*, 1998). A field experiment conducted at Dharward, (Karnataka), during rainy seasons of 1990 and 1991 to find out the differences in yield and quality parameters of 4 chilli cultivars (Byadagi, Sankeshwar, G-3 and Jwala), 6 lines (GPC-80, GPC-69, GPC-77, GPC-6, GPC-10 and KDSC- 110-10) and 2 hybrids (H-1 and H-2) revealed that capsaicin and total colouring matter contents were highest in cultivars, followed by hybrids and were least in lines (Nawalagatti *et al.*, 1999).

Devi and Arumugam (1999) reported high heritability coupled with high genetic advance as percentage of mean for fruits/plant and fruit weight, indicating existence of additive genes in the expression of these traits, which could be easily exploited. Two hundred and eighty nine accessions of chilli (*C.baccatum, C.pubescens, C.annuum, C.chinense* and *C.frutescens*)

were evaluated for more than 40 different characters at Pantnagar (Uttar Pradesh) during 1996. Genotype 'P2072' was the best for maximum fruit length, uniform fruiting and appealing colour, whereas P1718, EC 362901, EC 362910, EC 362913 and EC 362925 were disease tolerant (Verma *et al.*, 1999). Twelve varieties of chilli (*C.annuum)* were tested during spring – summer 1994 and 1995 under the agro climatic conditions of Pantnagar (Uttar Pradesh). G4, CA 586, Pant C1 and CA 206 outyielded the control variety 'Pusa Jwala' by 39.3, 41.2, 51.0 and 57.0% respectively (Singh *et al.,* 1999). Ten chilli varieties (*C.annuum*) and cultivars (local and exotic) were evaluated for yield and yield components during 1995 under Islamabad conditions. Yield was the highest in 'Korean' (1.23 Kg/m^2) followed by 'Huaysithan'. 'Korean' and 'Huaysithan' had the highest number of fruits/plant, weight of fruits /plant and number of pickings (Mahmood *et al.*, 1999).

Pigments

Colour in paprika is the principle criterion for assessing its quality value. The pigment content of paprika powder ranges from 0.1 to 0.8%. Colour value of paprika is usually expressed in terms of ASTA colour value (American Spice Trade Association). This is the extractable colour present in paprika. Common paprika ASTA colours preferred in the industry are 85, 100, 120 and 150 (Tainter andGrenis, 1993). The major colouring pigments in paprika are Capsanthin and Capsorubin comprising 60% of the total carotenoids. Other pigments are Beta-carotene, Zeaxanthin, Violaxanthin, Neoxanthin and Lutein.

A spectrophotometric method for analysis of colour using dried chilli powder using isopropanol as solvent was described. Potassium dichromate (0.5 mg/ml) in 1.8-M sulphuric

acid was used as standard and the absorbance was read at 450 nm against isopropanol as blank. (Hort and Fisher, 1971). The carotenoids of red bell peppers were analyzed without saponification by HPLC using octadecyl silica as stationary and methanol-ethyl acetate as mobile phases. Capsanthin accounted for 60% of the total carotenoids. Beta-carotene (11%) and capsorubin (20%) were also present (Gregory *et al.*, 1987). Determination of natural colouring matter in paprika using acetone blank was described in ISO 7541, 1989. ASTA method 20.0 described a spectrophotometric method for determination of colour in paprika using an acetone extract and potassium dichromate + cobaltous ammonium sulphate in 1.8 M sulphuric acid as standard. A method for evaluating paprika colour was exemplified based on light reflection using a spectrophotometer. The colour spectra from conventional red varieties were compared with those from dark red varieties with chlorophyll retainer genes (modifying the visually determined colour rating as result of the presence of chlorophyll in ripe fruit). The spectra of the two types of variety could be distinguished from each other at a wavelength of 670 nm (Navarro and Costa, 1991). Paprika colour was estimated using visual estimation of redness, determination of carotenoid and chlorophyll contents, total pigment extraction (ASTA method 20.1) and calculation of tint. Several qualitative differences were established between cultivars, notable differences being in extractable colour (ASTA units), tint and red and yellow carotenoid contents. Correlation between results from different evaluation methods showed that it was possible to accurately determine ASTA units on the basis of red carotenoid or total carotenoid content and visual colour assessments (Gomez *et al.*, 1997). Different parameters of colour measurements, such as ASTA and tint determination were evaluated. Combination of the

information from the ASTA method with that of the carotenoid composition of the red and yellow fractions, acquired by HPLC, enabled greater accuracy in judging both the quality of the final sample and the soundness of the process for obtaining it (Mosquera and Gualez, 1998).

The capsanthin-capsorubin synthase (ccs) gene was found activated specifically during the final stages of pepper fruit ripening. Paprika fruit contained alpha-tocopherol in the pericarp and gamma-tocopherol in the seeds. Both antioxidants when added to the ground products substantially reduced colour impairment occurring during storage (Biacs *et al.*, 1994).

The equilibrium solubilities of binary solid mixture bete-carotene-capsaicin in liquid and supercritical CO_2 were measured using a static-analytic method by Skerget and Knez (1997). Skerget *et al.*, (1998) also extracted the aromatic and colour components of paprika using supercritical CO_2 as solvent.

Pungent Principle

The primary pungent principle was first isolated in a crystalline state from the crude extract by Thresh (1846) who named the compound capsaicin (Purseglove, *et al.*, 1981). The heat of capsicum powder is measured by scoville heat units (Scoville, 1912). One part per million concentration of capsaicinoids is measured as 15 scoville units. The nature of pungency has been established as a mixture of seven homologous - branched chain alkyl vanillyl amides, named capsaicinoids. Capsaicinoids identified in Capsicum are Capsaicin,

Dihydrocapsaicin, Nordihydrocapsaicin, Homodihydrocapsaicin, Homocapsaicin, Nonanoic acid vanillylamide and Decanoic acid vanillylamide.

Capsaicinoid, carotenoid, free aminoacid and ascorbic acid were determined in Capsicum fruits (cv. Bugang) by different chromatography systems. Each capsaicinoid was separated using reversed phase HPLC with a Nova-Paka C10 RCM column, and identified using fast atom bombardment MS. Five natural capsaicinoids were identified: nordihydrocapsaicin, capsaicin, dihydrocapsaicin, vanillyl decanamide and homodihydrocapsaicin; homocapsaicin was not detected. The concentration of total capsaicinoids in fruits was 5.4-mg/100g fresh weight (FW) (Kim *et al.* 1997). A novel unique capsaicinoid profile was observed in *C.pubescens*. An isomer of dihydrocapsaicin was the predominant capsaicinoid (Zewdie *et al.*, 1998). *In vitro* capsaicin production by immobilized cells and placental tissues of Capsicum was reported by Johnson *et al.* (1990).

Organoleptic method for determination of scoville heat unit was described under ISO 3513 (1977) and spectrophotometric method for determination of total capsaicinoid content using methanolic solution of extracts of chillies at wavelengths 248nm and 296 nm under ISO 7543 (1988). Determination of the pungent principles of chillies and ginger by reversed phase high performance liquid chromatography (RP HPLC) using a single standard (Caprilic acid vanillyl amide) was described by Wood (1987) and Hoffman *et al.*, (1983). ISO 7543-2 (1993) also described the HPLC method for determination of percentage of capsaicinoids. Collins *et al.* (1995) reported another HPLC method for determination of capsaicin.

Govindarajan and Ananda Krishna (1970) described a paper chromatographic method for separation of capsaicin from colour and fat constituents. Hawer *et al.* (1994) reported a capillary gas chromatographic method of determination of the heat principles in chilli. Several other procedures for determining pungency were outlined (Bajaj, 1980, Anan *et al.*, 1996, Samson *et al.*, 1997 and Mandal *et al.*, 1998).

Cytology

Kostoff (1926) was the first to report the basicchromosome number of *Capsicum* as x=6, which was corrected by later workers. Raghavan and Venkatasubban, (1940) also studied the chromosome numbers and cytology of *C.annuum* recording 24 as the somatic number in all chilli varieties. Pickersgill (1988) surveyed mitotic chromosomes of chilli and reported that all domesticated chilli peppers were diploids with 2n=2x=24 and had a pair of acrocentrics and the remaining 22 were meta and submetacentric chromosomes. Most of the *Capsicum* species studied shared a common basic chromosome number, x=12. Two exceptions were *C.ciliatum* from Western South America and a Southern Brazilian wild species that has yet to be identified with certainty. These two species had n=13 (Pickersgill, 1991). Baruah and Borua (1994) also made similar reports. *C.lanceolatum,* a wild species reported by Stadley and Steyermark (1940) was also found to have a chromosome number 2n=26 (Tong and Bosland, 1997).

Singh and Roy (1984) studied cytology, pollen stainability and yield in desynaptic auto tetraploid of Capsicum. Egawa and Tanaka (1986) studied the chromosome pairing at metaphase I in PMCs of *C.annuum, C. baccatum* and their sterile F1 hybrid and showed that

C.annuum and *C. baccatum* differed from each other by the presence of at least three reciprocal translocations. Eduado (1990) studied the chromosome and karyotype in *C.chacoense*. Conieella *et al.* (1990) studied cytogenetics of 15 wild and cultivated accessions of *C.annuum* from different geographic areas throughout the U.S.A, Mexico, Central America and S.America. Polyploid studies in chilli were performed by Das and Bhaumik (1991). Lanteri and Pickersgill (1993) studied structural changes in *C.annuum* and *C.chinense*. Sadanandam and Subhash (1984) studied the effect of chemical mutagens on chiasma frequency in *C.annuum*. They also induced a multiple aneuploid in Capsicum by treatment with 40KR gamma rays (Sadanandam and Subhash, 1985). The aneuploid was vigorous but showed irregular meiosis and produced 90% sterile pollen and a very few fruits. Giemsa C banded karyotypes in Capsicum were studied by Moscone *et al.* (1993).

Seed protein analysis

Proteins are attractive for direct genetic study because they are primary products of stuctural genes. Proteins separated by electrophoretic methods undergo the process of evolution with relative slowness due to their "non-essential nature"(Margoliash and Fitch, 1968). Analysis of proteins and isozyme electrophoresis are additional tools for supplementing the evidence obtained by comparative morphology, breeding experiments and cytological analysis.

Panda *et al.* (1986) used seed protein electophoresis to study the phylogenetic relationships in chilli pepper. Vladova and Pandeva, (1994) used elecrophoretic spectra of seed urea extracts for species and cultivar identification of Capsicum. Identification of pepper cultivars by SDS capillary gel electrophoresis (CGE) was carried out by Lucchese *et al.*

(1999). The resolution and efficiency of separation confirmed SDS CGE as a valid and complementary tool to gel electrophoresis for cultivar identification. The distinctness of each species and wild and cultivated nature of concerned taxa were confirmed. Analysis of seed proteins of diploids, tetraploids and tetraploid hybrids of Capsicum were performed by Srivalli *et al.* (1999). Odeigah *et al.* (1999) investigated the possibility of using electrophoresis to characterize varieties of pepper, *C.annuum* and *C.frutescens* cultivated in Nigeria.

***In Vitro* Culture**

Recently enormous progress was made in the science of tissue culture for the improvement of crop plants. Application of tissue culture technology showed its importance in the crop improvement programme of horticultural crops (Evans and Sharp, 1981 and Bajaj, 1986). The major breakthrough in plant tissue culture was achieved after the discovery of auxins and cytokinins. Skoog and Miller (1957) through their classic experiments in tobacco callus established the hormonal control of shoot and root regeneration. Somatic embryos were regenerated from direct explant source or through callus and cell suspensions (Reinert, 1959; Steward *et al.*, 1964). *In vitro* haploid plant formation from pollen grains was obtained by Guha and Maheshwari (1964). The isolation of plant protoplasts by Cocking (1960) and somatic hybridization through fusion of plant protoplasts by Carlson *et al.*,(1972) were milestones in the history of plant biotechnology. 'Meristem culture' technique in orchids was pioneered by Morel (1960). Considerable information is available on clonal propagation through tissue culture technique in economically important plant species and several protocols are available for micropropagation of different species (Murashige, 1974;

1977, Vasil and Vasil, 1980; Hu and Wang, 1983; Styler and Chin, 1983 and Sharp *et al.*, 1984) which were commercially exploited for large scale production of uniform propagules in orchids, banana, cardamom, pepper, sugarcane etc.

Tissue culture as a source of variation

'Somaclonal variation' resulting from plant tissue culture was first reported by Larkin and Scowcroft (1981). In wheat, a number of papers are published dealing with somaclonal variations, (Larkin *et al.*, 1984; Karp and Maddock, 1984; Cooper *et al.*, 1986; Davies *et al.*, 1986 and Liang *et al.*, 1986). In rice, morphological and biochemical variations were observed (Sun *et al.*, 1983; Bajaj and Bidani 1986). Phenotypic variations like dwarf or twisted plants (Nishi *et al.*, 1968), abnormal glumes, auns, strips (Abrigo *et al.*, 1985), less leaf number and early maturity (Sun, 1980) were observed in regenerated plants. In potato, phenotypic variation was observed amongst regenerants from cultured shoot apices of cv.Cara (Ahloowalia, 1982a), explant derived regenerants of cv. Golden Wonder (Austin and Cassells, 1983) and leaf explant derived clones of cv.Desiree and Record (Wheeler *et al.*, 1985). Variations observed include maturation time, tuber shape, tuber size, tuber number, tuber colour, eye depth, leaf shape, leaf size and total yield. Extensive variation was observed in growth habit, tuber characters, photo period requirement and maturation date among plants regenerated from protoplasts (Shepard *et al.*, 1980; Secor and Shepard, 1981; Dolbik, 1990). Variation for disease resistance was observed among regenerated plants (Behnke, 1980; Shepard *et al.*, 1980 and Sebastiani *et al.*, 1994). In tomato, changes in ploidy levels were observed in plants regenerated from cotyledons. Studies on variation in progenies of plants regenerated from tomato cotyledons revealed that mutation frequencies

were very high and mutation spectrum was different both from that covered by spontaneous mutations and that observed in traditional mutagenesis experiments (Evans and Sharp 1983, Evans *et al.*, 1984; Buitali *et al.*, 1985; Evans, 1986; Gavazzi *et al.*, 1987). Variation among regenerated plants in disease resistance was also observed in tomato (Barden *et al.*, 1986; Shahin and Spiney 1986). High levels of variations among regenerated plants have been reported in tobacco (Larkin and Scowcroft, 1981). Plants regenerated from range of callus tissues obtained from microspores, pith and leaf mesophyll showed variation in flowering date, leaf shape, plant height, total vegetative yield, alkaloid content sugar content, disease resistance and male sterility (Burk *et al.*, 1979, Chalaff and Kiel, 1981; Prat, 1983 and Scherbatenko *et al.*, 1991).

Factors affecting variation

Various factors contribute to the extent of variation observed among regenerated plants. These are genotype of the parent, physiological state of the parental material, type of explants used, pre existing variation in the explant tissue, tissue culture pathway (micropropagation, direct or indirect organogenesis or embryogenesis, anther culture and protoplast culture), time in culture, kind of medium and growth regulators used and culture conditions (Meins, 1983; Gould, 1986; Ogura, 1990; Siby, 1990 and George 1993,a). Chromosomal structural changes and gene mutations, as well as other genetic alterations in regenerated plants have been postulated as responsible for the variations. (Ahloowalia, 1982 b; Karp and Maddock, 1984; Larkin *et al.*, 1984; Cooper *et al.*, 1986; Davies *et al.*, 1986 and Maddock, 1986).

Changes in the organelle DNA and proteins including enzymes can be correlated to the occurrence of variation. In potato, changes in organelle DNA were observed in protoplast derived plants (Kemble and Shepard, 1984). Culhis (1983) working on flax cell cultures, observed about 15% decrease in total DNA quantity and reported a dramatic effect for a satellite DNA sequence in two-fold range that led to sequence deamplification. Unstable expression is also a hall mark of transposon induced changes and has been reported in a number of cases such as wheat (Ahloowalia and Sherington, 1985), tobacco (Lorz and Scowcroft, 1983) and alfa alfa (Groose and Bing ham, 1984). In addition to these, there are also several other factors causing somaclonal variations. With this background, literature on *in vitro* culture of Capsicum species is reviewed here.

***In vitro* studies in Capsicum**

The family *Solanaceae* is one of the most responsive and diverse plant groups among the dicotyledons in the context of the application of tissue culture techniques. It has long been recognized that cells, tissues and organs from members of this family (tobacco, potato, tomato, and petunia) undergo morphogenesis and *in vitro* plant regeneration easily. However, tissue culture of Capsicum has lagged behind, most likely due to the lack of success in early attempts to regenerate plants from cultured tissues. Unlike other solanaceous species, chilli has been a recalcitrant species with regard to its capacity for *in vitro* plant regeneration. Most of the work on *in vitro* techniques in chilli was concerned with direct organogenesis in exotic cultivars. Multiple shoots were obtained from several explants in Capsicum. Multiple shoots from shoot tip explants were reported by Agrawal *et al.*, (1988); Sun and Wang (1990); Fortunato and Tudisco (1991); Bahette *et al.*, (1994);

Christopher *et al.*, (1994) and Mirza and Narkhede, (1996). Organogenesis from cotyledon explants was reported by Gunay and Rao (1978), Sripichitt (1987), Hayashi *et al.*, (1988), Subhash and Sumalini, (1990), Arroya and Revilla (1991), Cao and Jia (1993), Gatz and Rogozinska (1994), Jiang and Mi (1994), Tudanca and Corzana (1994) and Zhou *et al.*, (1994). Multiple shoot induction from hypocotyl explants were reported by Gunay and Rao (1978), Fari and Czako (1981), Ochoa and Ireta (1990), Arroyo and Revilla (1991), Christopher *et al.*, (1991), Bahette *et al.*, (1994) and Malagon and Alejo (1996). Several other reports of organogenesis from different explants were made by Fari *et al.*, (1990), Pundeva and Simeonova (1992,a), Gupta *et al.*, (1993), Lazic (1997) and Berljak (1998). In rare cases, spontaneous shoot regeneration from explants cultured on a medium devoid of growth regulators has been observed (Ezura *et al.*, 1993 and Binzel *et al.*, 1996). Commonly cultured explants were placed onto an agar-solidified shoot induction medium supplemented with a cytokinin (Benzyl adenine (BA), Kinetin, Zeatin or Thidiazuron (TDZ) and often also an auxin (IAA, IBA or NAA). Subsequently, shoot elongation took place after transfer of shoot or shoot bud clusters to a shoot/stem elongation medium *in vitro*, because shoot elongation has repeatedly been found as a major obstacle in obtaining normal pepper plants. Most of the buds got transformed into leafy structures or aberrant shoots. Gibberilic acid (GA3) was usually added to elongation medium (Stenitz *et al.*, 1999). Duchenne *et al.*, (1998) used 24-epi-brassinolide for shoot elongation. Coconut milk or casein hydrolysate in the medium also promoted shoot elongation (Cao and Jia, 1993). Adventitious shoots were found to root either spontaneously on a hormone-free medium, or

on a medium supplemented with low concentration of auxin. Agrawal *et al.* (1989) reported elongation of shoot buds on medium with IBA.

Induction of callus and organogenesis in Capsicum were reported difficult by Agrawal *et al.* (1989), but induction of callus and organogenesis was obtained by Ge *et al.* (1989, 1991), Pundeva and Simeonova, (1992,b) and Gatz, (1994). Callus regeneration through embryogenesis was reported by Christopher *et al.* (1991). Selection of chilli somaclones for resistance to *Colletotrichum capsici* was done by Anuar *et al.* (1994). Variations among culture-derived plants were also detected by Huolin *et al.* (1994). PEG tolerant cell clones of chilli pepper were obtained by Diaz and Alejo, 1994. An early bearing type of pepper was obtained by somaclonal variation (Benedecic and Berljak, 1996) and streptomycin resistant plantlets were obtained by mutagenesis *in vitro* (Subhash *et al.*, 1996).

MATERIALS AND METHODS

Anu Augustine “Selection of promising lines, production of somaclones and their utilization in paprika (Capsicum annuum L.) ” Thesis. Indian Institute of Spices Research Calicut, University of Calicut, 2001

Materials and Methods

The present study was carried out at the Indian Institute of Spices Research campus, chelavoor, Calicut, during the period from 1996 to 2000. The experimental field was located at an altitude of 15m above MSL between 11° 7' 22''N and 11° 48' 32''N and longitudes 75° 30' 58''E and 76° 8' 20''E. The area enjoyed a warm humid tropical climate. The pH of the soil was 5.6.

The studies were conducted on the following aspects

1. **Selection of promising lines of paprika.**
2. **Production of somaclones and their utilization.**

Selection of promising lines of paprika

a. Field evaluation of paprika lines.

b. Biochemical studies for quality.

a. Field evaluation of paprika lines

Paprika genotypes were collected through survey and correspondence from centers of cultivation and gene banks like AVRDC (Asian Vegetable Research and Development Centre, Taiwan), KAU (Kerala Agricultural University, Trichur), IIHR (Indian Institute of Horticultural Research, Bangalore), IARI (Indian Agricultural Research Institute), Regional Station, Katrain, Himachal Pradesh, Institute of Plant Genetics and Crop Plant Research, Gaterslaben, Germany, Agricultural Research Station, Lumle, Nepal and Beltzville, U.S.A. (Fig.1). Field survey of 'Byadagi' chillies of the Dharward district in Karnataka was done. Samples were collected from farmer's field and practices of cultivation and post harvest operations were studied (Fig.2). Details of genotypes used in this study are given under Table 2.

Table 2 Sources of paprika genotypes evaluated for field performance

Sl. no	Genotype	Source
1	PBC 436	AVRDC, Taiwan
2	PBC 554	AVRDC, Taiwan
3	PBC 1369	AVRDC, Taiwan
4	PBC 066	AVRDC, Taiwan
5	PBC 375	AVRDC, Taiwan
6	PBC 384	AVRDC, Taiwan
7	PBC 385	AVRDC, Taiwan
8	PBC 473	AVRDC, Taiwan
9	PBC 535	AVRDC, Taiwan
10	PBC 717	AVRDC, Taiwan
11	PBC 743	AVRDC, Taiwan
12	PBC 1347	AVRDC, Taiwan
13	PBC 1350	AVRDC, Taiwan
14	PBC 828	AVRDC, Taiwan
15	PBC 999	AVRDC, Taiwan
16	PBC 971	AVRDC, Taiwan
17	CAP 1088/35	Institute of plant genetics and Crop Plant Research, Gaterslaben, Germany.
18	CAP 35/95	Institute of plant genetics and Crop Plant Research, Gaterslaben, Germany
19	CAP 1036/35	Institute of plant genetics and Crop Plant Research, Gaterslaben, Germany
20	CAP 1063/35	Institute of plant genetics and Crop Plant Research, Gaterslaben Germany
21	Paprika king	Beltzville, U.S.A. (Synthite, Cochin)
22	Cluster Chilly	Lumle Agriclutural ResearchStation, Nepal
23	Kt-pl-18	IARI-regional station Katrain, Himachal Pradesh
24	Kt-pl-8	IARI-regional station Katrain, Himachal Pradesh
25	Kt-pl-19	IARI-regional station Katrain, Himachal Pradesh
26	Kt-pl-20	IARI-regional station Katrain, Himachal Pradesh
27	Kt-pl-22	IARI-regional station Katrain, Himachal Pradesh
28	Kt-pl-23	IARI-regionalstation Katrain, Himachal Pradesh
29	Kt-pl-24	IARI-regional station Katrain, Himachal Pradesh
30	Kt-pl-25	IARI-regional station Katrain, Himachal Pradesh
31	Kt-19	IARI-regional station Katrain, Himachal Pradesh
32	Arka Abir	IIHR – Bangalore
33	CA-219	KAU – Trichur
34	Modhpur	KAU – Trichur
35	Paprika type –1	KAU – Trichur
36	Round Ornamental	KAU – Trichur
37	Small Conical	KAU – Trichur
38	517 –1	KAU – Trichur
39	Jwala	KAU – Trichur
40	Byadgi type	Byadgi thaluk – Karnataka

Fig.1 Sources of germplasm collection of paprika.

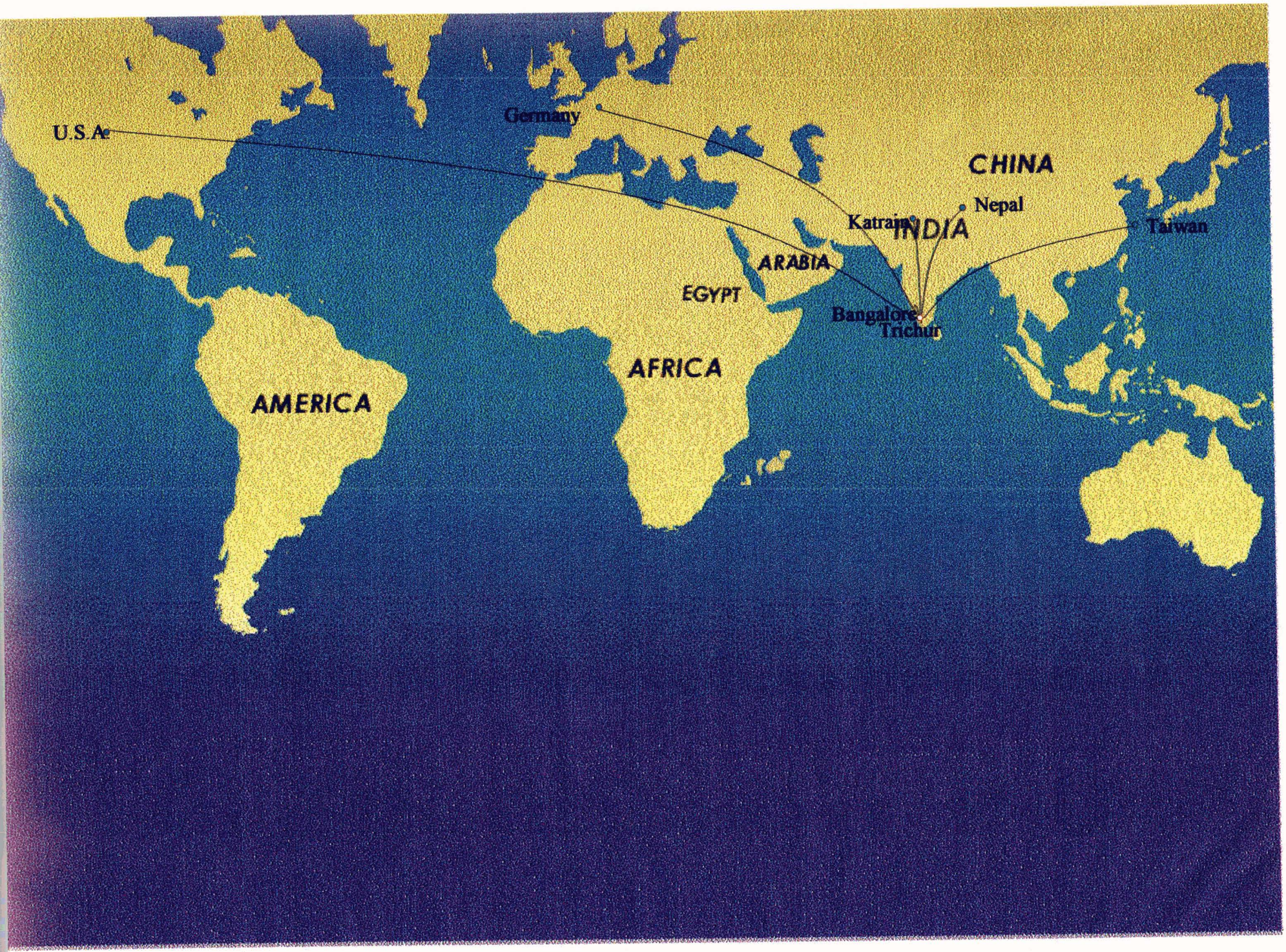
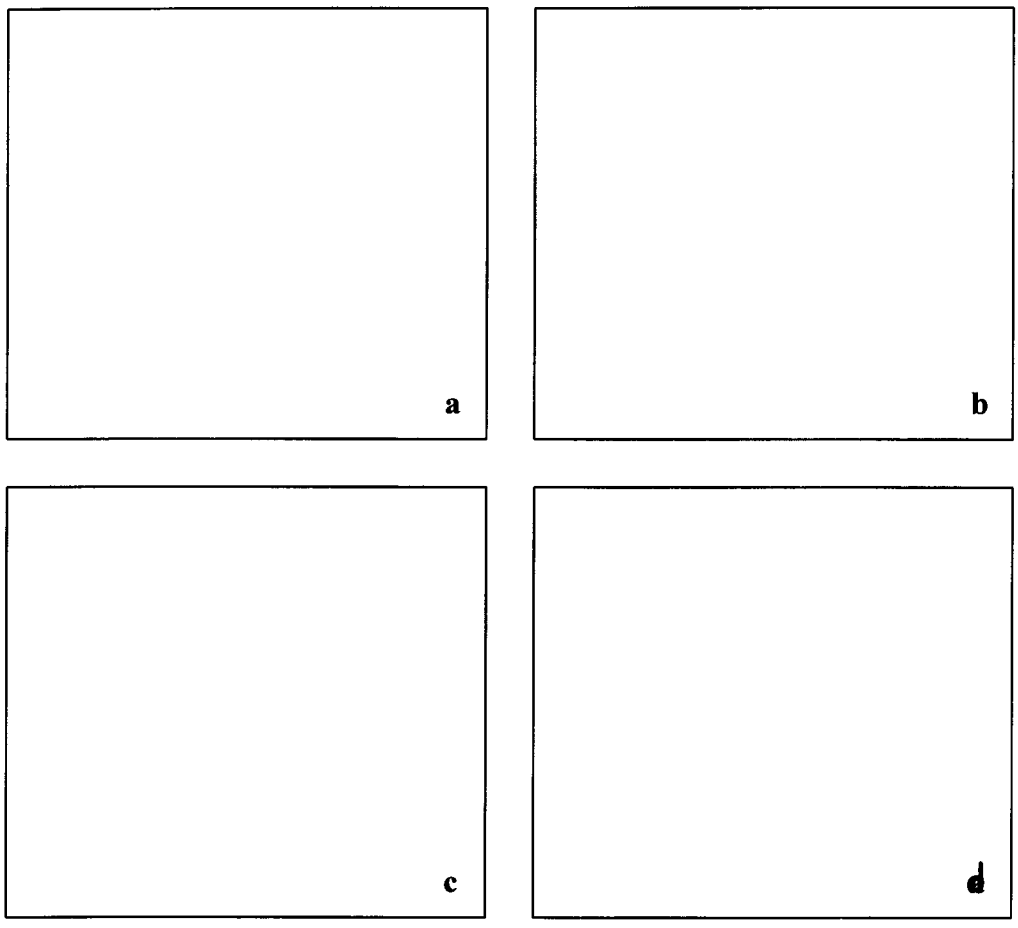

U.S.A
Germany
CHINA
Nepal
Katraj
INDIA
Taiwan
ARABIA
EGYPT
Bangalore
Trichur
AFRICA
AMERICA

Fig. 2 Paprika cultivation and post harvest practices at Dharward, Karnataka

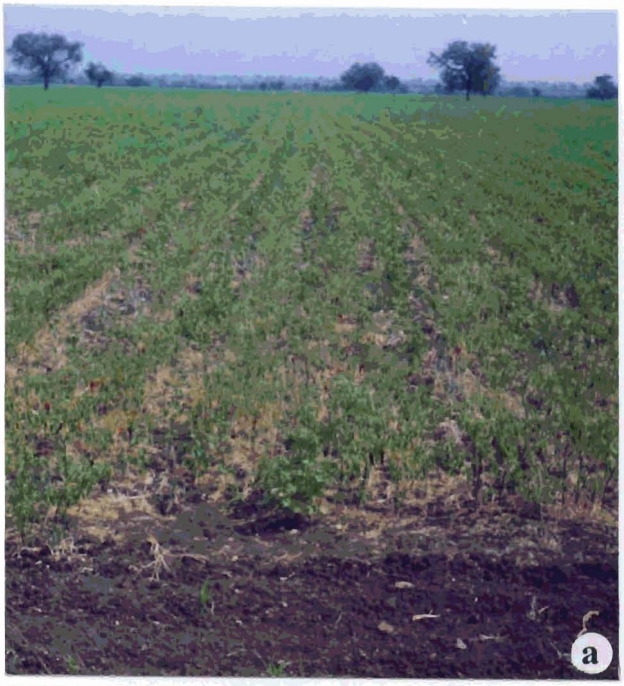


a A chilli field at Dharward.

b Mixed cultivation of Byadagi chilli with cotton.

c Sorting of chillies after harvest.

d Dried chilli ready to be packaged and transported.


a


b


c


d

Methods

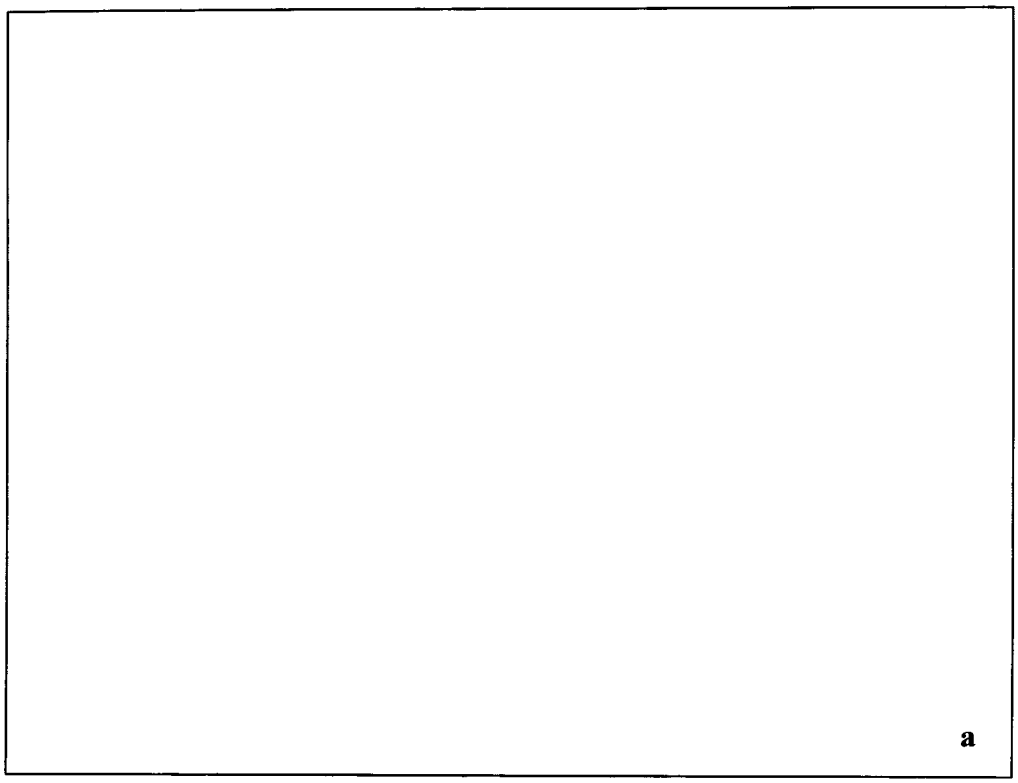
Three seasons (January to June 1997, January to June 1998 and September 1998 to March 1999) were selected for evaluation of the genotypes. During the three seasons, 40 genotypes were evaluated. Seeds of all genotypes were sown in sterilized sand in plastic cups and transplanted to pots. The potting mixture had a composition of soil: sand: farmyard manure in the ratio of 1: 1: 1. The mixture was chemically sterilized using formalin. The solution was prepared by mixing formaldehyde with water in the ratio of 1: 30. Three litres of solution was applied per m^2 of soil when the soil was moist. The mixture was covered for three days, stirred, covered again for three days and kept in open condition for 15 days.

There were six plants under each genotype and observations were recorded from five plants. One plant out of each genotype was kept for selfing to collect selfed seeds for the next generation. Selfing was done by covering the pot with a cage with mesh size 20x16 holes/2.5 cm^2 (Bosland PW, 1993) to prevent insect pollination (Fig.3). The plants were watered daily except during rains. Morphological evaluation of these lines was done according to the IPGRI (International Plant Genetic Resources Institute) descriptor list. The observations recorded are given under Table 3 and 4.

b.Biochemical studies for quality determination

1. Extractable colour – ASTA method (Hort and Fisher, 1971)
2. Percentage of Capsaicin – ISO/ DIS 7543 –1, 1988
3. Seed protein content – Spectrophotometric method (Lowry *et al.*, 1951), Gel electrophoretic method (Hames, 1994)

Fig. 3 Selfing of paprika using cage to prevent insect pollination



a Cage used for selfing paprika.


a

Table 3 Observations of paprika genotypes recorded for field evaluation

No	Character	Descriptor state
1	Plant growth habit (Observed when 50% of the plants bear ripe fruits)	Prostrate, Intermediate (compact), Erect,
2	Branching habit	Sparse, Intermediate, Dense
3	Stem shape (Observed at plant maturity)	Cylindrical. Angled, Flattened
4	Stem pubescence	Sparse, Intermediate, Dense
5	Leaf colour	Yellow, Light green, Green, Dark green, Light purple, Purple, Variegated, Others
6	Leaf shape	Deltoid. Ovate, Lanceolate
7	Number of flowers/axil	One, Two, Three or more, Many flowers in bunches but each in individual axil (Fasciculate growth), Others
8	Flower position (Recorded at anthesis)	Pendent, Intermediate, Erect
9	Corolla colour	White, Light yellow, Yellow, Yellow-green, Purple with white base, White with purple margin, Purple, Others
10	Anther colour (Observed immediately after blooming before anthesis)	White, Yellow, Pale blue, Blue, Purple, Others
11	Stigma exsertion (In relation to anthers at full anthesis)	Inserted, Same level, Exserted
12	Calyx margin	Entire, Intermediate, Dentate, Others
13	Calyx annular constriction (At the junction of calyx and pedicel. Observed at mature stage)	Absent, Present
14	Fruit colour at intermediate stage (Recorded on fruits just before the ripening stage)	White, Yellow, Green, Orange, Purple, Deep purple, Others
15	Fruit colour at mature stage	White, Lemon yellow, Pale orange, Orange yellow, Pale orange, Orange, Light red, Red, Dark red, Purple, Brown, Black, Others
16	Fruit shape	Elongate, Almost round, Triangular, Campanulate, Blocky, Others
17	Fruit shape at blossom end	Pointed, Blunt, Sunken, Sunken and pointed, Others
18	Fruit surface	Smooth, Semi wrinkled, Wrinkled
19	Placenta length	<1/4 fruit length, ¼-1/2 fruit length, > ½ fruit length
20	Seed colour	Straw, Brown, Black, Others

Table 4 Quantitative characters of paprika genotypes studied

1. Plant height (cm)
2. Days to flowering (Number of days from sowing/transplanting until 50% plants have at least one open flower)
3. Days to fruiting (Number of days from transplanting until 50% of the plants bear mature fruits at the first and second bifurcation
4. Mature leaf length (cm)
5. Mature leaf width (cm)
6. Fruit length (cm) – Average fruit length of 10 ripe fruits of the second harvest
7. Fruit width (cm) – Measured at the widest point. Average width of 10 ripe fruits of second harvest
8. Fruit pedicel length (cm) – Average length of 10 pedicels of the second harvest to one decimal place
9. Fruit weight (g) – Average fruit weight of 10 ripe fruits of the second harvest
10. Fruit yield / plant (g)

Extractable colour

Red ripe chillies were dried and the stalk and seeds were removed before powdering. 0.1 g of ground chilli powder was transferred in to a 250 ml Erlenmeyer flask, and kept overnight at room temperature. The contents were filtered through a Whatman No.42 filter paper, the first 10-ml was discarded and 25 ml of the filtrate was pipetted into a volumetric flask and diluted to the mark with isopropanol. The absorbance was read at 450 nm against isopropanol as blank.

Standard colour solution was prepared by dissolving 0.5mg/ml of reagent grade potassium dichromate in 1.8 M sulphuric acid.

$$\textit{Absorbitivity of standard colour solution (a)} = \frac{\text{Absorbance of standard colour solution at 450 nm}}{\text{Cell length (cm) X concentration (mg/ml)}}$$

$$\textit{Extractable colour in ASTA units} = \frac{\text{Absorbance of extract at 450 nm X 200}}{\text{Cell length (cm) X a X concentration of the solution (mg/ml)}}$$

Percentage of Capsaicin

Whole chillies were dried and powdered. 10g of the powder was quantitatively transferred to a soxhlet apparatus and extracted using 100ml tetrahydrofuran for eight hours. The solvent was then evaporated to the maximum extent possible in the rotary vacuum evaporator under reduced pressure in a 250ml round bottomed flask on water bath.

0.05 to 0.1g of carbon black was added to the extract so as to maintain a ratio of the order of 10 between the extract and carbon black. 90ml of methanol was added to this and agitated in magnetic stirrer for 30 minutes. The solution was allowed to stand for 5 minutes and filtered through a membrane filter into a 100ml one-mark volumetric flask and made up to the mark with methanol solution (70 parts methanol and 30 parts water). Using this filtrate, dilutions were prepared for spectrophotometric measurements.

Preparation of dilutions for spectrophotometry:

a. To a 25 ml flask was transferred, three ml water, 2 ml Hcl acid (1M) and made up to the mark with methanolic solution. (Blank acid solution **A**).
b. To a 25 ml flask was transferred three ml water, 2 ml NaOH (1M) and made up to the mark with methanolic solution. (Blank alkali solution **B**).
c. To three 25 ml flasks marked **a1, a2 and a3** were transferred one ml filtrate, 2.7ml water 2ml of Hcl acid and made up to the mark with methanolic solution.
d. To three 25 ml volumetric flasks marked **b1, b2 and b3** were transferred one ml filtrate, 2.7 ml NaOH solution and made up to the mark with methanolic solution.

Spectrophotometric measurements:

Zero was adjusted with methanolic solution. Blank absorbances were measured at 248 nm and 296 nm by placing the blank alkali solution (B) in the measuring cell and the blank acid solution (A) in the reference cell. Absorbance of each sample solution was measured at 248 and 296 nm by placing the solution b1 in the measuring cell and a1 in the reference cell. The absorbances of solutions b2 and a2 and b3 and a3 were also measured the same way.

Calculation:

The total capsaicinoid content W248 was calculated as a percentage by mass, at a wavelength of 248 using the formula-

$$W248 = \frac{(As\text{-}Ab) \times d}{314 \times m}$$

As – Absorbance of the sample solution

Ab – Absorbance of the blank

d – dilution factor (25 x100)

m – mass in grams of the test portion

Total capsaicinoid W296 was also calculated in the same way. The mean of the two values was recorded as the total capsaicinoid content.

Seed protein content

Seed protein was estimated by Lowry's method (Lowry *et al.*, 1951)

The following reagents were prepared

1. 2% Sodium carbonate in 0.1N Sodium hydroxide (Reagent **A)**

2. 0.5% Copper sulphate (CuSO4.5H2O) in 1% potassium sodium tartrate (Reagent **B**)

3. Alkaline Copper solution – 50ml of A and 1ml of B were mixed prior to use (Reagent **C**)

4. Folin – Ciocalteau Reagent (Reagent **D**) – A mixture consisting of 100g sodium tungstate ($Na_2WoO_4.2H_2O$), 700ml water, 50ml 0f 85% phosphoric acid, and 100ml of concentrated hydrochloric acid was refluxed gently for 10 hours in a 1.5L flask. 150g lithium sulphate, 50-ml water and a few drops of bromine water were added. The mixture was boiled without condenser to remove excess bromine. Cooled, diluted to 1litre and filtered.

5. Protein Solution (Stock standard) – 50mg of bovine serum albumin was weighed accurately and dissolved in distilled water and made up to 50ml in a standard flask.

6. Working standard – 10 ml of the stock solution was diluted to 50ml in a standard flask.

Method

Extraction of protein from sample

500mg of dried seeds were homogenised with Tris Hcl buffer (0.05M, pH 7.4) at 4°C, for extraction of proteins. The homogenate was centrifuged at 10, 000g for 15 minutes at 4°C. The supernatant was used for protein estimation.

Estimation of protein

1. 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard were pipetted out into a series of test tubes.
2. 0.1ml and 0.2 ml of the sample extract were pipetted out in two other test tubes.
3. Volumes in all the test tubes were made up to 1ml. A tube with 1-ml water was used as blank.
4. 5ml of reagent C were added to each tube including blank. This was mixed well and allowed to stand for 10 minutes.

5. 0.5ml of reagent D was then added, mixed well and incubated at room temperature in the dark for 30 minutes until blue colour was developed.
6. Readings were taken at 660 nm and standard graph drawn and the amount of protein in the samples were calculated.

Calculation

The amount of protein was expressed as mg /100mg of sample.

SDS (Sodium dodecyl sulphate) polyacrylamide gel electrophoresis

Equipment - Hoefer mini gel electrophoresis unit

Stock solutions

1. Monomer solution

60g acrylamide (FW 71.08)

1.6g bis acrylamide

dd H_2O to 200 ml

Can be stored up to three months at 4^0C in the dark.

2. 4X Running Gel Buffer (1.5 M Tris-Cl, pH 8.8)

36.3g Tris (FW 121.1)

150 ml dd H_2O

pH adjusted to 8.8 with Hcl

Can be stored up to three months at 4^0C in the dark.

3. 4X Stacking Gel Buffer (0.5M Tris – Cl, pH 6.8)

3g Tris (FW 121.1)

40 ml dd H_2O

pH adjusted to 6.8 with Hcl

dd H_2O to 50ml

Can be stored up to three months at 4°C in the dark.

4. **10 % SDS**

10 g SDS

dd H2O to 100ml

Can be stored up to six months at room temperature.

5. **10 % Ammonium per sulphate (Initiator)**

0.1g ammonium per sulphate

dd H_2O to 1.0 ml

Used fresh.

6. **Running Gel Overlay (0.375M Tris – Cl, 0.1% SDS, pH 8.8)**

25 ml Running Gel Buffer

1.0 ml 10 % SDS

dd H2O to 100ml

Can be stored up to three months at 4°C in the dark.

7. **2X Treatment Buffer (0.125M Tris – Cl, 4 % SDS, 20 % v/v Glycerol, 0.2 M DTT, 0.02 % Bromophenol Blue, pH6.8)**

2.5 ml 4X Stacking Gel Buffer

4.0 ml 10 % SDS

2.0 ml Glycerol

2.0 mg bromophenol blue

0.31g dithio threilol (DTT, FW 154.2)

dd H_2O to 100 ml

Can be stored in 0.5-ml aliquots at –20°C for six months.

8. **Tank Buffer (0.025M Tris, 0.192M Glycine, 0.1% SDS, pH 8.3)**

30.28g Tris (FW 121.1)

144.13g Glycine

10 g SDS

dd H_2O to 10 L.

This solution can be made up directly in large reagent bottles because it is not necessary to check the pH. Can be stored at room temperature for up to one month.

Running Gel Final Gel Concentration (30 ml; 20 ca 0.75 mm thick SE 600/400 gels)

7.5%

Monomer solution – 7.5 ml

4X Running Gel Buffer – 7.5 ml

10 % SDS – 0.3 ml

dd H2O – 14.6 ml

10% Ammonium persulphate – 150 µl

- TEMED – 10 µl.
- Added after deaeration

Stacking Gel Solution (4% acrylamide) Gel thickness – 0.75 mm

Monomer solution – 1.33ml

4X Stacking Gel Buffer – 2.5 ml

10 % SDS – 0.1ml

dd H2O – 6.0 ml

10 % APS – 50 µl

TEMED (N, N, N', N' – Tetra methyl ethylene diamine) – 5 µl.

Staining Solution (0.025 % Coomassie Brilliant blue R 250, 40 % methanol, 7 % acetic acid)

0.5 g Coomassie Brilliant blue

800 ml methanol

(Stirred until dissolved)

140 ml acetic acid

dd H2O to 2L

Filtering not needed.

Can be stored at room temperature up to 6 months.

De staining solution I (40 % methanol, 7 % acetic acid)

400 ml methanol

70 ml acetic acid

dd H_2O to 1L

Can be stored at room temperature indefinitely.

De staining solution II (7 % acetic acid, 5 % methanol)

700 ml acetic acid

500 ml methanol

dd H_2O to 10 L

Can be stored at room temperature in definitely.

Method

Equal parts of protein sample and 2X-treatment buffer were boiled in a test tube by placing in boiling water bath for 90 seconds. 20µl of the sample was loaded into the wells and was run at a constant current of 40mA until the tracking dye (bromophenol blue) reached the bottom. The gel was taken out and stained by keeping the gel in Coomassie blue stain solution over night. The gel was destained using destaining solution I followed by destaining solution II until blue bands were visible on a clear background. Em values of the bands were noted and zymogram drawn.

Electrophoretic mobility (Em) = Distance migrated by protein

Distance migrated by marker (Usually the dye front)

The percentage of similarities between different genotypes were calculated as follows:

Percentage similarity = No. of pairs of similar bands

No.of different bands + No.of similar bands.

Callus induction and regeneration

Materials

The genotypes used for tissue culture experiments were PBC 535, PBC 066, PBC 375, PBC 385 and Round ornamental. Seeds of these genotypes were germinated in MS basal medium. Explants were collected from eight-week-old seedlings. The explants used included leaf, stem, shoot tip and nodal segments.

Culture medium

MS (Murashige and Skoog, 1962) basal medium, the most commonly used medium for tissue culture studies in Capsicum was used in the present study. MS medium in full strength was used in all experiments (Table 5).

The chemicals used for micro and macronutrients were obtained from 'Hi – Media', Bombay and the vitamins and growth regulators were from 'Sigma', USA.

Table 5 - Composition of Murashige and Skoog* basal medium

Composition		Concentration
Macro nutrients (mgl-1)		
Ammonium nitrate	NH_4NO_3	1650.00
Potassium nitrate	KNO_3	1900.00
Calcium chloride	$Cacl_2.2H_2O$	440. 00
Potassium ortho phosphate	KH_2PO_4	170.00
Magnesium Sulphate	$MgSO_4.7H_2O$	370.00
Micro nutrients (mgl-1)		
Sodium EDTA	Na_2EDTA	37.30
Ferrous sulphate	$FeSO_4.7H_2O$	27.80
Boric acid	H_3BO_3	6.20
Manganese sulphate	$MnSO_4.4H_2O$	22.30
Potassium iodide	KI	0.83
Zinc sulphate	$ZnSO_4.7H_2O$	8.60
Sodium molybdate	$Na_2MoO_4.2H_2O$	0.25
Copper sulphate	$CuSO_4.5H_2O$	0.025
Cobalt chloride	$CoCl_2.6H_2O$	0.025
Vitamins (mgl-1)		
Myo – inositol	$C_6H_{12}O_6$	100.00
Thiamine HCl	$C_{12}H_{17}CIN_4OS.HCl$	0.10
Nicotinic acid	$C_6H_5NO_2$	0.50
Pyridoxine HCl	$C_8H11NO_3.HCl$	0.50
Amino acid (mgl-1)		
Glycine	$C_2H_5NO_2$	2.00

*Murashige and Skoog, 1962

Carbon source

Sucrose (Qualigens, Bombay) was used as carbon source at the rate of $30gml^{-1}$ in all the experiments.

Growth regulators

Auxins used in this study were 2,4-dichlorophenoxy acetic acid (2,4-D), Naphthalene acetic acid (NAA), Indole-3-butyric acid (IBA) and Indole-3-acetic acid (IAA) at

concentrations (0-10 mgl^{-1}). Cytokinins used in this study were 6-benzyl aminopurine and 6-furfuryl aminopurine (Kinetin) at concentrations (0-10mgl^{-1}).

Gelling agent

'Qualigens' bacteriological grade agar agar was used as the solidifying agent at a concentration of $7gl^{-1}$.

Glasswares

'Borosil' culture tubes were used for culture initiation and callus induction. For proliferation of callus and regeneration of callus, both culture tubes, as well as borosilicate glass bottles were used.

Sterilization of culture media

The culture medium was sterilized by autoclaving at 121^0C for 20 minutes at 1.5-Kg cm^{-2} pressure.

Plugging the culture vessel

The culture tubes were closed with cotton plugs made of non- absorbent cotton covered with cheesecloth and culture bottles with polypropylene caps.

Incubation Conditions

The cultures were incubated at 22 ± 2^0C and were given a photoperiod of 12 hours with light intensity 30 $E\mu m^{-2}s^{-1}$, provided by 'Philips' cool white fluorescent tubes.

Distilled Water

Double glass distilled water or Millipore 'Milli Q' water was used for preparation of stocks and media.

Instruments

'Nat Steel' horizontal autoclave was used for sterilizing the culture media and other instruments like blades, forceps, petriplates etc. Nikon SMZ – U stereomicroscope was used for observation of callus.

Method

The seeds were treated with Fytolan (Copper oxychloride) for 20 minutes, washed with distilled water three to four times to remove all traces of fungicide. It was then, under aseptic conditions in a laminar flow, treated with mercuric chloride for two to three minutes and washed several times in sterile water. The surface sterilized seeds were then inoculated in MS basal medium without growth regulators.

Preparation of nutrient medium

Separate stocks were prepared for macronutrients, micronutrients, vitamins and amino acids. Stocks of Calcium chloride, Ferrous sulphate, Sodium EDTA and glycine were prepared separately. Separate stocks were prepared for each of the growth regulators used (Table 6).

Sucrose and agar agar, at concentration of $30gml^{-1}$ and $7gml^{-1}$ respectively, were added directly to the medium. pH was adjusted to 5.8 before adding agar. The agar was melted to ensure uniform distribution in the medium.

For callus induction and plant regeneration, 2,4-D, NAA, IBA, IAA, BAP and Kinetin were tried in different combinations. For rooting and elongation of regenerated plants, IAA and IBA were used in different combinations.

Observations

Observations were recorded for number of cultures developing callus, roots and shoots. The treatments showing best responses were repeated to confirm repeatability.

Table 6 - Details of various stock solutions for MS medium

Stock	Composition	Stock Strength	Quantity for one litre medium
A	**Macro nutrients**	X 20	50ml
	NH_4NO_3		
	KNO_3		
	$CaCl_2.2H_20$		
	KH_2PO_4		
	$MgSO_4.7H_2O$		
B	**Micro nutrients**	X 100	10ml
	H_3BO_3		
	$MnSO_4.4H_2O$		
	KI		
	$ZnSO_4.7H_2O$		
	$Na_2MoO_4.2H_2O$		
	$CuSO_4.\ 5H_2O$*		
	$CoCl_2.6H_2O$*		
C	**Micro nutrients**	X100	10ml
	Na_2 EDTA*		
	Fe $SO_4.7H_2O$*		
D	**Vitamins**	X 100	10ml
	Thiamine HCl		
	Nicotinic acid		
	Pyridoxine		
E	**Amino acid**	X100	10ml
	Glycine		
F	Myo – inositol	X100	10ml
	Growth regulators		
	2,4 – D	50mg/100ml	
	NAA	50mg/100ml	
	IBA	50mg/100ml	
	IAA	50mg/100ml	
	BAP	50mg/100ml	
	Kinetin	50mg/100ml	

- Dissolved separately before mixing in the final stock

Hardening

The rooted plants (10-15 cm long) were washed under running water to remove agar completely and transferred to plastic cups containing sand and potting mixture in the ratio 3:1. The cups were kept covered with polythene bags and uncovered in a shade

house. The plants that were covered were watered once in a week and those left uncovered were watered once in two days. The polythene cover was removed after one month.

Evaluation of somaclones

The callus-regenerated plants were transplanted to black polythene bags containing sterile potting mixture. The morphological characters of the plants were recorded as per the IPGRI descriptor. The colour values were determined using the procedure described earlier. The young flower buds of the callus-regenerated plants were used for cytological investigations. The seeds of the somaclones were collected and the next generation of plants were raised to study whether the variations observed pass through the seed sieve. The morphological characters and biochemical characters of the seed progeny was also studied.

Cytological studies

Young unopened flower buds collected from field grown callus regenerated plants were fixed in alcohol acetic acid mixture (3:1) for 12 hours and then transferred to 70% alcohol. The flower buds were dissected and anthers were taken out. The anthers were stained with acetocarmine (2%), pressed well and observed under microscope for abnormalities during meiosis.

RESULTS

Anu Augustine “Selection of promising lines, production of somaclones and their utilization in paprika (Capsicum annuum L.) ” Thesis. Indian Institute of Spices Research Calicut, University of Calicut, 2001

Results

Results obtained from the present investigation are presented under different heads.

Evaluation of paprika lines

Morphological characters of 40 paprika lines were documented as per the IPGRI descriptor for three seasons (January to June 1997, January to June 1998 and September 1998 to March 1999) and given under Table 7.

Stem shape

All the genotypes studied had cylindrical stem shape.

Stem pubescence

Among the genotypes studied, CAP 1086/35-showed dense stem pubescence. PBC 385, PBC 473, PBC 535 and Byadagi showed intermediate pubescence and the remaining genotypes showed sparse or no pubescence at all (Table7, Fig. 4).

Plant growth habit

37.5% of the lines showed erect growth habit, 45 % of the lines intermediate growth habit and the remaining 17.5% compact growth habit (Table7, Fig. 4).

Branching habit

Branching was high in Cluster Chilli and sparse in Byadagi, CA- 219, Kt-19, Paprika King, Kt-pl-18, Kt-pl-20 and Round Ornamental. The remaining genotypes showed intermediate branching habit (Table7, Fig. 4).

Leaf colour

Leaf colour was light green in Jwala and Byadagi, green in 31 lines and dark green in 7 lines (Table7, Fig. 4).

Leaf shape

37 lines out of 40 had ovate leaf shape while 517-1, CAP 1088/35 and PBC 971 had lanceolate leaf (Table7, Fig. 4).

No. flowers /axil

32 lines had one flower/axil and 8 lines had two or more (Table7, Fig 4).

Flower position

24 lines had pendent flower, six had intermediate flower position, and 10 lines had erect flower position (Table 7, Fig. 4).

Corolla colour

32 lines had white corolla and 8 had light yellow corolla (Table7, Fig. 5).

Anther colour

Anther colour was blue in 17 lines and purple in 23 lines (Table 7, Fig. 5).

Stigma exsertion

Stigma was found exserted in 33 genotypes, inserted in 5 genotypes and in the same level as the anthers in 2 genotypes (Table 7, Fig. 5).

Calyx margin

Calyx margin was deeply dentate in 19 lines and with intermediate dentation in 21 lines (Table 7, Fig. 5).

Calyx annular constriction

Calyx annular constriction was present in 24 lines and absent in 16 lines (Table 7, Fig. 5).

Fruit colour at intermediate stage

Fruit colour at intermediate stage was green in 32 lines, dark green in 5 lines, light green in Modhpur and yellowish green in Cluster chilly and Jwala (Table 7, Fig. 5).

Fruit colour at mature stage

34 lines had red fruit colour at mature stage and 6 lines had dark red fruit colour (Table 7).

Fruit shape

The fruit was elongate in 27 lines, triangular in 10 lines, round in Round Ornamental and blocky in PBC 1369 and PBC 436 (Table7, Fig. 6).

Fruit shape at blossom end

28 lines showed pointed end, 8 lines showed blunt end, 3 had sunken end and one line (Kt-pl-25) had sunken and pointed blossom end (Table 7 Fig. 6).

Fruit blossom appendage

38 lines had no blossom appendage, while it was present in Small Conical and PBC 436 (Table 7, Fig. 6).

Fruit surface

Fruit surface was smooth in 31lines, semi-wrinkled in 8 lines and wrinkled in Byadagi (Table 7, Fig. 6).

Placenta length was greater than half fruit length in all the lines (Table 7).

Seed colour was straw in all genotypes (Table7).

The representative genotypes of the paprika types, plants with fleshy, elongated and pendent fruits (Fig.7), plants with erect fruits (Fig. 8), plants with elongated and narrow fruits (Fig.9) and plants with clustered fruits are given (Fig.10).

Quantitative characters

Quantitative characters of the paprika lines were recorded for three seasons and are presented in Tables 8 - 13.

Plant height (cm)

Plant height ranged from 32.3 cm to 92.0 cm (Table 8). Short genotypes with plant height ranging from 32.3 cm to 49.0 cm were PBC 436, PBC 535, PBC 554, Kt-pl-18, Cluster Chilli, Small Conical, Round Ornamental, Modhpur, CAP 1088/35, CAP 1063/35, PBC 1347, Dokomlasi 640, Kt-pl-24, Kt-pl-25, Kt-pl-23, Kt-pl-8, Kt-pl-20, Jwala and PBC1369. Tall genotypes were PBC 743 (70.6), Arka Abir (82.6), PBC 717 (84.0), Kt-19 (86.0) and Byadagi (92.0). Lines with intermediate height were PBC 385, PBC 384, PBC 375, CAP 1086/35, Kt-pl-19, PBC 1350, PBC 828, PBC 971, 517-1, PBC 999, Kt-pl-19, PBC 1350, PBC 828, PBC 971, 517-1, PBC 999, Kt-pl-22, Paprika type-1, PBC 066, CA-219, PBC 473 and Paprika King.

Table 7 Morphological characters of 40 paprika genotypes

Characters	Expression	Genotypes
Stem shape	Cylindrical	All
Stem pubescence	Dense	CAP 1086/35
	Intermediate	PBC 385, PBC 473, PBC 535, Byadagi.
	Sparse /nil	CA 219, PBC 066, PBC 1369, PBC375, PBC 384, PBC 554, PBC 436, Small conical, Round ornamental, Arka Abir, Modhpur, CAP 1088/35,Kt-pl-19, CAP1063/35, PBC 1350, PBC 1347, PBC 743, PBC 717, Paprika type –1, Dokomlasi 640, Kt-19, Cluster chilli, 517-1, PBC 828, PBC 971, Kt-pl-22, Kt-pl-24, Kt-pl-25, Kt-pl-18, Kt-pl-23, Kt-pl-8, Kt-pl-20, PBC 999, Jwala, Paprika king.
Plant growth habit	Erect	PBC 385, PBC 473, PBC 535, Byadagi, CA 219, PBC 1347, PBC 743, Paprika type –1, Dokomlasi 640, Kt-19, PBC 828, PBC 999, Jwala, Paprika king, Arka Abir.
	Intermediate	CAP 1086/35, PBC 066, PBC 1369, PBC375, PBC 384, PBC 554, Kt-pl-19, PBC 1350, PBC 717, 517-1, Kt-pl-22, Kt-pl-25, Kt-pl-18, Kt-pl-23, Kt-pl-8, Kt-pl-20, PBC 971, Modhpur.
	Compact	PBC 436, Small Conical, Round Ornamental, CAP 1088/35, CAP1063/35, Cluster chilli, Kt-pl-24.
Branching habit	high	Cluster chilli
	intermediate	PBC 385, PBC 473, PBC 1347, PBC 743, Paprika type –1, Dokomlasi 640, PBC 828, PBC 999, Jwala, CAP 1086/35, PBC 066, PBC 1369, PBC375, PBC 384, PBC 554, Kt-pl-19, PBC 1350, PBC 717, 517-1, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-8, PBC 436, Small conical, CAP 1088/35, CAP1063/35, Kt-pl-24, PBC 971, PBC 535, Modhpur, Arka Abir.
	sparse	Byadagi, CA 219, Kt-19, Paprika king, Kt-pl-18, Kt-pl-20, Round ornamental
Leaf colour	Light green	Jwala, Byadagi.
	Green	PBC 385, PBC 473, PBC 1347, Paprika type –1, Dokomlasi 640, PBC 066, PBC 1369, PBC 384, PBC 554, Kt-pl-19, PBC 1350, PBC 717, 517-1, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-8, PBC 436, Smallconical, CAP1063/35, Kt-pl-24, CA 219, Paprika king, Kt-pl-18, Kt-pl-20, Round ornamental, PBC 971, PBC 535, PBC 743, Arka Abir, Modhpur.
	Dark green	Cluster chilli, PBC 828, PBC 999, CAP 1086/35, PBC375, CAP 1088/35, Kt-19.

Continued-

Table 7 cont. Morphological characters of 40 paprika genotypes

Characters	Expression	Genotypes
Leaf shape	Ovate	Jwala, Byadagi, PBC 385, PBC 473, PBC 1347, Paprika type –1, Dokomlasi 640, PBC 066, PBC 1369, PBC 384, PBC 554, Kt-pl-19, PBC 1350, PBC 717, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-8, PBC 436, Smallconical, CAP1063/35, Kt-pl-24, CA 219, Paprika king, Kt-pl-18, Kt-pl-20, Round ornamental, Cluster chilli, PBC 828, PBC 999, CAP 1086/35, PBC375, Kt-19, PBC 535, Arka Abir, Modhpur, PBC 743.
	Lanceolate	517-1, CAP 1088/35, PBC 971.
No.of flowers/axil	1	Jwala, Byadagi, PBC 385, PBC 473, Paprika type –1, PBC 1347, Dokomlasi 640, PBC 066, Kt-pl-19, PBC 1350, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-8, PBC 436, Smallconical, Kt-pl-24, Paprika king, Kt-pl-18, Kt-pl-20, Round ornamental, PBC 828, PBC 999, PBC375, Kt-19, 517-1, CAP 1088/35, PBC 971, PBC 535, Arka Abir, Modhpur, PBC 743.
	>2	PBC 1369, PBC 384, PBC 554, PBC 717, CAP1063/35, CA 219, Cluster chilli, CAP 1086/35.
Flower position	Pendent	Byadagi, PBC 385, PBC 473, PBC 1347, Dokomlasi 640, PBC 066, Kt-pl-19, PBC 1350, Kt-pl-22, Kt-pl-25, Kt-pl-24, Paprika king, Kt-pl-18, Kt-pl-20, PBC 828, PBC 999, PBC375, Kt-19, 517-1, CAP 1088/35, PBC 971, PBC 535, Modhpur, PBC 1369.
	Intermediate	Jwala, Kt-pl-23, Kt-pl-8, PBC 436, Arka Abir, PBC 554.
	Erect	Paprika type –1, Smallconical, Round Ornamental, PBC 743, PBC 384, CAP1063/35, CA 219, Cluster chilli, CAP 1086/35, PBC 717.
Corolla colour	White	Byadagi, PBC 385, PBC 473, PBC 1347, Dokomlasi 640, PBC 066, Kt-pl-19, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-24, Kt-pl-18, Kt-pl-20, PBC 828, PBC 999, PBC375, Kt-19, 517-1, CAP 1088/35, PBC 971, PBC 535, Modhpur, Jwala, PBC 436, Arka Abir, Paprika type –1, Round ornamental, PBC 384, CA 219, Cluster chilli, CAP 1086/35, PBC 717.
	Light yellow	PBC 1350, Paprika king, PBC 1369, Kt-pl-8, PBC 554, Smallconical, PBC 743, CAP1063/35.
Anther colour	Blue	Byadagi, PBC 473, Kt-pl-22, Kt-pl-25, Kt-pl-23, Kt-pl-20, PBC 828, 517-1, PBC 971, Modhpur, Jwala, Arka Abir, Round ornamental, Paprika king, Smallconical, PBC 743, CAP1063/35.
	Purple	PBC 385, PBC 1347, Dokomlasi 640, PBC 066, Kt-pl-19, Kt-pl-24, Kt-pl-18, PBC 999, PBC375, Kt-19, CAP 1088/35, PBC 535, PBC 436, Paprika type –1, PBC 384, CA 219, Cluster chilli, CAP 1086/35, PBC 717, PBC 1350, PBC 1369, Kt-pl-8, PBC 554,

Table 7 – cont. Morphological characters of 40 paprika genotypes

Characters	Expression	Genotypes
Stigma exsertion	Exserted	Byadagi, PBC 473, Kt-pl-22, Kt-pl-23, Kt-pl-20, PBC 971, Jwala, Arka Abir, Round ornamental, Paprika king, Smallconical, PBC 743, CAP1063/35, PBC 385, PBC 1347, Dokomlasi 640, Kt-pl-19, Kt-pl-24, Kt-pl-18, PBC 375, CAP 1088/35, PBC 535, PBC 436, Paprika type –1, PBC 384, CA 219, CAP 1086/35, PBC 717, PBC 1350, PBC 1369, Kt-pl-8, PBC 554, PBC 066.
	Same level	Kt-pl-25, Modhpur
	Inserted	Cluster chilli, Kt-19, 517-1, PBC 828, PBC 999
Calyx margin	Dentate	Byadagi, PBC 473, Kt-pl-22, Kt-pl-23, Kt-pl-20, Modhpur, Round ornamental, Smallconical, Kt-pl-19, Kt-pl-24, Kt-pl-18, PBC 999, PBC 828, PBC 436, PBC 1350, PBC 1369, Kt-pl-8, Kt-pl-25, Paprika type –1.
	Intermediate	PBC 971, Jwala, Arka Abir, PBC 375, Paprika king, PBC 743, CAP1063/35, PBC 385, PBC 1347, Dokomlasi 640, PBC 066, 517-1, CAP 1088/35, PBC 535, PBC 384, CA 219, CAP 1086/35, PBC 717, PBC 554, Kt-19, Cluster chilli .
Calyx annular constriction	Present	Byadagi, PBC 473, Kt-pl-22, Kt-pl-23, Modhpur, Round ornamental, Paprika king, Smallconical, Kt-pl-19, Kt-pl-24, Kt-pl-18, PBC 999, PBC 828, PBC 436, PBC 1350, Kt-pl-8, Kt-pl-25, Paprika type –1, Arka Abir, PBC 375, CAP1063/35, PBC 066, PBC 535, Kt-pl-20.
	Absent	PBC 1369, PBC 971, Jwala, PBC 743, PBC 385, PBC 1347, Dokomlasi 640, 517-1, CAP 1088/35, CAP 1086/35, PBC 384, CA - 219, PBC 717, PBC 554, Kt-19, Cluster chilli.
Fruit colour at intermediate stage	Green	PBC 554, PBC 1369, PBC 066, PBC 473, PBC 535, PBC 717, PBC 1347, PBC 1350, PBC 971, PBC 999, PBC 828, PBC 436, 517-1, PBC384, Paprika King, CAP 1086/35, CAP 1088/35, CAP 1063/35, Arka Abir, CA-219, Paprika type-1, Round ornamental, Small conical, Byadagi, Kt-pl-22, Kt-pl-24, Kt-pl-18, Kt-pl-23, Kt-pl-20, Kt-pl-8, Kt-pl-19, Kt-pl-25.
	Dark green	PBC 375, PBC 385, PBC 743, Dokolasi 640, Kt-19.
	Light green	Modhpur
	Yellowish green	Cluster chilli, Jwala.
Fruit colour at mature stage	Red	PBC 554, PBC 1369, PBC 473, PBC 535, PBC 717, PBC 1347, PBC 1350, PBC 971, PBC 999, PBC 828, PBC 436, PBC384, CAP 1086/35, CAP 1088/35, CAP 1063/35, Arka Abir, CA-219, Paprika type-1, Round ornamental, Small conical, Byadagi, Kt-pl-22, Kt-pl-23, Kt-pl-8, Kt-pl-25, PBC 385, 517 – 1, PBC 743, Dokolasi 640, Kt-19, Modhpur, Cluster chilli, Jwala, PBC 375.
	Dark red	PBC 066, Paprika King, Kt-pl-18, Kt-pl-20, Kt-pl-19, , Kt-pl-24.

Table 7. Cont.

Characters	Expression	Genotypes
Fruit shape	Elongate	PBC 554, PBC 473, PBC 535, PBC 717, PBC 1347, PBC 1350, PBC 971, PBC384, CAP 1063/35, Arka Abir, CA-219, Byadagi, Kt-pl-22, Kt-pl-23, PBC 385, PBC 743, 517 – 1, Dokomlasi 640, Kt-19, Modhpur, Jwala, PBC 066, Paprika King, Kt-pl-18, Kt-pl-20, PBC 375, Kt-pl-24.
	Triangular	PBC 999, PBC 828, CAP 1086/35, CAP 1088/35, Paprika type-1, Small conical, Kt-pl-8, Kt-pl-25, Cluster chilli, Kt-pl-19
	Round	Round ornamental.
	Blocky	PBC 1369, PBC 436.
Fruit shape at blossom end	Pointed	PBC 473, PBC 535, PBC 717, PBC 1347, PBC 971, PBC384, CAP 1063/35, CA-219, Byadagi ,Arka Abir, PBC 385, 517 - 1PBC 743, Dokomlasi 640, Kt-19, Modhpur, Jwala, PBC 066, Paprika King, Kt-pl-18, Kt-pl-20, PBC 375, Kt-pl-24, PBC 999, CAP 1086/35, CAP 1088/35, Kt-pl-8, Cluster chilli,
	Blunt	PBC 554, PBC 1350, Kt-pl-22, Kt-pl-23, PBC 828, Paprika type-1, Small conical, Kt-pl-19,
	Sunken	Round ornamental PBC 1369, PBC 436.
	Sunken and pointed	Kt-pl-25.
Fruit blossom end appendage	Absent	PBC 473, PBC 535, PBC 717, PBC 1347, PBC 971, PBC384, CAP 1063/35, CA-219, Byadagi , Arka Abir, PBC 385, PBC 535, PBC 743, Dokomlasi 640, Kt-19, Modhpur, Jwala, PBC 066, Paprika King, Kt-pl-18, Kt-pl-20, PBC 375, Kt-pl-24, PBC 999, CAP 1086/35, CAP 1088/35, Kt-pl-8, Cluster chilli, PBC 554, PBC 1350, Kt-pl-22, Kt-pl-23, PBC 828, Paprika type-1, Kt-pl-19, Round ornamental PBC 1369, Kt-pl-25, 517-1.
	Present	Small conical, PBC 436
Fruit surface	Smooth	PBC 535, PBC 717, PBC 971, PBC384, CAP 1063/35, CA-219, Arka Abir, Modhpur, Jwala, Paprika King, Kt-pl-20, PBC 375, Kt-pl-24, PBC 999, CAP 1086/35, CAP 1088/35, Cluster chilli, PBC 554, PBC 1350, Kt-pl-22, Kt-pl-23, PBC 828, Paprika type-1, Kt-pl-19, Round ornamental, PBC 1369, Kt-pl-25, PBC 436, PBC 1347, Small conical, 517-1.
	Semiwrinkled	PBC 473, PBC 385, PBC 743, Kt-19, PBC 066, Kt-pl-18, Kt-pl-8, Dokomlasi 640, Kt-19
	Wrinkled	Byadagi
Placenta length	> 1/2	All genotypes
Seed colour	Straw	All genotypes

Fig. 4 Frequency distribution of discrete characters in paprika

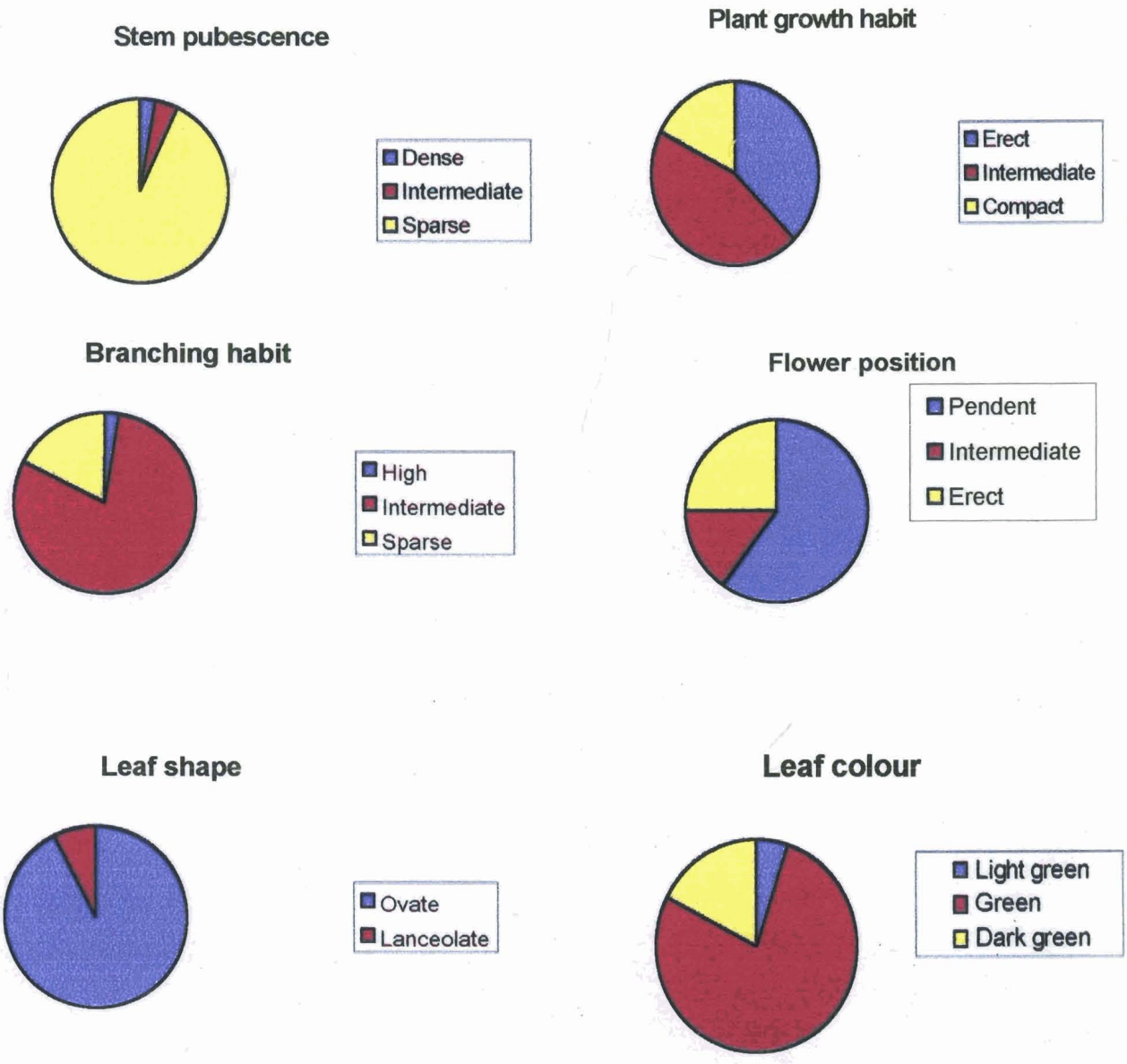


Fig. 5 Frequency distribution of discrete characters in paprika

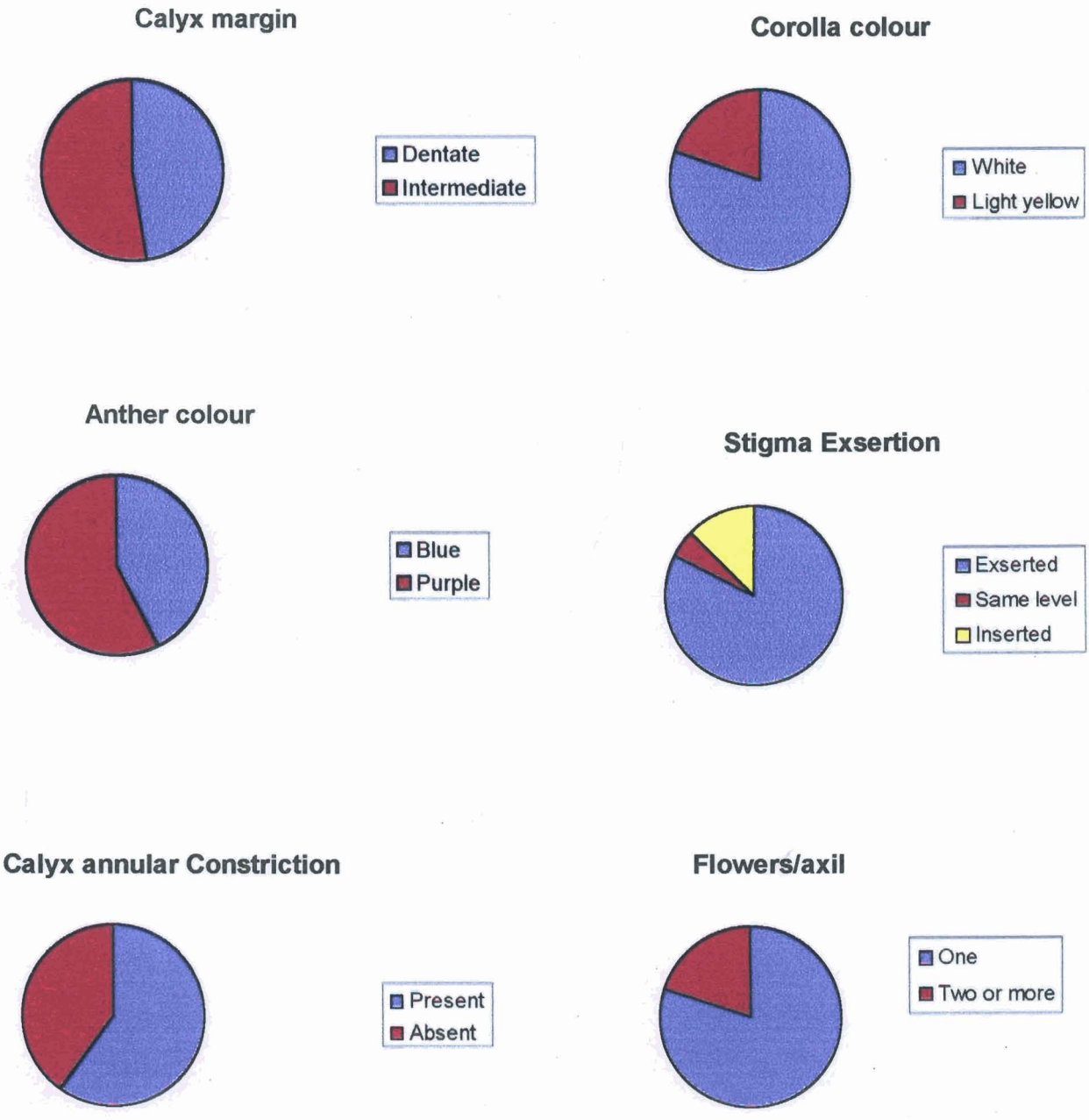
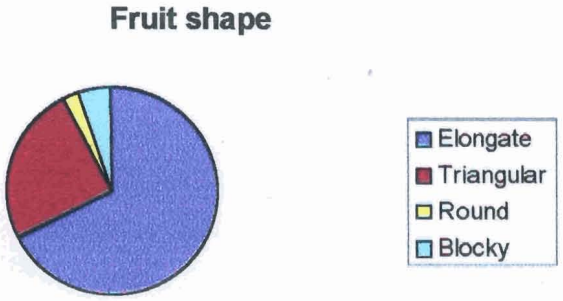
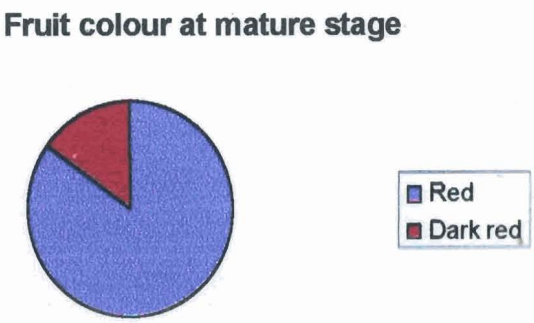
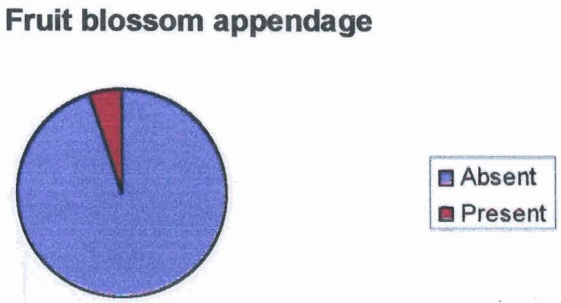
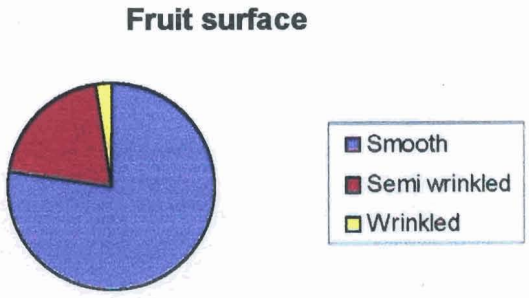


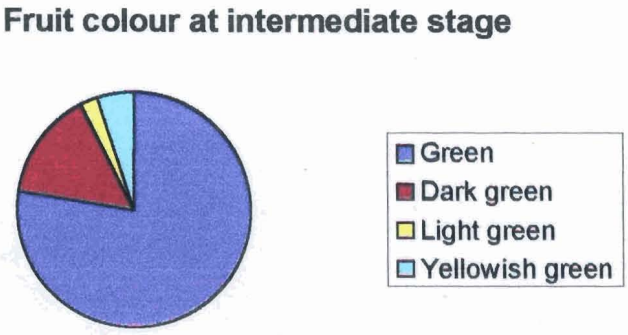
Fig 6 Frequency distribution of discrete characters in paprika

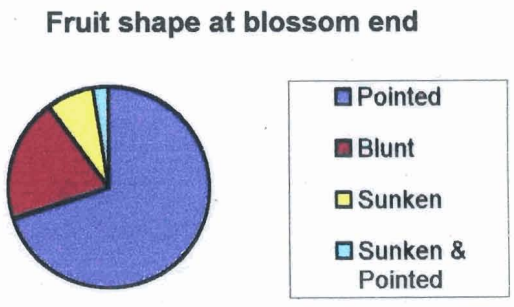






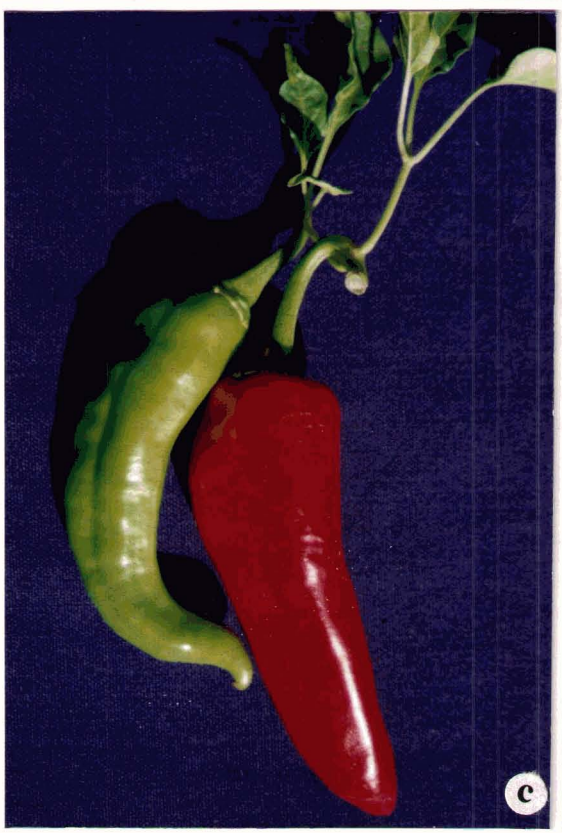


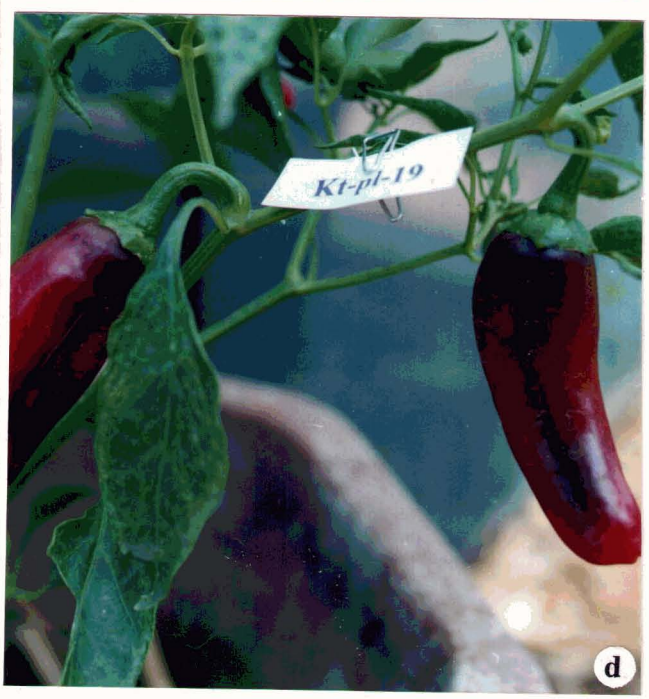




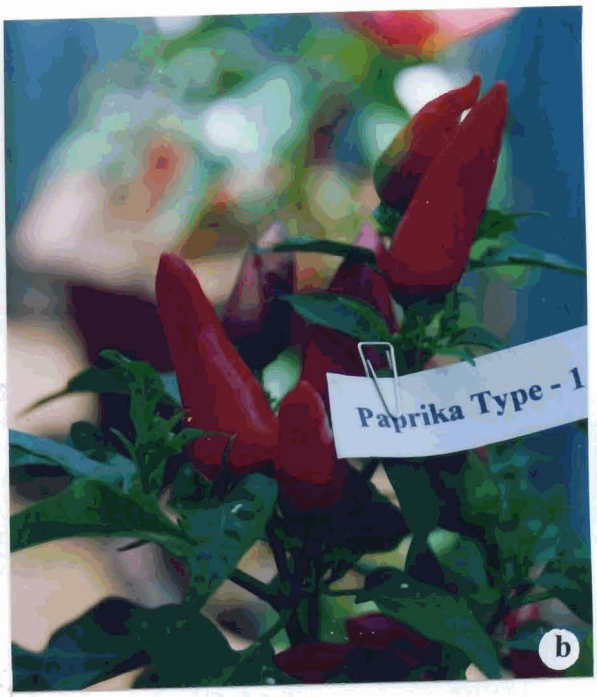

a


PBC 066
b


c


Kt-pl-19
d


Round Ornamental
a


Paprika Type - 1
b


CAP 1086/35
c


PBC-717
d

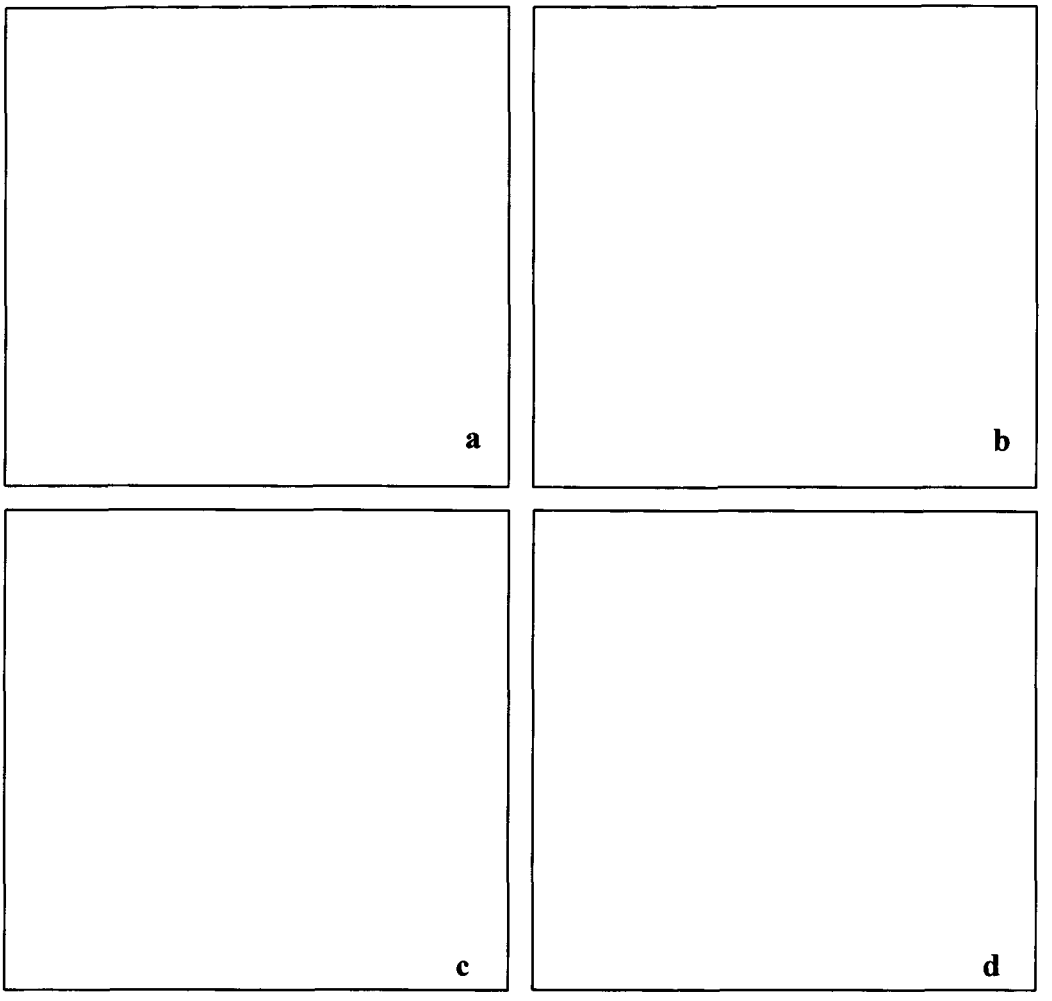

PBC 1347
a
PBC 385
b
PBC 535
c
CAP 1088/35
d


CA-219 (Ujwala)
a


Cluster chilly
b


PBC 473
c

Fig. 7 Paprika genotypes



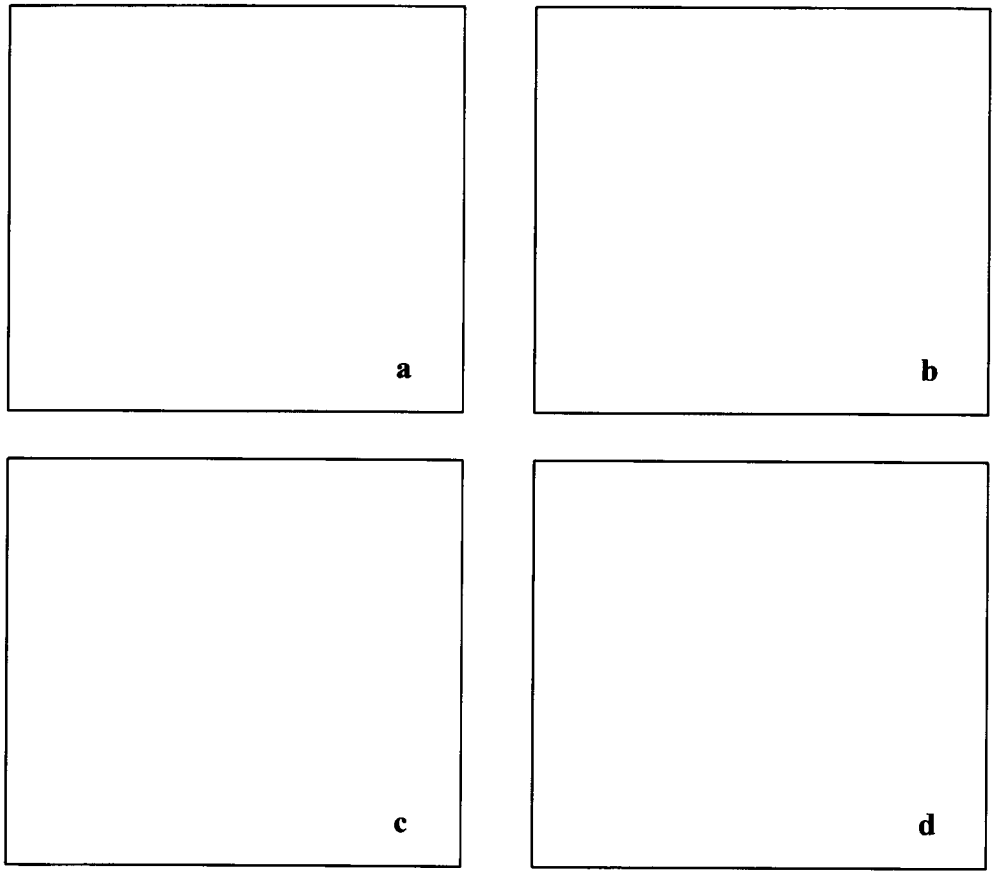
a Paprika King – a high yielding, high colour and low pungency paprika genotype.

b PBC 066- a high yielding, high colour, low pungent paprika genotype.

c Fruits of Paprika King.

d Kt-pl-19 – High colour, low pungent paprika genotype.

Fig. 8. Paprika genotypes with erect fruits



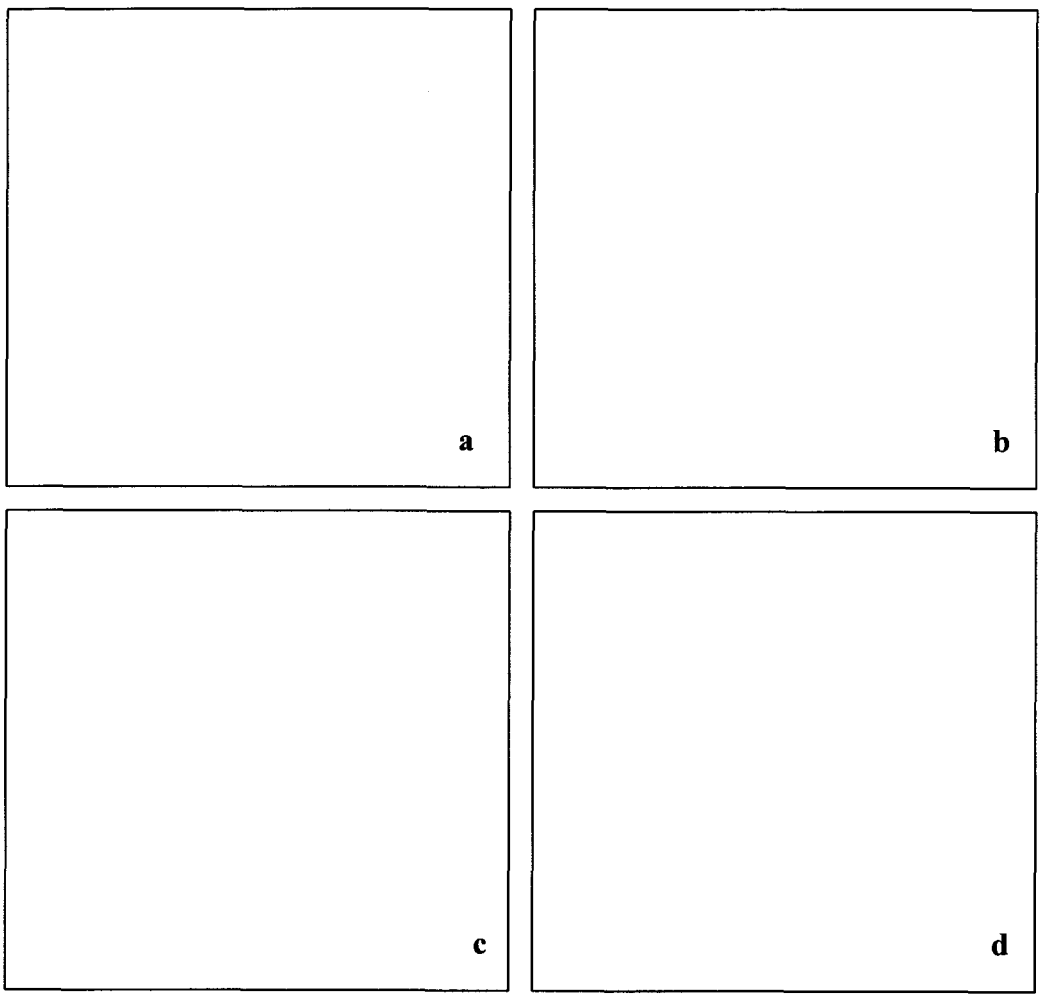
a Round Ornamrntal

b Paprika type – 1

c CAP 1086/35

d PBC 717

Fig. 9 Paprika genotypes with pendent fruits



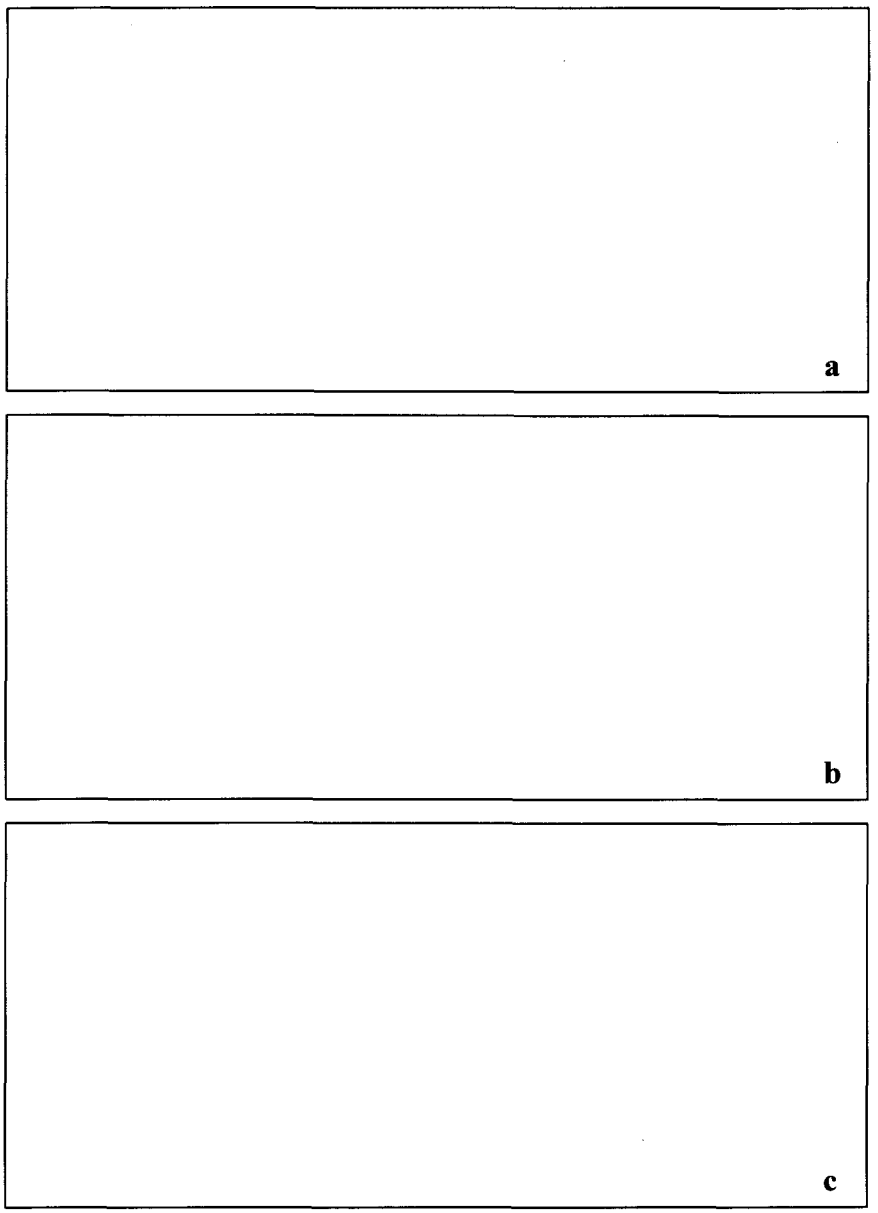
a PBC 1347

b PBC 385

c PBC 535

d CAP 1088/35

Fig. 10 Paprika genotypes showing clustering fruit habit.



a CA-219

b Cluster Chilly

c PBC 473

Table 8 Variability of paprika genotypes in plant height

Sl. no.	Accession no.	Plant height			Mean
		S1	S2	S3	
1.	PBC 436	34	30	33	32.3
2.	PBC 385	63	75	58	65.3
3.	PBC 384	43	78	65	68.6
4.	PBC 375	65	68	45	59.3
5.	PBC 1369	46	49	39	44.6
6.	PBC 066	62	68	45	58.3
7.	CA 219	64	76	46	62.0
8.	PBC 473	56	58	42	52.0
9.	PBC 535	45	43	58	48.6
10.	PBC 554	43	40	41	41.3
11.	Kt-pl-18	44	42	46	44.0
12.	Cluster Chilli	43	45	47	45.0
13.	Small Conical	44	45	47	45.3
14.	Round Ornamental	44	48	45	45.6
15.	Arka Abir	78	82	88	82.6
16.	Byadagi	92	95	89	92.0
17.	Modhpur	46	48	53	49.0
18.	CAP 1088/35	44	45	42	43.6
19.	CAP 1086/35	52	58	55	55.0
20.	Kt-pl-19	58	48	45	50.3

S1- Season1, S2- Season2, S3-Season 3

continued-

Table 8 cont. Variability of paprika genotypes in plant height

Sl no	Accession no.	Plant height			Mean
		S1	S2	S3	
21.	CAP 1063/35	48	49	45	47.7
22.	PBC 1350	46	52	55	51.0
23.	PBC 1347	44	45	48	45.6
24.	PBC 743	84	85	43	70.6
25.	PBC 717	82	86	84	84.0
26.	Paprika type -1	64	68	72	68.0
27.	Dokomlasi - 640	43	45	42	43.3
28.	Kt-pl-22	54	56	49	53.0
29.	Kt- 19	81	86	91	86.0
30.	Kt-pl-24	30	34	46	36.6
31.	Kt-pl-25	55	49	43	49.0
32.	Kt-pl-23	41	48	53	47.3
33.	Kt-pl-8	44	48	42	44.6
34.	Kt-pl-20	42	46	43	43.6
35.	PBC 828	72	61	71	68.0
36.	PBC 971	91	46	63	66.6
37.	PBC 999	78	42	65	61.6
38.	Jwala	44	47	43	44.6
39.	517-1	75	76	63	71.3
40.	Paprika king	68	65	72	68.3
	Mean	56.3	56.9	54.1	
	SD	16.3	16.3	14.9	

*CD (5%) Not significant

* Between seasons

S1- Season1, S2- Season2, S3-Season 3.

Days to flower

Days to flowering ranged from 29 – 64.6 (Table 9). Early flowering lines were Kt-pl-20 (29), Kt-pl-18, Kt-pl-24, Kt-pl-25, Kt-pl-23, PBC 385, PBC 1369, PBC 066, CA-219, CAP 1063/35, Kt-pl-22, Kt-pl-8, PBC 828, Jwala, 517-1 and Paprika King (39).

Kt-19 (64.60) and Dokomlasi 640 (55.6) were late flowering lines and the remaining lines showed intermediate days to flowering.

Days to fruit

Days to fruiting ranged from 42-80 (Table 9). Early flowering lines were also early fruiting. Kt-pl-20 (42), Kt-pl-18, Ktpl-24 and other early flowering types were early fruiting. Kt-19 (80) and Dokomlasi – 640 (68.3) were late fruiting lines.

Table 9 Variability of paprika genotypes in days to flower and fruit

Sl. no.	Accession no.	Days to flower			Mean	Days to fruit			Mean
		S1	S2	S3		S1	S2	S3	
1.	PBC 436	43	43	45	43.6	57	54	59	56.6
2.	PBC 385	38	41	40	39.6	51	52	55	52.6
3.	PBC 384	43	39	42	41.3	56	50	58	54.6
4.	PBC 375	39	40	42	40.3	50	53	56	53.0
5.	PBC 1369	30	38	39	35.6	43	50	50	47.6
6.	PBC 066	41	32	35	36.0	55	45	48	49.3
7.	CA 219	37	36	38	37.0	51	48	50	49.6
8.	PBC 473	42	40	42	41.3	55	52	54	53.6
9.	PBC 535	41	42	44	42.3	54	55	56	55.0
10.	PBC 554	45	43	45	44.3	58	54	57	56.3
11.	Kt-pl-18	43	24	28	31.6	55	36	38	43.0
12.	Cluster Chilli	58	47	53	52.6	70	58	66	64.6
13.	Small Conical	48	43	46	45.6	62	56	54	57.3
14.	Round Ornamental	55	42	43	46.6	70	53	58	60.3
15.	Arka Abir	44	43	48	45.0	59	55	59	57.6
16.	Byadagi	46	47	51	48.0	58	62	69	63.0
17.	Modhpur	42	48	42	44.0	57	60	55	57.3
18.	CAP 1088/35	43	39	42	41.3	57	52	59	56.0
19.	CAP 1086/35	42	40	41	41.0	54	55	52	53.6
20.	Kt-pl-19	45	38	39	40.6	58	51	53	54.0

S1- Season1, S2- Season2, S3 -Season 3 Continued-

Table 9 cont. Variability of paprika genotypes in days to flower and fruit

Sl. no.	Accession no.	Days to flower			Mean	Days to fruit			Mean
		S1	S2	S3		S1	S2	S3	
21.	CAP 1063/35	43	34	39	38.6	55	45	52	50.6
22.	PBC 1350	43	38	42	41.0	58	49	56	54.3
23.	PBC 1347	48	40	41	43.0	61	52	54	55.6
24.	PBC 743	48	43	40	43.6	62	55	51	56.0
25.	PBC 717	45	42	48	45.0	59	52	61	57.3
26.	Paprika type -1	48	40	41	43.0	64	52	54	56.6
27.	Dokomlasi - 640	51	58	58	55.6	64	73	68	68.3
28.	Kt-pl-22	34	36	39	36.3	48	52	51	50.3
29.	Kt- 19	67	62	65	64.6	85	77	78	80.0
30.	Kt-pl-24	31	34	38	34.3	45	48	52	48.3
31.	Kt-pl-25	32	31	38	33.6	43	46	50	46.3
32.	Kt-pl-23	25	32	38	31.6	36	42	48	42.0
33.	Kt-pl-8	44	25	35	34.6	57	35	48	46. 6
34.	Kt-pl-20	32	24	31	29.0	46	34	46	42.0
35.	PBC 828	35	33	36	34.6	47	42	51	46.6
36.	PBC 971	45	42	38	41.6	56	56	49	53.6
37.	PBC 999	41	42	41	41.3	55	57	52	54.6
38.	Jwala	32	33	31	32.0	44	45	43	44.0
39.	517-1	31	30	32	31.0	45	42	48	45.0
40.	Paprika king	31	33	32	32.0	46	48	48	47.3
	Mean	41.3	38.9	41		54.9	51.32	54.6	
	S.D	4.59	7.68	7.1		6.51	8.42	7.25	
	*CD (5%)7.20					4.707			

S1- Season 1, S2- Season 2, S3- Season 3

*Between seasons

Fruit length (cm)

Fruit length ranged from 1.65cm-13.6cm (Table 10). Genotypes with short fruits were Round ornamental (1.65cm), PBC 1369, PBC 436, CAP 1086/35, PBC 743, PBC 717 and Paprika type –1(4.10). Lines with long fruit were Paprika King (13.6cm), PBC 828, PBC 999, Kt-pl-24, PBC 385, PBC 066, and PBC 375 (10.06). The remaining lines had fruit of intermediate length. Variation in fruit length is shown under Fig.11

Fruit width (cm)

Fruit width ranged from 0.60 cm – 3.83cm (Table 10). Fruit width was high in PBC 1369 (3.83cm), PBC 436, PBC 066, Kt-pl-19, Kt-pl-24, Kt-pl-23, PBC 828, PBC 999 and Paprika King (2.26cm). PBC 743 (0.60cm), PBC 717 and Jwala (0.77) were narrow fruited lines.

Table 10 Variability of paprika genotypes in fruit length and fruit width

Sl. no.	Accession no.	Fruit length (cm)			Mean	Fruit width (cm)			Mean
		S1	S2	S3		S1	S2	S3	
1.	PBC 436	4	4	5.5	4.5	3.5	3.9	4	3.8
2.	PBC 385	10.7	8	7.5	8.73	1.5	1	2.0	1.5
3.	PBC 384	10	11	10.5	10.5	2	2.1	2.2	2.1
4.	PBC 375	12	8	10.2	10.6	1.6	1.8	2.2	1.86
5.	PBC 1369	3.1	3.5	4.1	3.56	4.0	3.7	3.8	3.83
6.	PBC 066	13.1	10.5	9.5	11.03	3.0	4.3	2.2	3.16
7.	CA 219	5.3	6.6	6.1	6.0	1.1	1.2	2.7	1.6
8.	PBC 473	10.5	9.8	9	9.76	2	1.8	2.1	1.96
9.	PBC 535	9.5	12	7	9.5	2	1.5	2.5	1.96
10.	PBC 554	12.2	10.1	6.7	9.6	1.5	1.8	2.2	1.83
11.	Kt-pl-18	7.5	7	8	7.5	1.2	1.3	2.5	1.66
12.	Cluster Chilly	5.6	6	5	5.53	1.6	2	1.8	1.80
13.	Small Conical	4.1	5.1	5.5	4.90	1.5	2.1	2.2	1.93
14.	Round Ornamental	1.5	1.45	2.0	1.65	1.75	1.75	2.2	1.90
15.	Arka Abir	7.4	7.5	10.6	8.5	1.75	2.0	1.67	1.87
16.	Byadagi	8.27	9.2	10.5	9.32	1.37	2.0	1.56	1.64
17.	Modhpur	7.1	7.9	8.6	7.86	1.8	1.6	1.5	1.63
18.	CAP 1088/35	7.5	7.5	7.6	7.53	4.1	4.2	4.1	1.36
19.	CAP 1086/35	2.2	1.5	4.2	3.04	1.3	1	1.1	1.13
20.	Kt-pl-19	4.5	6.5	8	6.33	2.7	2.5	2.5	2.56

S1- Season 1, S2 – Season2, S3 – Season 3 Continued-

Table 10 cont. Variability of paprika genotypes in fruit length and fruit width

Sl. no.	Accession no.	Fruit length (cm)			Mean	Fruit width (cm)			Mean
		S1	S2	S3		S1	S2	S3	
21.	CAP 1063/35	4.2	5.3	7.9	5.8	1.0	2.5	2.5	2.0
22.	PBC 1350	4.3	6	7.6	5.96	3.2	2.0	1.4	2.2
23.	PBC 1347	6.1	7.5	10.5	8.03	1.2	1.3	2.5	1.66
24.	PBC 743	4	5	6.6	5.2	0.62	0.60	0.6	0.60
25.	PBC 717	4.1	5.1	6.0	5.06	0.92	0.85	0.9	0.89
26.	Paprika type -1	3.12	5	4.2	4.10	1.4	3.2	2.7	2.43
27.	Dokomlasi - 640	6.7	7.8	7.2	7.23	1.6	1.3	1.5	1.46
28.	Kt-pl-22	9	8	10.4	9.13	2.0	2.2	2.1	2.1
29.	Kt- 19	9.4	9.6	10	9.6	1.2	1.2	1.7	1.36
30.	Kt-pl-24	10	9.8	11	10.26	1.2	1.0	2.5	1.56
31.	Kt-pl-25	8	7	9	8.0	1.8	2	2.1	1.96
32.	Kt-pl-23	8.2	8.0	7.95	8.05	3.0	3.2	2.7	2.96
33.	Kt-pl-8	6.7	7.1	7.5	7.1	2.8	2.2	2.1	2.36
34.	Kt-pl-20	10	9	9.3	9.43	2.1	2.2	1.8	2.03
35.	PBC 828	12.4	8.5	9.1	10.0	4	2.2	3.1	3.10
36.	PBC 971	12.4	11.7	13.2	12.4	2.3	1.3	1.7	1.76
37.	PBC 999	14.5	12.1	13.2	13.23	3.2	3.6	3.1	3.30
38.	Jwala	7.1	7.5	7.9	7.5	0.6	0.82	0.9	0.77
39.	517-1	3.8	3.6	3.5	3.63	1.3	1.4	1.2	1.30
40.	Paprika king	14.0	12.4	14.6	13.6	2.5	2.2	2.1	2.26
	Mean	7.59	7.47	8.0		1.98	1.94	2.14	
	S.D	3.42	2.70	2.73		0.92	0.90	0.72	
	*CD (5%)	2.34				0.61			

*Between seasons

S1- Season 1, S2 – Season2, S3 – Season 3

Fruit weight (g)

Fruit weight ranged from 0.16 - 18.2g (Table 11). Fruit weight was high in CAP 1088/35(18.2g), PBC 1369(16.6g), Paprika King (16.9g), PBC 436 (13.3g), Kt-pl-20 (13.16g) and PBC 066 (11.4g). Fruit weight was low in PBC 743 (0.16g), PBC 717

(0.53g), CAP 1086/35 (0.57g), CA-219 (1.11g), Round Ornamental (1.80g), Jwala (1.56g), 517-1 (1.20g), Kt-19 (1.79g) and Paprika type – 1(1.85g). Rest of the lines had intermediate fruit weight ranging from 2.13g – 8.5g.

Yield /plant (g)

Yield /plant ranged from 53.3 – 255.6g (Table 11). Yield was found to be low in PBC 1369 (53.3g), PBC 436 (60.3g) and CAP 1086/35 (56g) and high in Paprika King (255.6g), PBC 066 (227.3g), Kt-pl-8 (190.3g), Round Ornamental (174g), PBC 1347 (173g), Kt-pl-25 (165g), PBC 1347 (173g) and PBC 1350 (162.6g). The remaining genotypes had intermediate yield ranging from 62 - 157.3g.

Seed size (cm)

Seed size ranged from 0.24 - 0.50 cm (Table 12). PBC 999 (0.50cm), PBC 1369, PBC 436, PBC 554, Kt-pl-18, Kt-pl-19, Kt-pl-8, Kt-pl-24, Kt-pl-23, Kt-pl-20, PBC 828, PBC 971, Paprika King, CAP 1088/35 and Byadagi (0.41cm) had large seeds and CAP 1063/35 (0.24cm), PBC 717, PBC 743, CAP 1086/35, PBC 385 (0.28cm) had small seeds.

Seed number

Seeds/ fruit ranged from 61- 140 (Table 12). Paprika King (61), CAP 1063/35, CAP 1088/35 (67) had a few seeds and Cluster chilly (140), Small conical, PBC 535(129) and PBC 375(122) had many seeds.

Table 11 Variability of paprika genotypes in fruit weight and yield/plant

Sl. no.	Accession no.	Fruit weight (g)			Mean	Yield/plant			Mean
		S1	S2	S3		S1	S2	S3	
1.	PBC 436	10	16	14	13.3	75	63	43	60.3
2.	PBC 385	2.1	1.8	2.5	2.13	128	115	133	125.3
3.	PBC 384	2.4	3.2	3.1	2.90	160	158	148	155.3
4.	PBC 375	2.3	2.1	2.5	2.30	162	175	172	169.6
5.	PBC 1369	19	16.4	14.5	16.6	52	65	43	53.3
6.	PBC 066	11	12.5	10.7	11.4	225	230	227	227.3
7.	CA 219	0.83	1.3	1.2	1.11	72	102	103	92.3
8.	PBC 473	2.7	2.1	2.05	2.28	162	158	161	110.3
9.	PBC 535	1.2	1.8	2.5	1.83	128	126	130	128.0
10.	PBC 554	3.3	5.1	4.2	4.20	124	106	111	113.6
11.	Kt-pl-18	2.6	4.8	3.4	3.60	160	154	158	157.3
12.	Cluster Chilli	2.8	4.2	3.2	3.40	105	94	86	95.0
13.	Small Conical	4.8	5.1	4.3	4.70	144	122	104	123.3
14.	Round Ornamental	1.7	1.6	2.1	1.80	172	186	165	174.3
15.	Arka Abir	2.3	2.1	1.98	2.12	123	108	120	117.0
16.	Byadagi	2.6	2.5	2.8	2.63	110	120	115	115.0
17.	Modhpur	2.2	2.3	1.9	2.13	106	112	123	113.6
18.	CAP 1088/35	21.0	15.3	18.4	18.2	153	141	131	141.6
19.	CAP 1086/35	0.3	0.88	0.54	0.57	65	45	58	56.0
20.	Kt-pl-19	9.1	8	8.5	8.53	116	120	125	120.3

S1- Season 1, S2 – Season2, S3 – Season 3 Continued-

Table 11 cont. Variability of paprika genotypes in fruit weight and yield/plant

Sl. No.	Accession No.	Fruit weight (g)			Mean	Yield / plant (gm)			Mean
		S1	S2	S3		S1	S2	S3	
21.	CAP 1063/35	0.57	0.63	0.84	0.68	67	78	69	71.3
22.	PBC 1350	3.8	2.5	2.8	3.03	148	205	135	162.6
23.	PBC 1347	2.1	2.2	2.5	2.26	148	204	168	173.3
24.	PBC 743	0.23	0.07	0.19	0.16	63	52	71	62.0
25.	PBC 717	0.41	0.65	0.55	0.53	78	65	84	75.6
26.	Paprika type -1	1.6	2.2	1.76	1.85	102	97	105	101.3
27.	Dokomlasi - 640	2.2	2.1	1.78	2.02	123	86	90	99.66
28.	Kt-pl-22	6.9	5.78	5.3	5.99	132	145	128	135.0
29.	Kt- 19	2.1	1.78	1.5	1.79	80	96	104	93.33
30.	Kt-pl-24	5.6	4.8	5.2	5.2	105	113	122	113.3
31.	Kt-pl-25	9.2	8.6	6.5	8.1	180	165	156	167.0
32.	Kt-pl-23	4.8	5.1	4.3	4.73	156	132	145	144.3
33.	Kt-pl-8	9.9	6.9	5.4	7.40	195	190	186	190.3
34.	Kt-pl-20	13.4	12.5	13.6	13.16	156	164	145	155.0
35.	PBC 828	5.6	4.8	6.3	5.56	105	110	111	108.6
36.	PBC 971	8.1	9.2	8.2	8.50	104	106	112	107.3
37.	PBC 999	8.8	6.8	7.3	7.63	92	104	115	103.6
38.	Jwala	1.7	1.8	1.2	1.56	78	75	82	78.3
39.	517-1	1.2	1.1	1.3	1.20	104	123	111	119.6
40.	Paprika king	16.2	16.5	18.1	16.9	260	242	265	255.6
	Mean	4.82	4.74		4.95		125	125.5	124.2
	SD	4.99	4.69		4.78		45.2	47.3	49.2
	*CD (5%)	Not significant					Not significant		

*Between seasons

S1- Season 1, S2 – Season2, S3 – Season 3

Table 12 Variability of paprika genotypes in seed size and seed number

Sl. no.	Accession no.	Seed size (cm)			Mean	Seed number			Mean
		S1	S2	S3		S1	S2	S3	
1.	PBC 436	0.41	0.5	0.42	0.44	68	85	75	76
2.	PBC 385	0.28	0.25	0.31	0.28	112	130	115	119
3.	PBC 384	0.35	0.38	0.28	0.33	98	84	96	92.6
4.	PBC 375	0.32	0.30	0.31	0.31	123	140	104	122.3
5.	PBC 1369	0.45	0.49	0.50	0.48	70	78	83	77
6.	PBC 066	0.41	040	0.35	0.38	95	98	110	101
7.	CA 219	0.32	0.31	0.28	0.30	113	125	110	114
8.	PBC 473	0.31	0.33	0.30	0.31	120	115	107	114
9.	PBC 535	0.30	0.32	0.41	0.34	132	142	115	129.6
10.	PBC 554	0.42	0.44	0.51	0.45	76	85	98	86.3
11.	Kt-pl-18	0.45	0.48	0.46	0.46	82	98	78	86.0
12.	Cluster Chilli	0.31	0.34	0.32	0.32	135	145	142	140.6
13.	Small Conical	0.32	0.29	0.31	0.30	140	122	134	132.0
14.	Round ornamental	0.35	0.32	0.30	0.32	75	82	81	79.3
15.	Arka Abir	0.38	0.41	0.48	0.42	110	95	96	100.3
16.	Byadagi	0.39	0.41	0.43	0.41	85	112	115	104.0
17.	Modhpur	0.30	0.32	0.36	0.32	105	114	112	110.3
18.	CAP 1088/35	0.48	0.45	0.40	0.44	66	63	72	67.0
19.	CAP 1086/35	0.29	0.28	0.25	0.27	89	93	86	89.3
20.	Kt-pl-19	0.48	0.45	0.44	0.45	82	75	72	76.3

S1- Season 1, S2 – Season2, S3 – Season 3 Continued-

Table 12 cont. Variability of paprika genotypes in seed size and seed number

Sl. no.	Accession no.	Seed size (cm)			Mean	Seed number			Mean
		S1	S2	S3		S1	S2	S3	
21.	CAP 1063/35	0.25	0.23	0.24	0.24	63	58	65	62
22.	PBC 1350	0.32	0.35	0.40	0.35	111	116	99	108
23.	PBC 1347	0.35	0.38	0.32	0.35	125	142	138	135.0
24.	PBC 743	0.22	0.24	0.32	0.26	103	112	113	109.3
25.	PBC 717	0.21	0.20	0.32	0.24	95	84	93	90.6
26.	Paprika type -1	0.32	0.34	0.38	0.34	92	96	107	98.3
27.	Dokomlasi - 640	0.35	0.38	0.28	0.33	97	98	104	99.6
28.	Kt-pl-22	0.39	0.41	0.35	0.38	89	98	83	90.0
29.	Kt- 19	0.28	0.29	0.30	0.29	105	97	100	100.6
30.	Kt-pl-24	0.38	0.41	0.36	0.38	103	102	96	100.3
31.	Kt-pl-25	0.41	0.45	0.52	0.46	98	96	108	70.6
32.	Kt-pl-23	0.42	0.48	0.52	0.47	88	102	95	95.0
33.	Kt-pl-8	0.48	0.49	0.39	0.45	79	85	93	85.6
34.	Kt-pl-20	0.49	0.48	0.41	0.46	92	87	93	90.6
35.	PBC 828	0.42	0.41	0.38	0.40	86	91	92	89.6
36.	PBC 971	0.45	0.43	0.39	0.42	88	102	98	96.0
37.	PBC 999	0.49	0.53	0.48	0.50	91	87	94	90.6
38.	Jwala	0.32	0.35	0.40	0.35	99	103	112	104.6
39.	517-1	0.30	0.32	0.36	0.32	105	97	113	105.0
40.	Paprika king	0.42	0.44	0.50	0.45	58	63	62	61.0
	Mean	0.36	0.37	0.37		92.4	98.6	98.7	
	SD	0.07	0.08	0.07		13.9	20.26	19.01	
	*CD (5)%	0.02				Non significant			

*Between seasons

S1- Season 1, S2 – Season2, S3 – Season 3

Colour value (ASTA)

Colour value ranged from 70.3 – 268 ASTA (Table 13). Colour value was high in Paprika King (268ASTA), PBC 828 (258ASTA), Kt-pl-19 (225ASTA), Kt-pl-25 (223ASTA), Byadagi (216ASTA), CAP 1063/35 (188ASTA), Arka Abir (173.3ASTA)

and PBC 385 (172ASTA) and low in PBC 1369 (70.3 ASTA), CAP 1086/35 (89.3ASTA) and PBC 743 (88.66ASTA).

Percentage of Capsaicin

Percentage of capsaicin ranged from 0.05 - 0.63 (Table 13). Capsaicin content was high in 517-1 (0.63%), CAP 1086/35(0.60%) and Jwala (0.52%) and low in PBC 436 (0.05%), PBC 1369 (0.106%), Kt-pl-18 (0.14%) and Kt-pl-25 (0.16%).

Table 13 Variability of paprika genotypes in colour value and capsaicin content

Sl. no.	Accession no.	Colour value (ASTA)			Mean	% of Capsaicin			Mean
		S1	S2	S3		S1	S2	S3	
1.	PBC 436	128	100	135	121	0.06	0.05	0.06	0.05
2.	PBC 385	205	145	168	172	0.54	0.46	0.43	0.47
3.	PBC 384	150	135	146	143.8	0.57	0.54	0.48	0.53
4.	PBC 375	72	144	86	100.6	0.31	0.34	0.48	0.37
5.	PBC 1369	58	69	84	70.3	0.12	0.07	0.13	0.106
6.	PBC 066	131	126	129	128.6	0.34	0.16	0.18	0.226
7.	CA 219	103	123	124	116.6	0.57	0.53	0.48	0.526
8.	PBC 473	117	112	108	112.3	0.40	0.49	0.52	0.47
9.	PBC 535	91	73	95	86.3	0.24	0.16	0.28	0.22
10.	PBC 554	140	128	130	132.6	0.39	0.41	0.43	0.41
11.	Kt-pl-18	74	124	203	133.6	0.19	0.11	0.12	0.14
12.	Cluster Chilly	121	134	156	137.0	0.70	0.56	0.46	0.57
13.	Small Conical	107	113	99	106.3	0.53	0.48	0.49	0.50
14.	Round Ornamental	122	98	95	105.0	0.36	0.43	0.39	0.39
15.	Arka Abir	163	205	152	173.3	0.25	0.28	0.31	0.28
16.	Byadagi	256	230	162	216.0	0.23	0.31	0.32	0.286
17.	Modhpur	109	112	110	110.3	0.45	0.39	0.42	0.42
18.	CAP 1088/35	89	97	93	93.0	0.23	0.31	0.41	0.31
19.	CAP 1086/35	69	77	122	89.3	0.67	0.54	0.61	0.60
20.	Kt-pl-19	160	282	233	225.0	0.21	0.32	0.12	0.21

S1- Season 1, S2 – Season2, S3 – Season 3 Continued-

Table 13 cont. Mean performance of 40 paprika genotypes during 3 seasons

Sl. no.	Accession no.	Colour value (ASTA)			Mean	% of Capsaicin			Mean
		S1	S2	S3		S1	S2	S3	
21.	CAP 1063/35	210	156	198	188	0.28	0.31	0.32	0.30
22.	PBC 1350	107	98	112	105.6	0.29	0.22	0.28	0.263
23.	PBC 1347	110	83	167	120.0	0.53	0.38	0.37	0.426
24.	PBC 743	88	92	86	88.66	0.42	0.41	0.38	0.403
25.	PBC 717	96	93	93	94.0	0.48	0.38	0.42	0.426
26.	Paprika type -1	112	125	110	115.6	0.38	0.12	0.28	0.26
27.	Dokomlasi - 640	98	104	110	104	0.34	0.32	0.29	0.316
28.	Kt-pl-22	99	110	112	107	0.29	0.31	0.28	0.293
29.	Kt- 19	154	123	145	140.6	0.35	0.410.	0.39	0.383
30.	Kt-pl-24	151	145	149	148.3	0.05	0.08	0.06	0.063
31.	Kt-pl-25	239	220	210	223.0	0.17	0.16	0.15	0.16
32.	Kt-pl-23	153	156	167	158.6	0.29	0.30	0.31	0.30
33.	Kt-pl-8	110	112	84	102	0.26	0.28	0.31	0.283
34.	Kt-pl-20	143	145	123	137	0.46	0.38	0.32	0.386
35.	PBC 828	292	267	215	258	0.23	0.24	0.29	0.253
36.	PBC 971	88.9	145	123	118.9	0.25	0.24	0.23	0.24
37.	PBC 999	109	110	123	114.0	0.25	0.22	0.21	0.226
38.	Jwala	76.4	78.2	82	78.86	0.54	0.46	0.56	0.52
39.	517-1	137	145	121	134.3	0.64	0.63	0.62	0.63
40.	Paprika king	221	316	268	268.3	0.53	0.21	0.34	0.36
	Mean	129.2	133.6	135.6		0.78	0.32	0.32	
	S.D	53.0	55.6	44.5		0.14	0.14	0.44	
	*CD (5%)	Non significant				0.11			

*Between seasons

S1- Season 1, S2 – Season2, S3 – Season 3

Seed protein analysis

Electrophoretic profiles (Fig.12) of seed proteins from the representative genotypes were outlined in the form of an electrophorogram (Fig.13). Maximum bands (21) in CAP 1086/35 and minimum (9) in PBC 385 were observed. The Em values ranged from 0.13 to 0.97. Each genotype was distinct from the other with respect to the Em values, but certain bands were shared by a few genotypes. The 29 accessions could be grouped into two big clusters, accessions PBC 1346, PBC 971, PBC 743, PBC 375, PBC 1350, PBC 535, PBC 473 and Kt-pl-25 forming one cluster and the rest of the accessions forming the second cluster.

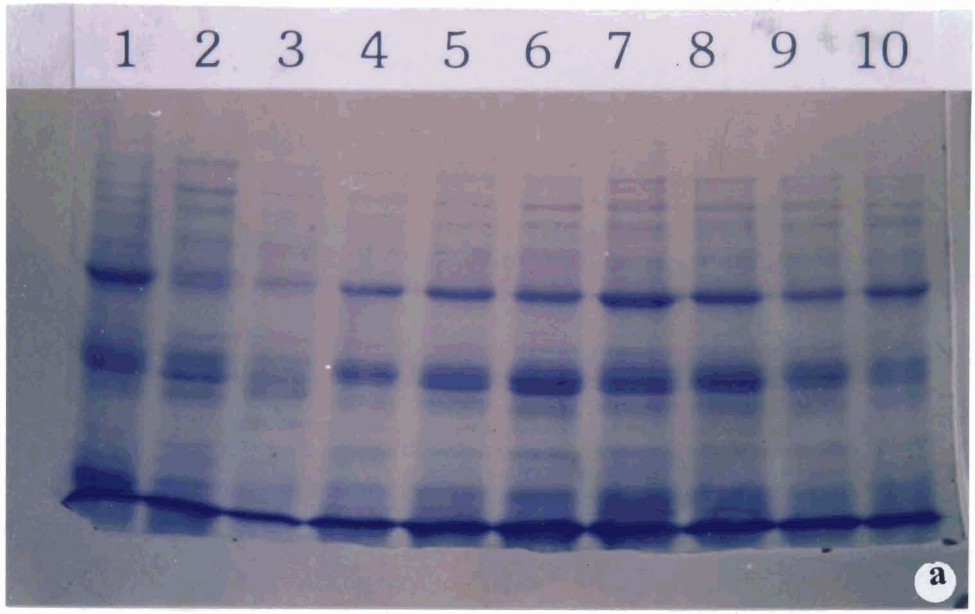
A dendrogram drawn based on percentage similarity, showed that there were 13 clusters (Fig. 14). Genotypes PBC 436, Paprika type-1, Round Ornamental and Jwala clustered together forming the first cluster. The second cluster was formed by accessions CA-219, PBC 384, PBC 828 and PBC 999. PBC 066, PBC 554, CAP 1086/35 and CAP 1063/35 formed the third cluster. CAP 1088/35, formed the fourth cluster. Kt-pl-24, Kt-pl-20 and Kt-pl-8 formed the fifth cluster, Kt-pl-19 and Kt-pl-23 formed the sixth cluster, Kt-pl-22 and Kt-pl-18 formed the seventh, PBC 385 formed the eighth, PBC 1347 and PBC 971 formed the ninth, PBC 743, PBC 375 and PBC 1350 formed the tenth, PBC 535 formed the eleventh, PBC 473, the twelfth and Kt-pl-25, the thirteenth cluster. Paired affinity indices of the genotypes were worked out (Fig. 15). Average similarity was highest (80%) between PBC 436 collected from AVRDC originated in Portugal and Round ornamental collected from KAU (Table 15).

Table 14 Seed protein percentage of paprika genotypes

Cluster	Accessions	Seed protein %
1	PBC 436	0.91
	Paprika type –1	2.8
	Round Ornamental –1	1.96
	Jwala	1.56
2	CA 219	3.4
	PBC 384	2.7
	PBC 828	3.29
	PBC 999	1.43
3	PBC 066	3.7
	PBC 554	0.61
	CAP 1086/35	1.14
	CAP 1063/35	1.44
4	CAP 1088/35	0.86
5	Kt-pl-24	3.0
	Kt-pl-20	1.56
	Kt-pl-8	5.4
6	Kt-pl-19	3.42
	Kt-pl-23	2.08
7	Kt-pl-22	3.52
	Kt-pl-18	2.21
8	PBC 385	2.23
9	PBC 1347	1.76
	PBC 971	3.34
10	PBC 743	1.71
	PBC 375	1.61
	PBC 1350	2.61
11	PBC 535	0.57
12	PBC 473	1.76
13	Kt-pl-25	3.4

Table 15 Comparison of paprika genotypes based on dendrogram

Node	Groups	Average similarity	No.of objects in a fused group
1	PBC 436 and Round Ornamental	80	2
2	CAP 1086/35 and CAP 1063/35	76	2
3	PBC 066 and PBC 554	74	2
4	CA 219 and PBC 828	72	2
5	PBC 375and PBC 1350	76	2
6	PBC 436, Jwala and Round Ornamental	71.3	3
7	CA 219, PBC 828 and PBC 999	70	3
8	PBC 1347 and PBC 971	70	2
9	Node 6 and Paprika type-1	65.3	4
10	Kt-pl-24, Kt-pl-8 and Kt-pl-20	64.6	3
11	PBC 375, PBC 743 and PBC 1350	74.6	4
12	Node 7 and PBC 384	66.5	4
13	Node 2, PBC 066 and PBC 554	66	4
14	Kt-pl-19 and Kt-pl-23	54	2
15	Node8 and PBC 535	57.3	3
16	Node 13 and CAP 1088/35	54	5
17	Node10 and Node 14	59.3	5
18	Kt-pl-22 and Kt-pl-18	46	2
19	Node 12 and Node 16	60.2	9
20	Node11, Node 15 and PBC 473	38.8	7
21	Node 17 and Node18	52.65	7
22	Node 19 and Node21	56.4	16
23	Node 22 and Node 9	55.05	13
24	Node 20 and Kt-pl-25	34.1	8
25	Node 23 and PBC 385	25.3	21
26	Node 24 and Node 25	29.7	29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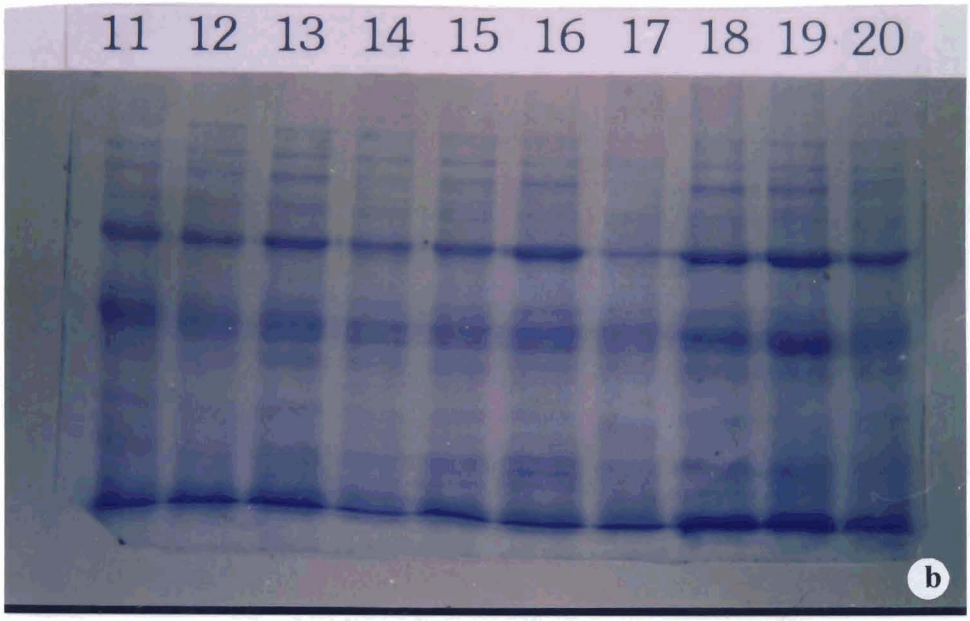
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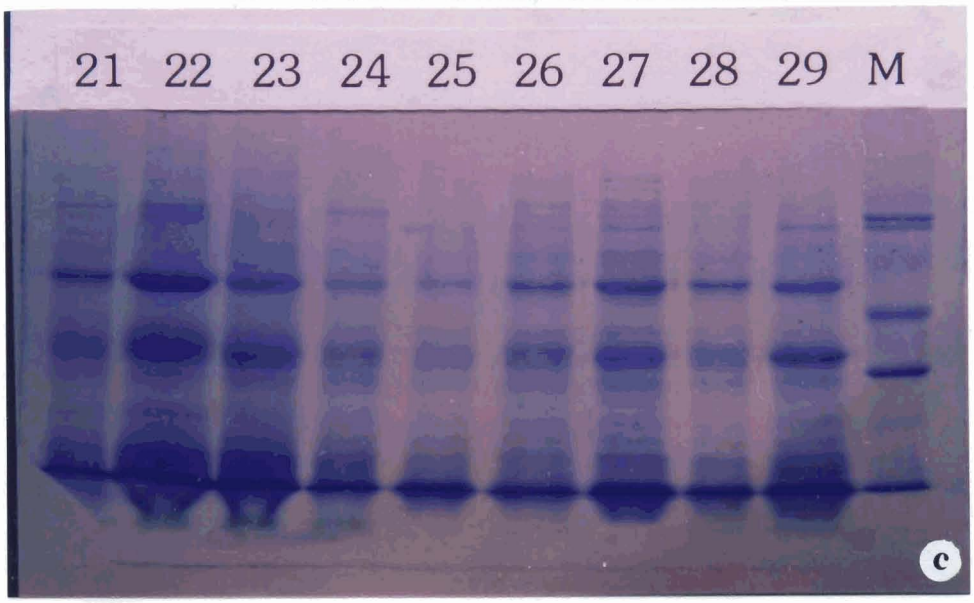
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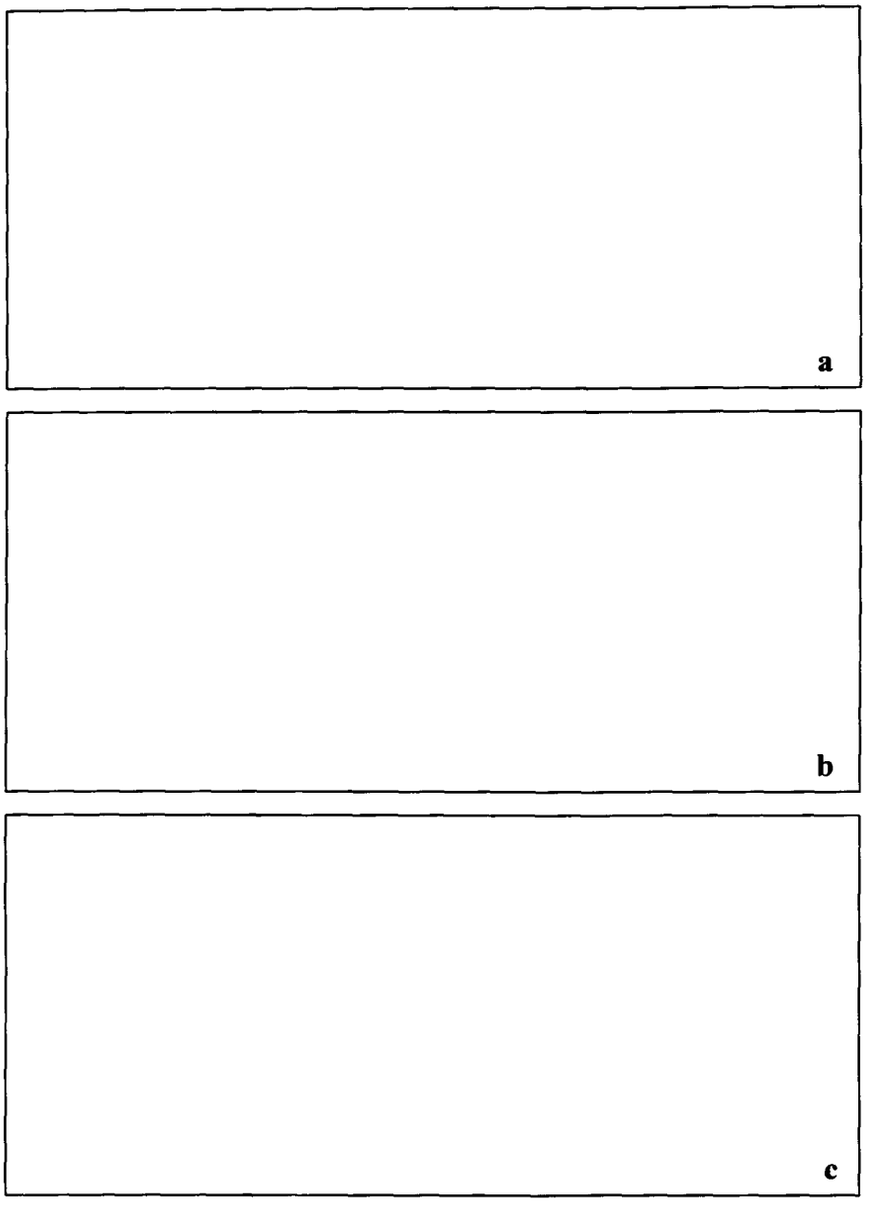
c

Fig. 12 Gels of seed protein electrophoresis of paprika genotypes



a 1-10 - Kt-pl-22, Kt-pl-25, Kt-pl-18, Kt-pl-24, Kt-pl-19, Kt-pl-23, Kt-pl-20, Kt-pl-8, PBC 385 and PBC 473.

b 11-20 – PBC 743, PBC 1347, PBC 971, PBC 535, PBC 375, PBC 1350, PBC 436, Paprika type-1, Round Ornamental, Jwala.

c 21-29 – CA-219, PBC 384, PBC 828, PBC 999, PBC 066, PBC 554, CAP 1063/35, CAP 1088/35 and M- molecular weight marker.

Fig.13 Electrophorograms showing the distribution of proteins in 29 accessions of *C.annuum*.

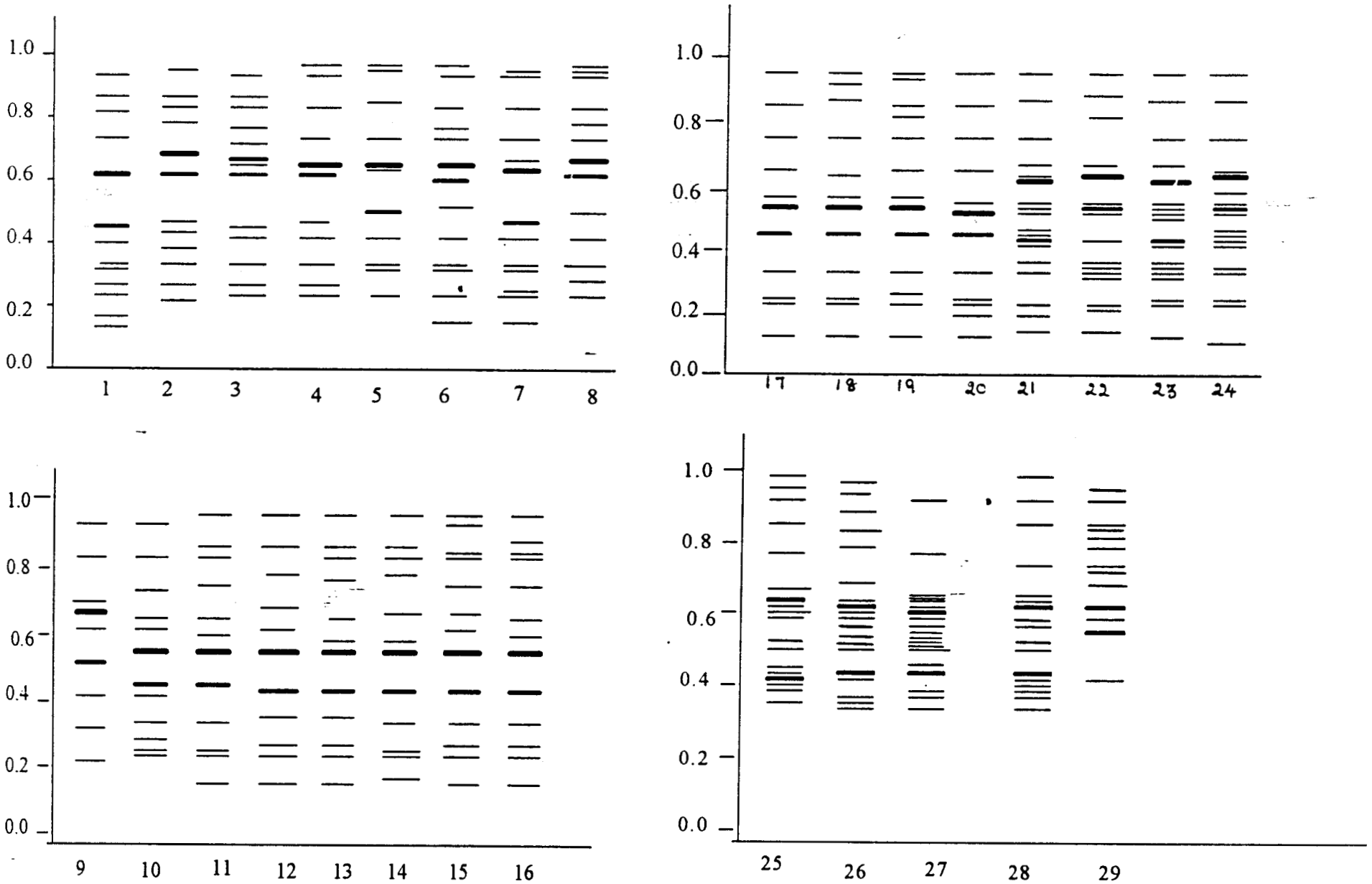


Fig. 14 Dendrogram based on cluster analysis of 29 genotypes of *C. annuum*.

1-29 - Kt-pl-22, Kt-pl-25, Kt-pl-18, Kt-pl-24, Kt-pl-19, Kt-pl-23, Kt-pl-20, Kt-pl-8, PBC 385 and PBC 473, PBC 743, PBC 1347, PBC 971, PBC 535, PBC 375, PBC 1350, PBC 436, Paprika type-1, Round Ornamental, Jwala, CA-219, PBC 384, PBC 828, PBC 999, PBC 066, PBC 554, CAP 1063/35 and CAP 1088/35.

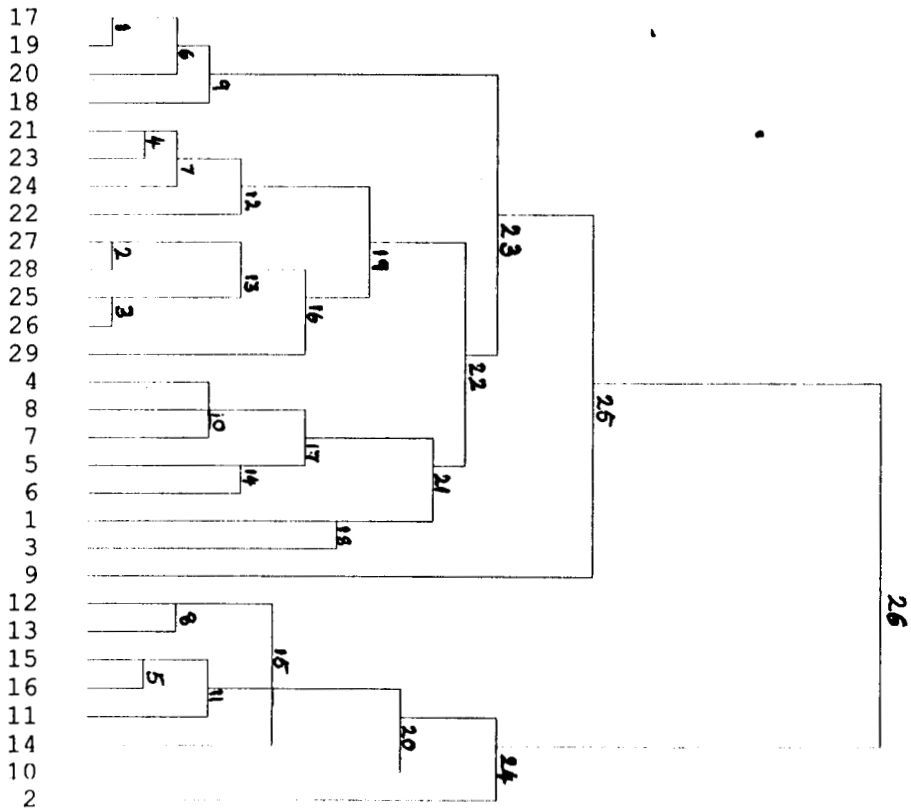


Fig.14 Cluster analysis dendrogram of 29 accessions of C.annuum based on seed protein gel electrophoresis

Fig. 15 Paired affinity indices of 29 genotypes of *C.annuum* based on seed protein electrophoretic profiles.

1-29 - Kt-pl-22, Kt-pl-25, Kt-pl-18, Kt-pl-24, Kt-pl-19, Kt-pl-23, Kt-pl-20, Kt-pl-8, PBC 385 and PBC 473, PBC 743, PBC 1347, PBC 971, PBC 535, PBC 375, PBC 1350, PBC 436, Paprika type-1, Round Ornamental, Jwala, CA-219, PBC 384, PBC 828, PBC 999, PBC 066, PBC 554, CAP 1063/35 and CAP 1088/35.

Fig.15 Paired affinity indices (% of similarity) of 29 accessions of *C.annuum* based on seed protein electrophoretic profiles

Acc No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	100.00	16.00	23.00	25.00	16.00	15.00	19.00	19.00	14.00	16.00	08.00	08.00	12.00	16.00	08.00	08.00	16.00	20.00	12.00	16.00	19.00	14.00	19.00	21.00	15.00	12.00	12.00	13.00	11.00
2		100.00	20.00	17.00	09.00	08.00	16.00	16.00	05.00	13.00	17.00	13.00	25.00	17.00	16.00	16.00	13.00	13.00	12.00	12.00	10.00	11.00	07.00	10.00	15.00	16.00	22.00	16.00	11.00
3			100.00	29.00	13.00	23.00	19.00	19.00	14.00	20.00	08.00	17.00	16.00	16.00	12.00	08.00	13.00	12.00	08.00	12.00	16.00	17.00	16.00	19.00	21.00	24.00	15.00	16.00	18.00
4				100.00	27.00	29.00	33.00	33.00	15.00	13.00	14.00	14.00	09.00	13.00	17.00	08.00	23.00	13.00	17.00	22.00	17.00	15.00	17.00	21.00	13.00	13.00	19.00	13.00	19.00
5					100.00	29.00	25.00	21.00	15.00	13.00	04.00	05.00	00.00	00.00	08.00	04.00	18.00	17.00	13.00	16.00	21.00	19.00	26.00	26.00	19.00	13.00	22.00	20.00	19.00
6						100.00	31.00	27.00	14.00	16.00	00.00	04.00	00.00	00.00	04.00	00 .00	29.00	25.00	19.00	20.00	23.00	21.00	29.00	23.00	15.00	12.00	15.00	13.00	21.00
7							100.00	31.00	09.00	04.00	04.00	04.00	04.00	04.00	04.00	08.00	25.00	12.00	19.00	24.00	13.00	14.00	19.00	23.00	21.00	18.00	18.00	19.00	08.00
8								100.00	09.00	08.00	08.00	00.00	04.00	08.00	08.00	04.00	17.00	16.00	12.00	20.00	16.00	17.00	19.00	19.00	18.00	15.00	18.00	16.00	04.00
9									100.00	19.00	03.00	05.00	05.00	09.00	18.00	05.00	10.00	10.00	09.00	05.00	15.00	12.00	11.00	07.00	13.00	17.00	13.00	14.00	13.00
10										100.00	29.00	13.00	17.00	21.00	24.00	20.00	04.00	04.00	04.00	04.00	10.00	11.00	10.00	07.00	15.00	13.00	06.00	10.00	01.00
11											100.00	22.00	29.00	29.00	28.00	36.00	04.00	04.00	04.00	08.00	03.00	04.00	03.00	03.00	12.00	09.00	09.00	06.00	03.00
12												100.00	35.00	26.00	29.00	25.00	00.00	04.00	00.00	04.00	07.00	07.00	07.00	00.00	03.00	00.00	09.00	07.00	08.00
13													100.00	25.00	28.00	32.00	00.00	08.00	04.00	04.00	03.00	14.00	03.00	03.00	06.00	06.00	09.00	03.00	04.00
14														100.00	28.00	24.00	00.00	08.00	00.00	03.00	07.00	00.00	03.00	12.00	12.00	12.00	09.00	03.00	04.00
15															100.00	38.00	00.00	00.00	00.00	04.00	03.00	10.00	06.00	00.00	09.00	06.00	12.00	06.00	07.00
16																100.00	04.00	00.00	08.00	08.00	03.00	07.00	03.00	03.00	12.00	12.00	12.00	06.00	07.00
17																	100.00	35.00	40.00	35.00	21.00	15.00	24.00	28.00	19.00	16.00	16.00	17.00	02.00
18																		100.00	32.00	28.00	27.00	18.00	23.00	27.00	15.00	19.00	15.00	13.00	07.00
19																			100.00	32.00	16.00	14.00	19.00	23.00	21.00	18.00	18.00	16.00	14.00
20																				100.00	27.00	16.00	27.00	30.00	15.00	13.00	18.00	23.00	15.00
21																					100.00	32.00	36.00	36.00	23.00	21.00	28.00	27.00	18.00
22																						100.00	32.00	26.00	27.00	25.00	27.00	20.00	13.00
23																							100.00	33.00	18.00	16.00	26.00	24.00	21.00
24																								100.00	21.00	26.00	31.00	30.00	21.00
25																									100.00	29.00	28.00	19.00	26.00
26																										100.00	34.00	26.00	26.00
27																											100.00	38.00	28.00
28																												100.00	29.00
29																													100.00

Callus induction

Callus induction is the preliminary step for production of somaclones. Eight-week-old *in vitro* germinated seedlings of paprika lines were used for tissue culture experiments. The explants used for callus induction were stem and leaf bits of 1cm length. The responses of leaf and stem explants to various combinations of auxins are given (Tables 16, 18, and 20). 2,4-D produced loose friable callus whereas NAA and IBA produced more compact callus. Direct regeneration from stem and leaf explants were observed at low concentrations of 2,4-D. 2,4-D at concentrations 0.1-0.5 mgl^{-1} induced roots and only callus at higher concentrations. 2,4-D at 10 mgl^{-1} and 5mgl^{-1} produced high amount of callus, but it turned brown soon (Fig. 16, c). 2,4-D at 2mgl^{-1} was optimal for induction of loose friable callus (Fig.17, a). Stem explant was better than leaf for callus induction (Table 16). Duncan's multiple range test also showed similar observation (Table 17). NAA induced roots and direct regeneration at concentrations 0.1 – 0.5 mgl^{-1} and callus with thick tufted roots at concentrations 1mgl^{-1} and 2mgl^{-1}. NAA at 10mgl^{-1} and 5mgl^{-1} also produced high amount of callus that turned brown soon (Fig. 16, a). NAA was not suitable for induction of friable callus, but at lower concentrations it induced compact callus suitable for regeneration. Stem was a better explant than leaf in this case also (Table 18). IBA at concentrations 0.1mgl^{-1} – 1mgl^{-1} induced roots with callus (Fig.17 c) and without callus (Fig. 17 b) and direct regeneration (Fig. 17,d). IBA at concentrations 2mgl^{-1} – 10mgl^{-1} induced white compact callus, but at higher concentrations, the callus turned brown soon (Fig. 16, b). IBA also at lower concentrations produced compact callus suitable for regeneration at lower concentrations (Table 20).

Table 16 Effect of 2,4 –D on callus induction using leaf and stem explants in *C.annuum.* (30 days after inoculation).

Sl. No.	2,4 – D (mgl^{-1})	% of response		Nature of response	Colour of callus	Weight of callus (g)	
		Leaf	Stem			Leaf	Stem
1	2,4 – D 0.1	18.7	-	Direct regeneration	-	0.0	0.0
		81.3	90	Roots	-	-	-
2	2,4 – D 0.25	18	54	Roots	-	-	-
		93	-	Loose friable callus	White	0.02	0.034
3	2,4 – D 0.5	98	99	Friable callus with roots	White	0.13	0.18
4	2,4 – D 1	98	98	Loose friable callus	Cream turning brown	0.15	0.21
5	2,4 – D 2	100	100	Loose friable callus	Cream turning brown	0.41	0.50
6	2,4 – D 5	100	100	Loose friable callus	Cream turning brown	0.53	0.56
7	2,4 – D 10	100	100	Loose friable callus	Brown	1.3	1.5

Table 17 Duncan's multiple range test for effect of 2,4 – D on callus induction using leaf and stem explants

Treatments	2,4-D (mgl^{-1})	Leaf - Ranked order	Stem-Ranked order
1	0.1	7A	7A
2	0.25	6B	6B
3	0.50	5C	5C
4	1.0	4D	4D
5	2.0	3D	3D
6	5.0	2E	2E
7	10.0	1E	1E
		Leaf LSD=0.059	Stem LSD=0.034

Table 18 Effect of MS basal medium with NAA on callus induction using leaf and stem explants in *C.annuum.* (30 days after inoculation)

Sl. No.	NAA ($mg\ l^{-1}$)	Percentage of response		Nature of response	Colour of callus	Weight of callus (g)	
		Leaf	Stem			Leaf	Stem
1	NAA 0.1	100	90	Roots	-	0.0	0.0
		-	10	Direct plant regeneration	-	0.0	0.0
2	NAA 0.25	100	70	Roots	-	0.0	0.0
		-	20	callus with roots	White	0.0	0.011
		-	10	Direct plant Regeneration	-		
3	NAA 0.5	95	80	Little callus with roots	White	0.02	0.15
		-	20	Direct plant regeneration	-		
4	NAA 1	100	100	Callus with thick tufted roots	White	0.12	0.16
5	NAA 2	100	100	Callus with thick tufted roots	White	0.32	0.41
6	NAA 5	100	100	Compact callus	White turning brown	0.51	0.53
7	NAA10	100	100	Compact callus	White turning brown	1.2	1.5

Table 19 Duncan's multiple range test for effect of NAA on callus induction using leaf and stem explants.

Treatments	NAAmgl^{-1}	Ranked order leaf	Ranked order stem
1	0.1	7A	7A
2	0.25	6B	6B
3	0.5	5C	5C
4	1	4D	4D
5	2	3E	3D
6	5	2E	2E
	10	1E	1E

Leaf LSD=0.048 Stem LSD = 0.048

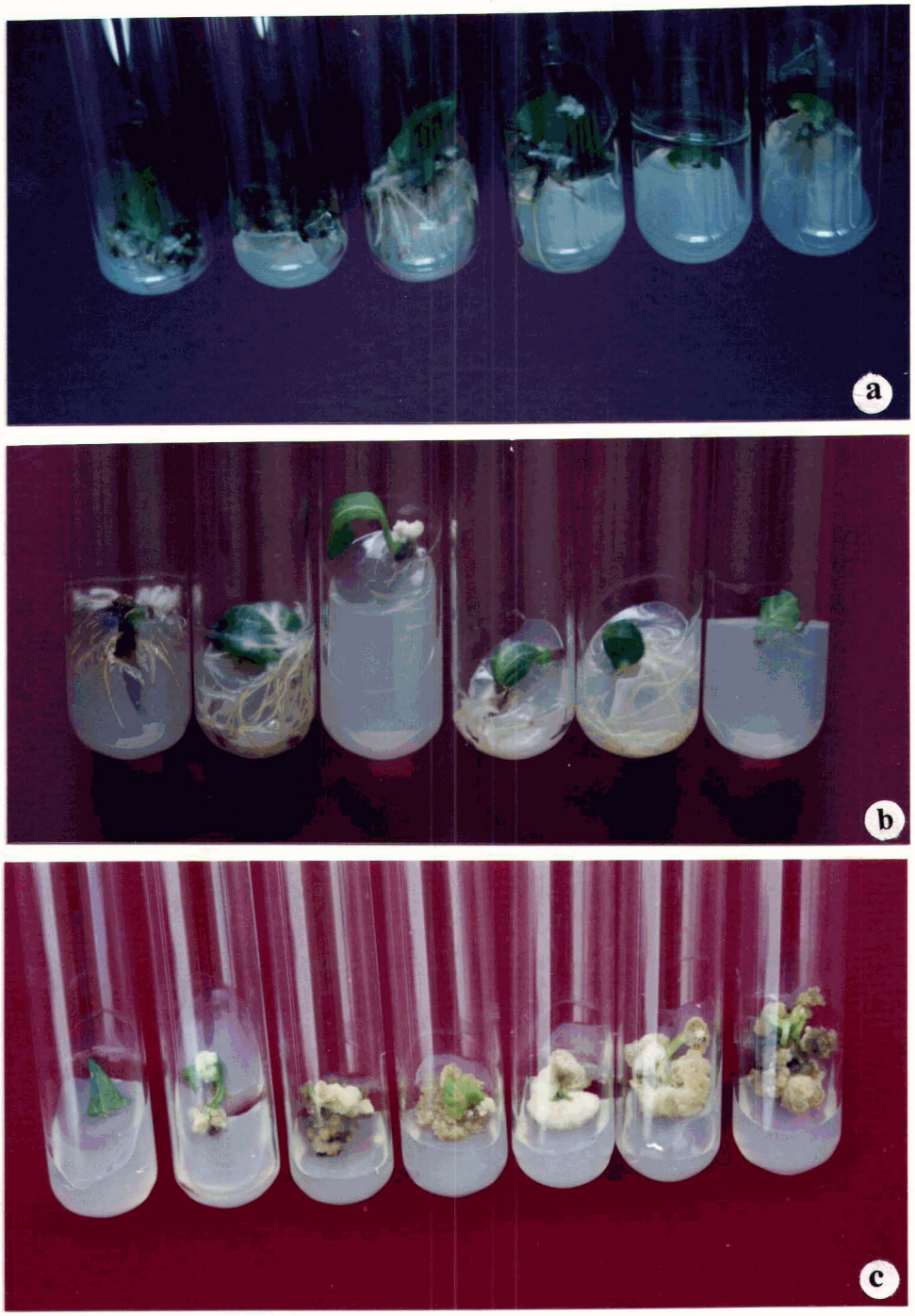
Table 20 Effect of MS basal medium with IBA on callus induction using leaf and stem explants in *Capsicum annuum*(30 days after inoculation).

Sl. No	IBA (mgl^{-1})	% of response		Nature of response	Colour of callus	Weight of callus (g)	
		Leaf	Stem			Leaf	Stem
1	0.1	5	3	Roots		0.0	0.0
2	0.25	6	4	Roots		0.0	0.0
3	0.5	90	90	Roots		0.0	0.0
4	1	80	0	Roots		0.0	0.0
		20	90	Direct regeneration			
5	2	90	95	Little callus with roots	White	0.05	0.12
		10		Direct regeneration			
6	5	95	95	Little callus with many roots	White turning brown	0.18	0.25
7	10	100	100	Little callus with many roots	White turning brown	0.32	0.43

Table 21 Duncan's multiple range test for effect of IBA on callus induction using leaf and stem explants.

Treatments	IBA(mgl^{-1})	Ranked order leaf	Ranked order stem
1	0.1	7A	7A
2	0.25	6B	6B
3	0.5	5C	5C
4	1.0	4D	4D
5	2.0	3D	3D
6	5.0	2D	2D
7	10	1D	1D

Leaf LSD=0.001 Stem LSD = 0.001


a
b
c

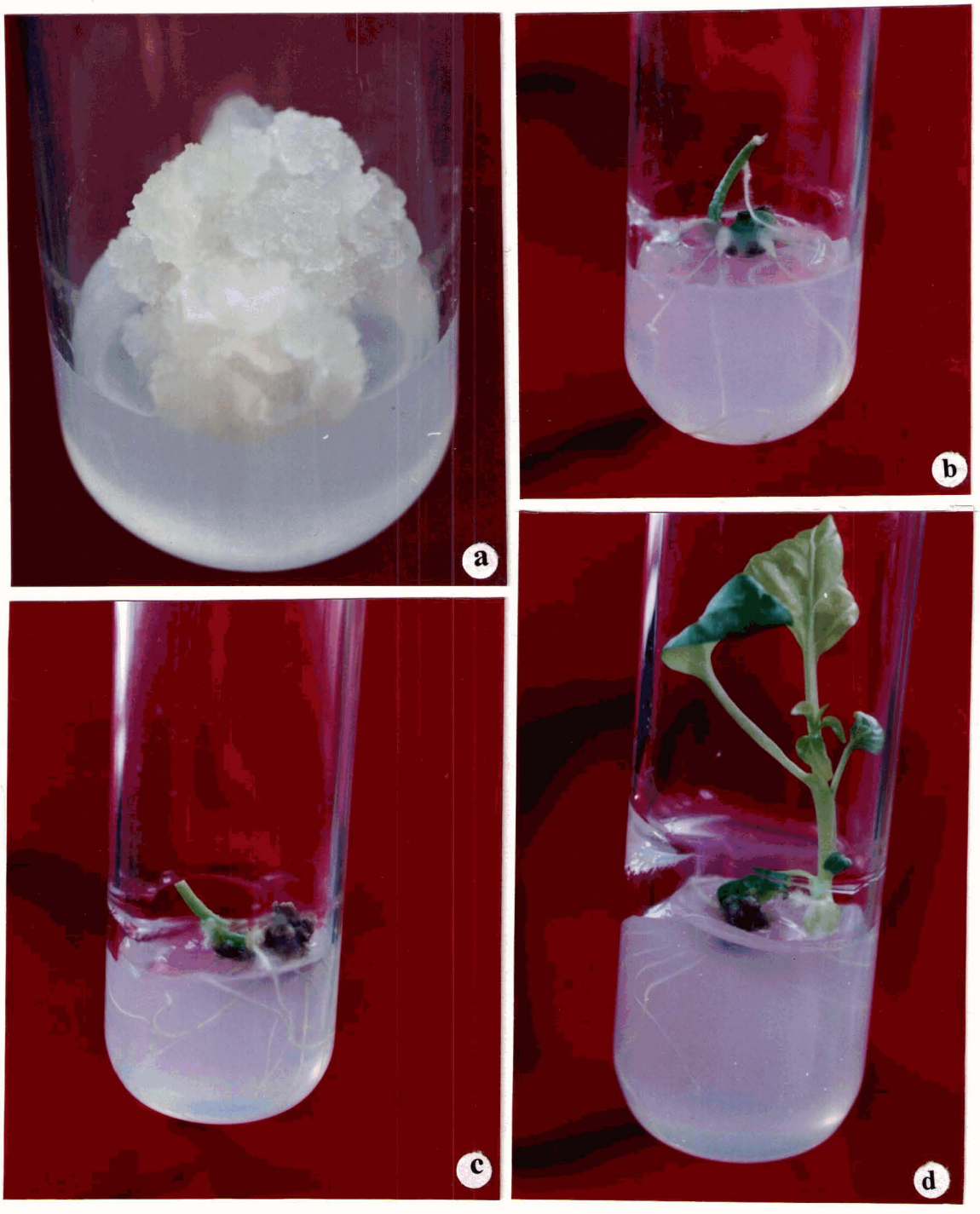
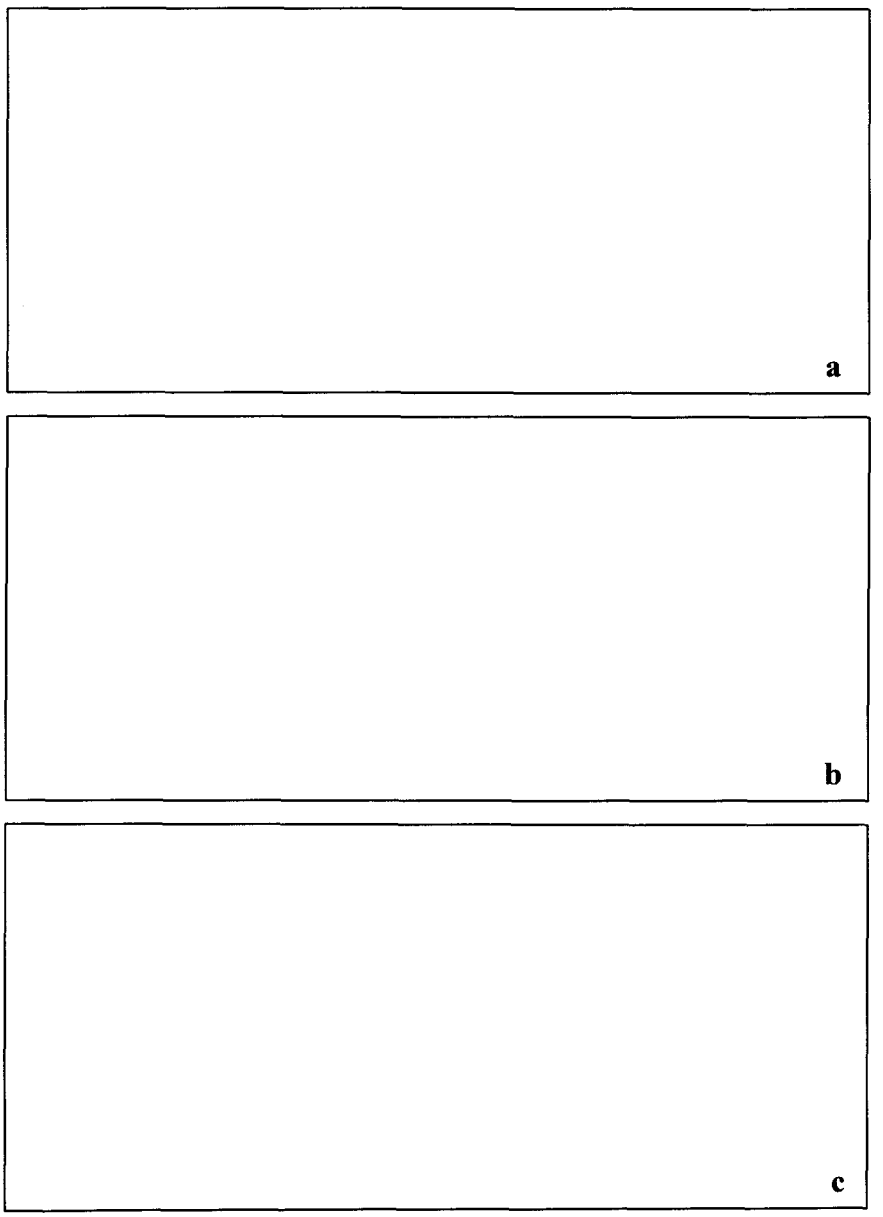

a
b
c
d

Fig. 16 Callus induction from leaf explants in *C.annuum* (8 weeks old culture).

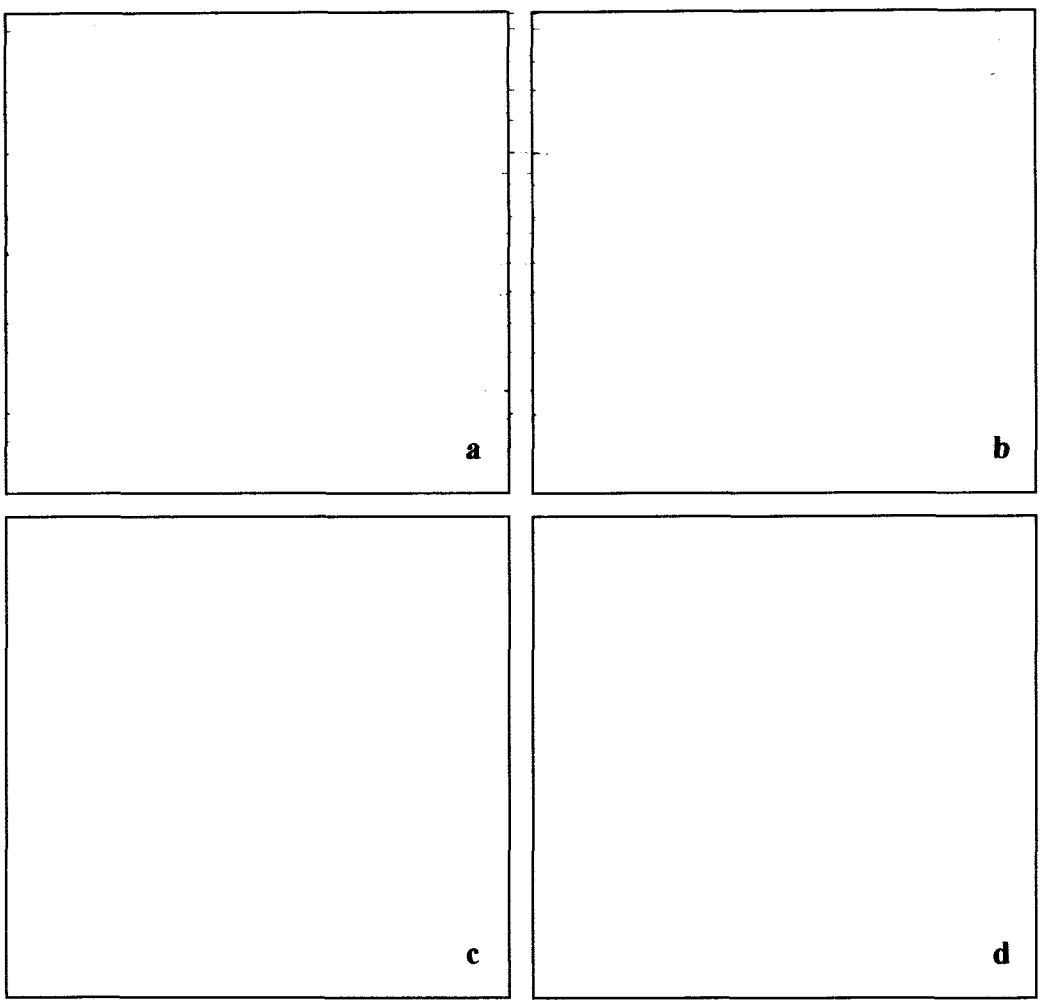


a L-R – NAA (mgl^{-1}) 10, 5, 2, 1, 0.5, 0.25

b L-R – IBA (mgl^{-1}) 10, 5, 2, 1, 0.5, 0.25

c L-R – 2,4-D (mgl^{-1}) 0, 0.25, 0.5, 1, 2, 5, 10

Fig. 17 Culture responses of *C. annuum*



a Callus proliferation from leaf explant (2,4-D 2mgl^{-1}- 4 weeks old).

b Induction of roots from leaf (IBA 0.25mgl^{-1}).

c Induction of callus with roots from leaf (IBA 2 mgl^{-1}).

d Direct regeneration from leaf (IBA 1 mgl^{-1}).

Micropropagation

BAP at concentrations 1-2mgl^{-1} induced multiple shoots and at higher concentrations induced callus and shoot buds. BAP at 2mgl^{-1} and 3mgl^{-1} was suitable for inducing multiple shoots (Fig.18,a; Table 22). Kinetin also showed similar response, lower concentrations induced multiple shoots and higher concentrations induced callus regeneration. (Table 22). BAP was better than kinetin for inducing multipleshoots and shoot tip was a better explant than leaf and stem for production of multiple shoots.

Table 22 - Effect of cytokinins on morphogenetic response of selected explants of *C.annuum* (30 days after inoculation).

Growth regulator	Leaf		Stem		Shoot tip	
(mgl^{-1})	N.R	P.E.R	N.R	P.E.R	N.R	P.E.R
BA1	C	25	C	20	M.sh	36
BA2	C	50	C	48	M.sh	53
					C+Sh	10
BA3	C	54	C	50	M.sh	40
					C+Sh	32
BA4	C	61	C	55	C+Sh	62
					M.Sh	10
BA 6	C	63	C	61	C+Sh	75
Kin 1	C	22	C	20	M.Sh	24
Kin 2	C	40	C	35	M.Sh	35
Kin3	C	45	C	41	M.Sh	20
					C+Sh	22
Kin4	C	53	C	51	M.Sh	25
					C+Sh	26
Kin6	C	55	C	54	C+Sh	55

N.R – Nature of response
P.E.R – Percentage of response (Mean of three independent experiments)
C – Callus
M.sh – Multiple shoots
C+Sh- Callus + shoots

Table 23 - Duncan's multiple range test for effect of cytokinins on inducing multiple shoots in shoot tip explants of *C.annuum*.

Treatments (mgl^{-1})		Ranked order shoot-tip
1	BAP 1	2A
2	BAP 2	3A
3	BAP 3	7B
4	BAP 4	1B
5	BAP 6	8C
6	Kin 1	9C
7	Kin 2	6C
8	Kin 3	5D
9	Kin 4	4D
10	Kin 5	10D

Shoot tip LSD=6.66

Callus regeneration

For callus regeneration, BAP in combination with NAA and IBA and Kinetin in combination with NAA and IBA were tried (Table 24). BAP with NAA induced callus with roots in leaf explants and shoot elongation with tuberous roots in shoot tip and nodal explants. Kinetin with NAA also produced similar response. BAP with IBA produced callus regeneration in shoot tip and nodal explants. Kinetin with IBA also produced callus regeneration, but the percentage of response was low. BAP3+IBA1, BAP4+IBA1 and BAP5+IBA1 were suitable combinations for callus regeneration (Table 25) and nodal explant was the best explant for callus regeneration.

BAP in combination with auxins IBA and IAA were tried to optimize the level of BAP and auxin required for callus regeneration in 5 genotypes (Table 26). It was found that BAP3 +IBA1 was superior to other combinations in inducing callus regeneration response among the five genotypes tried (Fig 18, b). Genotypes PBC 375 and PBC 385

showed high percentage of regeneration. The number of shoots produced did not vary much between the treatments tried. Different levels of auxins and cytokinines were tried to optimize the combination required for maximum percentage of response and maximum number of shoots for the five genotypes.

Table 24 Effect of combinations of auxins and cytokinins on morphogenetic response of selected explants of *C.annuum* (30 days after inoculation).

Growth regulator(mgl^{-1})	Leaf		Stem		Shoot tip		Nodal segment	
	N.R	P.E.R	N.R	P.E.R	N.R	P.E.R	N.R	P.E.R
BA1+NAA 0.1	C+R	26	C+R	23	Shoot elongation with swollen roots	50	Shoot elongation with swollen roots	52
BA2+ NAA 0.2	C+R	44	C+R	40	-do-	61	-do-	58
BA3+ NAA0.3	C+R	61	C+R	55	-do-	62	-do-	62
BA4+NAA0.4	C+R	65	C+R	61	-do-	65	-do-	68
Kin1+NAA0.1	C+R	21	C+R	20	-do-	42	-do-	43
Kin2+NAA0.2	C+R	36	C+R	32	-do-	52	-do-	54
Kin3+NAA0.3	C+R	42	C+R	39	-do-	58	-do-	57
Kin4+NAA0.4	C+R	55	C+R	52	-do-	63	-do-	65
BA1+IBA 0.5	C+R	58	C+R	50	C+Sh.b	30	C+Sh.b	35
					C+R	20	C+R	20
BA2+IBA 0.5	C+R	62	C+R	55	C+Sh.b	40	C+Sh.b	45
	C+Sh.b	5			C+R	22	C+R	32
BA3+IBA 1	C+R	71	C+R	65	C+Sh.b	72	C+Sh.b	78
	C+Sh.b	11			C+R	20	C+R	21
BA4+IBA 1	C+R	78	C+R	75	C+Sh.b	72	C+Sh.b	76
	C+Sh.b	12			C+R	22	C+R	20
BA5+IBA 1	C+R	80	C+R	82	C+Sh.b	69	C+Sh.b	72
	C+Sh.b	12			C+R	26	C+R	25
Kin1+IBA0.5	C+R	30	C+R	25	C+Sh.b	10	C+Sh.b	15
					C+R	15	C+R	17
Kin2+IBA0.5	C+R	42	C+R	33	C+Sh.b	20	C+Sh.b	25
	C+Sh.b	5			C+R	24	C+R	30
Kin3+IBA 1	C+Sh.b	8	C+R	41	C+Sh.b	45	C+Sh.b	51
	C+R	53			C+R	26	C+R	32
Kin4+IBA1	C+R	54	C+R	38	C+Sh.b	46	C+Sh.b	49
	C+Sh.b	9			C+R	25	C+R	30

N.R- Nature of response, C-Callus, R- Root, Sh.b-Shoot buds, P.E.R – Percentage of response

Table 25 - Duncan's multiple range test for effect of combinations of auxins and cytokinins on inducing callus regeneration in *C.annuum.*

Treatments (mgl^{-1})	Ranked order leaf	Ranked order shoot tip	Ranked order nodal segment
1 BAP2+IBA1	3A	2A	2A
2 BAP3+IBA1	4AB	3A	3AB
3 BAP4+IBA1	2ABC	4A	4B
4 BAP5+IBA1	8BC	8B	7C
5 Kin1+IBA0.5	7C	7B	8CD
6 Kin2+IBA 0.5	1D	1B	1D
7 Kin3+IBA1	5E	6C	6E
8 Kin4+IBA1	6E	5D	5F

Leaf LSD=3.16, Shoot tipLSD=4.561, Nodal segment LSD = 2.875

Table 26 - Optimization of cytokinin and auxin levels for maximum shoot bud production using nodal explants in selected genotypes of *C.annuum* (8 weeks after inoculation).

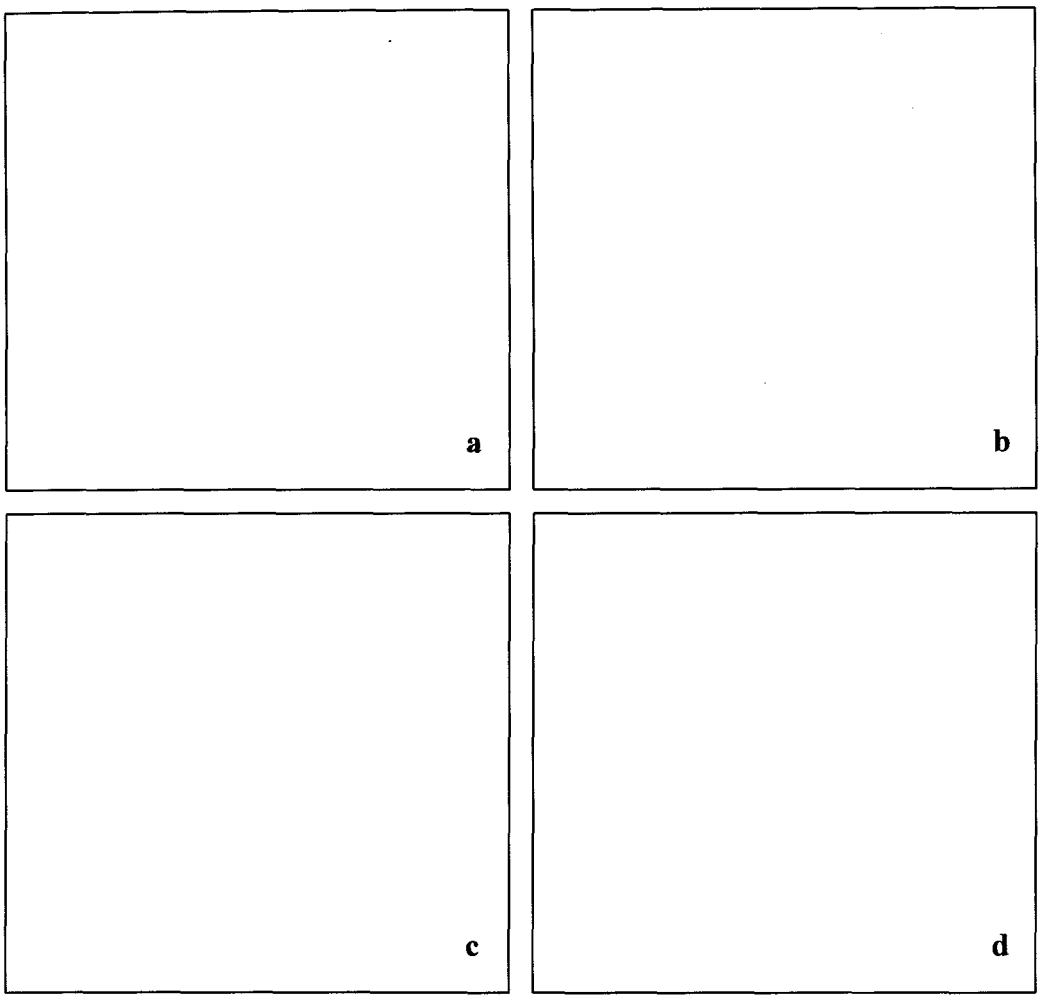
Growth regulator (mgl^{-1})	% of cultures showing callus regeneration				
	PBC 066	PBC 535	PBC 375	PBC 385	R.orn
BA3+	65	75	78	76	62
IBA1	*53.7*	*60*	*62.02*	*60.6*	*48.4*
BA4+	64	73	76	75	61
IBA1	*53.1*	*57.4*	*60.6*	*60*	*51.3*
BA5+	61	71	72	73	59
IBA1	*51.3*	*57.4*	*58.05*	*58.6*	*57.4*
BA3+	61	73	75	75	59
IAA1	*51.3*	*58.6*	*60*	*60*	*50.1*
BA4+	62	73	75	74	60
IAA1	*50.1*	*58.6*	*60*	*59.3*	*50.7*
BA5+	60	71	73	72	59
IAA1	*50.7*	*57.4*	*58.6*	*58.*	*50.1*

Values in italics – Transformed values.
R.orn – Round ornamental

Table 27 – Duncan's mutiple range test for optimization of auxin and cytokinin levels for maximum shoot bud production using nodal explants in selected genotypes of *C.annuum.* (Percentage of cultures showing regeneration)

Treatments (mgl^{-1})	Ranked order	Ranked order	Ranked order	Ranked order	Ranked order
	PBC 385	PBC375	PBC 535	PBC 066	Round ornamental
1 BAP3+IBA1	1A	2A	1A	1A	1A
2 BAP4+IBA1	2A	4A	4A	2A	2A
3 BAP5+IBA1	4A	1A	2A	5A	5A
4 BAP3+ IAA1	3AB	5A	3A	4A	4A
5 BAP4+IAA1	6AB	6A	6A	3A	3A
6 BAP5+IAA1	5AB	3A	5A	6A	6A
LSD	5.64	5.54	4.62	3.36	4.51

Fig. 18 Organogenesis in *C. annuum*

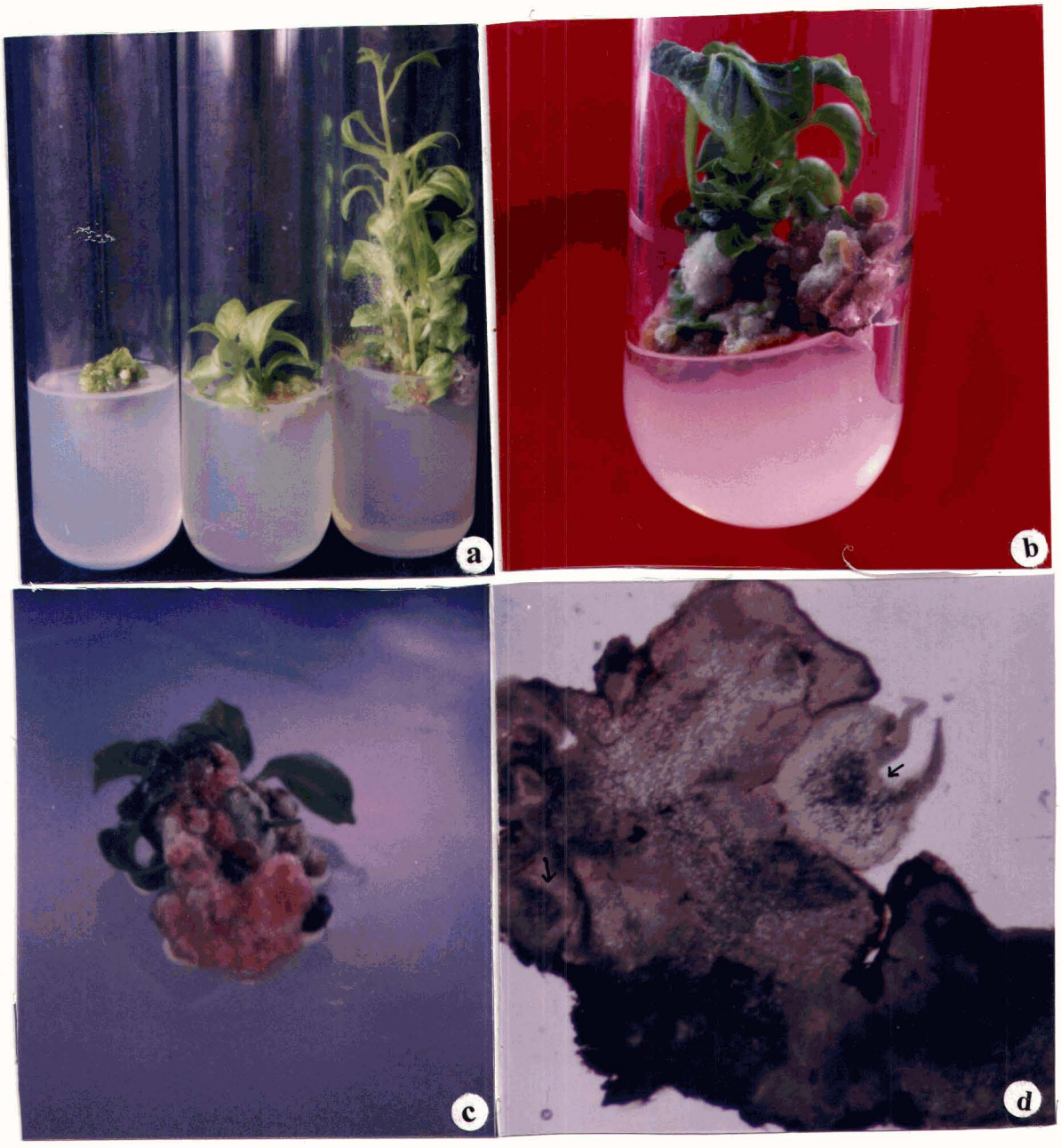


a Micropropagation of capsicum plants from shoot tip explants.

b Callus regeneration in capsicum.

c Regenerating callus showing colour production.

d Anatomy of callus showing shoot buds.


a
b
c
d

Elongation of regenerated shoots

The regenerated shoots clustered together and did not elongate in the regeneration medium. The shoots turned brown and died when cultured in the same medium. Various treatments (Table 28) were tried to make the shoots elongate. Of these MS+IBA1mgl^{-1} was the best for shoot elongation.

Table 28 – Elongation of regenerated shoots of *C.annuum*

Treatment	No. of shoots	No. elongated
MS	Numerous, difficult to count	2
1\2 MS	-do-	3
Sides of culture vessel covered with black paper	-do-	2
MS + ac. Charcoal 2gl^{-1}	-do-	4
MS + GA1mgl^{-1}	-do-	4
MS + IBA 1mgl^{-1}	-do-	7

Rooting of elongated shoots

The elongated shoots were transferred to different rooting media for rooting (Table 29). MS medium with activated charcoal was the best for rooting; all other combinations induced a small callus at the base of stem, which was not desirable for hardening (Fig.19, a).

Hardening of callus regenerated plants

For hardening of tissue cultured plants of *Capsicum annuum* (Fig.19, b and c), plastic cups containing potting mixture kept covered with polythene bags showed more percentage of survival than those left uncovered (Table 30).

Table 29 – Rooting of callus regenerated shoots of *C.annuum*

Treatments	Response
MS+IBA1mgl^{-1}	Roots from small callus at the base of stem
MS+IBA2mgl^{-1}	-do-
MS+IAA1mgl^{-1}	-do-
MS+IAA2mgl^{-1}	-do-
MS+ac.charcoal 2gl^{-1}	5-6 roots from the base of the stem without callus formation.
MS	3-4 roots with out callus

Table 30 – Hardening of tissue cultured *C.annuum* plants.

Treatments	% of survival	
	After 4 weeks	After 8 weeks
Transplanted to plastic cups containing sand and soil in 3:1 ratio - uncovered	20	15
Transplanted to plastic cups containing sand and soil in 3:1 ratio – covered with polythene bag	64	60

Evaluation of somaclones

Callus regenerated plants of five lines of paprika (PBC 535, PBC 375, PBC 066, PBC 385 and Round Ornamental were planted out for evaluation. The effect of culturing on the cytological behavior, morphological and biochemical characters of these lines were studied.

Cytological studies of somaclones

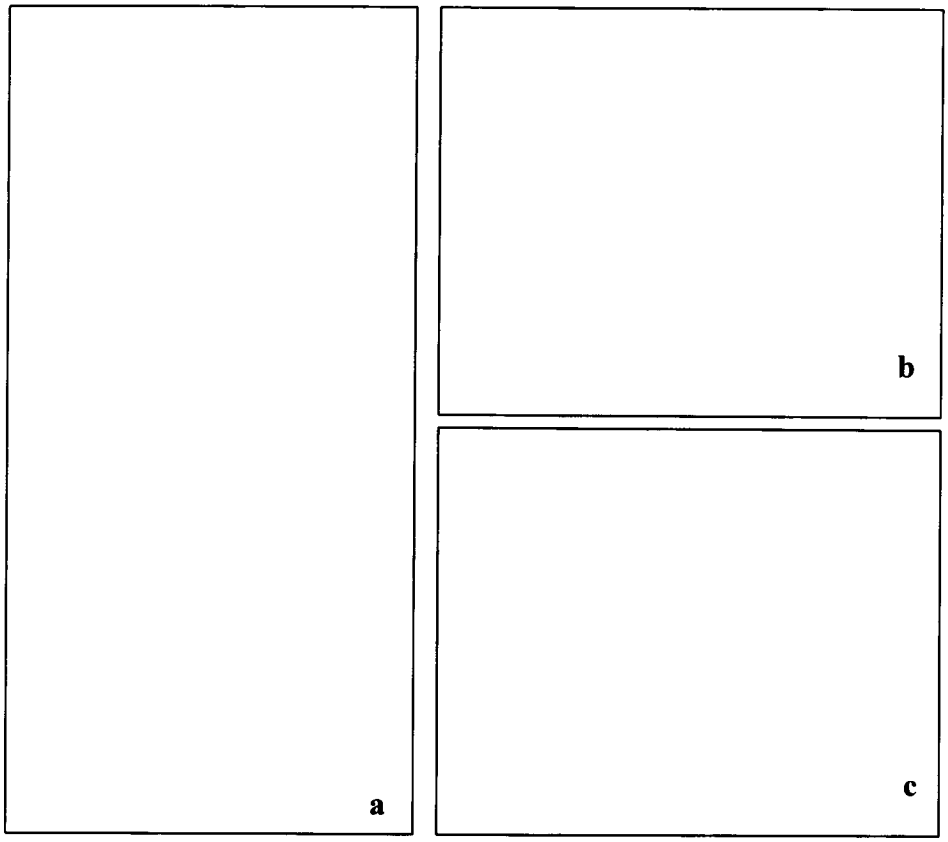
Anthers from young flower buds were used for cytological studies. Five hundred to thousand pollen mother cells of each genotype were observed and among them several abnormalities were observed. Stickiness of chromosomes was found in most genotypes.

Hexavalent formation (Fig. 20,a) was observed in the cells of Round Ornamental – 3 and bridge formation was observed in 375 –7. Abnormal tetrad formation during telophase was observed in 535 – 5 (Fig. 20,d). Laggards were also observed during telophase in the cells of PBC 385 (Fig. 20,c). In PBC 066, most of the cells observed were normal, with about 5% of the cells showing abnormalities like stickiness and lagging chromosomes.

Morphological characters of somaclones of Round Ornamental

Morphological characters of somaclones of Round ornamental were observed (Table – 31). Variation was observed in the growth habit of the plant, flower position, anther colour, stigma exsertion, fruit shape and fruit shape at blossom end (Fig.21). 12 plants out of 50 showed erect habit, while 38 plants showed compact growth habit as the mother plant. Flower position was pendent in 37 (74%) plants and erect as in the mother plant in 13 (26%) plants. Stigma was exserted in 38 plants and inserted in 12 plants. Fruit shape was elongate in 36 plants and triangular in 14 plants, none of the plants showed the round fruit shape of the mother plant. Fruit shape at blossom end was pointed in 45 plants and blunt in 5 plants.

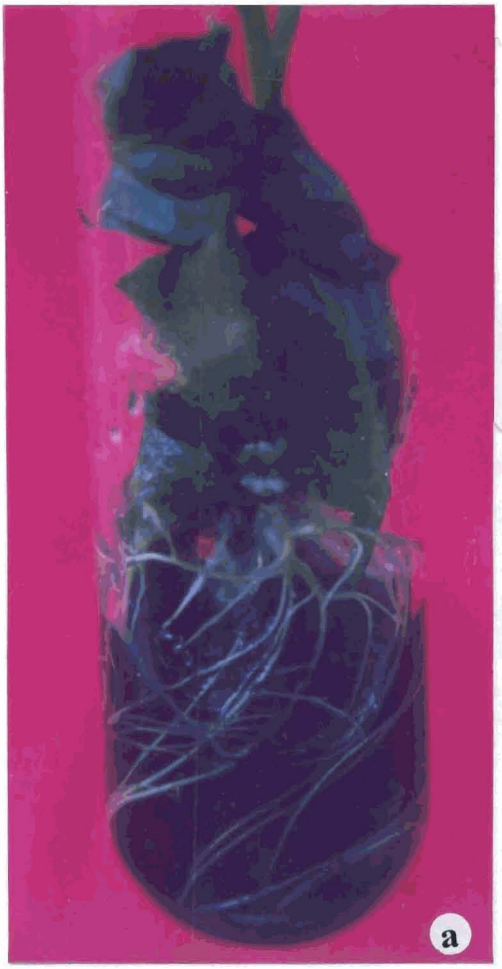
Fig. 19 Rooting and hardening of *C.annuum.*



a Rooting of capsicum plants in MS medium with activated charcoal.

b Hardening of capsicum plants.

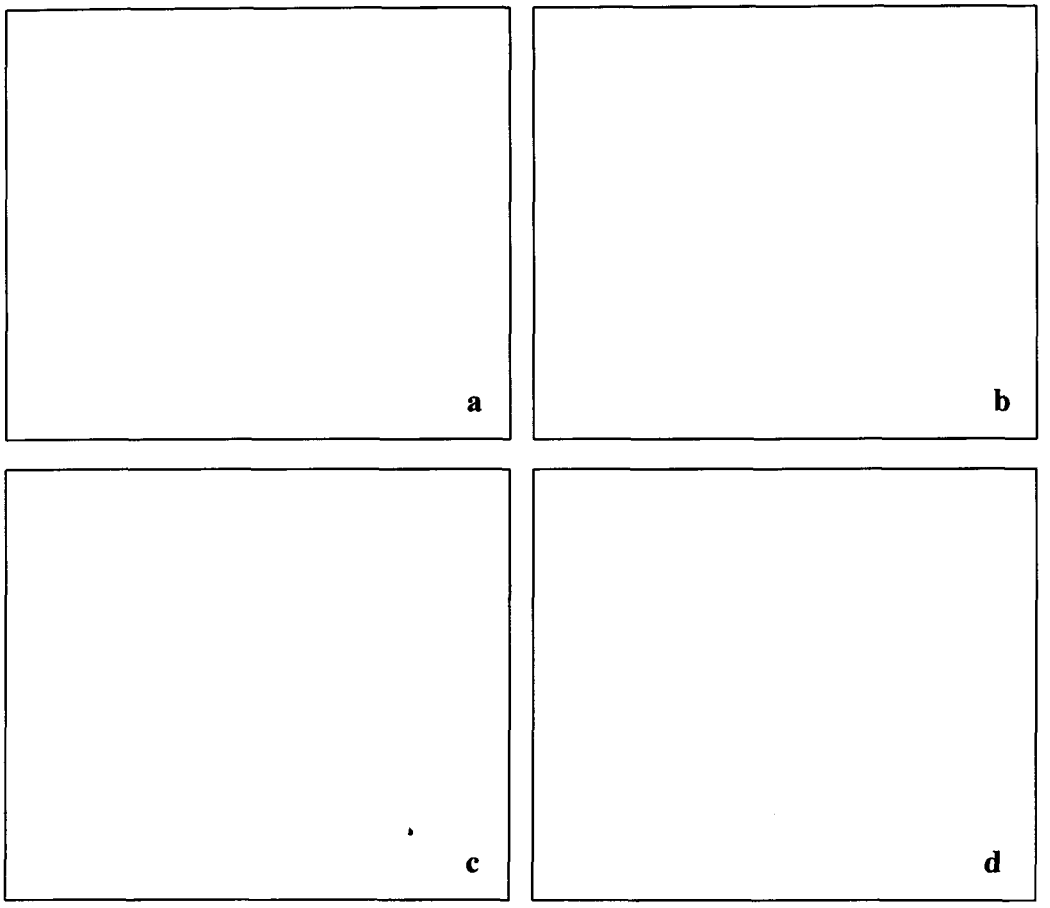
c Hardened plants ready for field transplant.


a


b


c

Fig. 20 Cytological behavior of capsicum somaclones during meiosis of pollen mother cells.



a Hexavalent formation due to stickiness of chromosomes – early metaphase.

b Bivalents sticking together due to homology.

c Chromosomes lagging behind during telophase.

d Unequal separation of chromosomes during telophase.

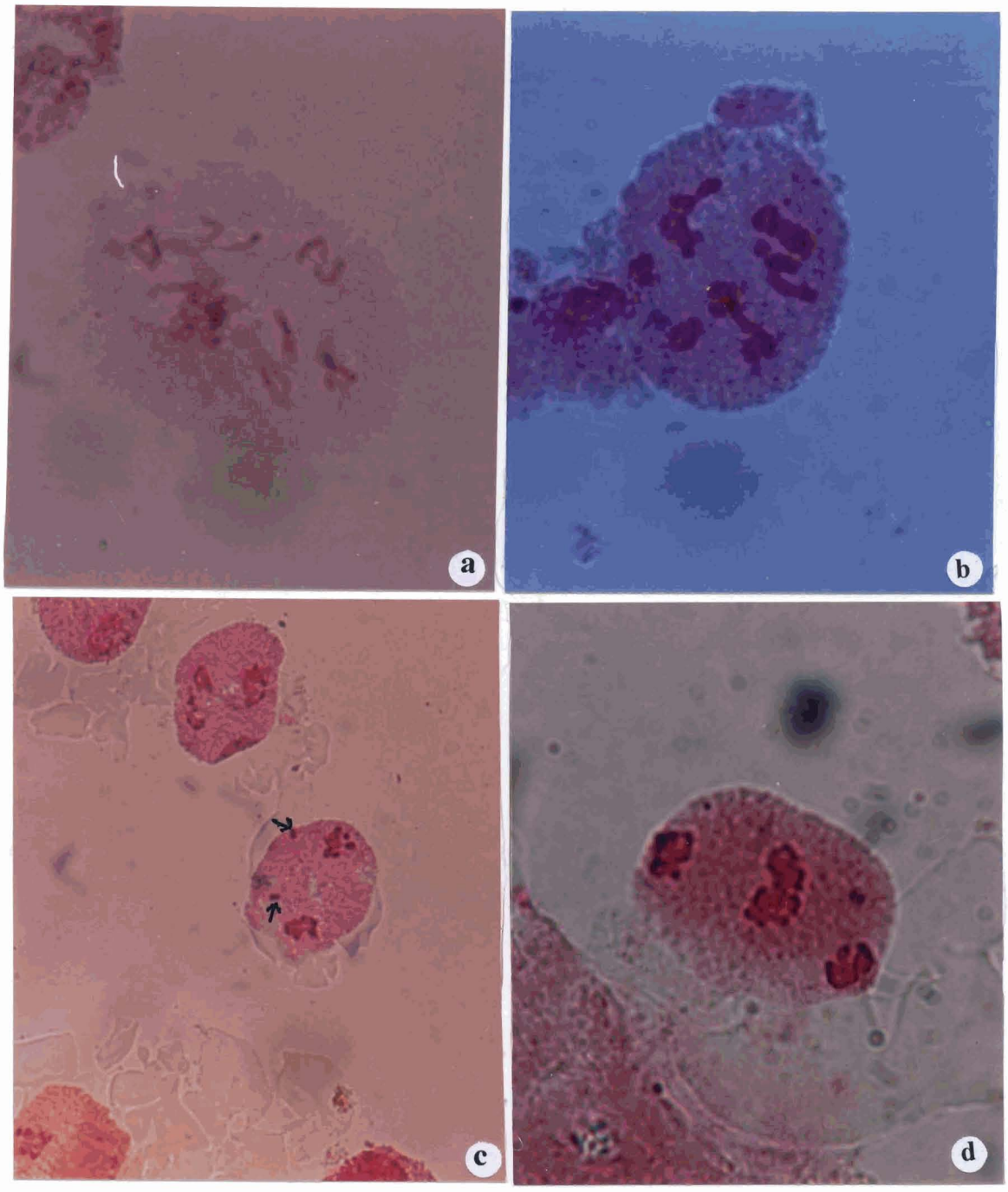

a
b
c
d

Table 31 Morphological characters of somaclones of Round Ornamental

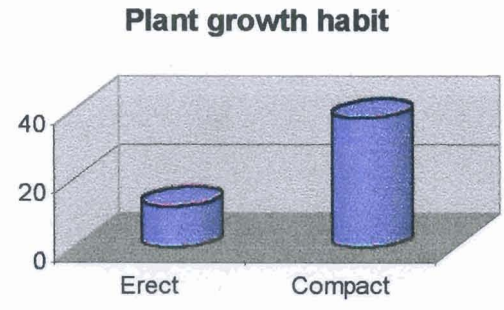
Characters	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	0
	sparse /nil	50
Plant growth habit	Erect	12
	Intermediate	0
	Compact	38
Branching habit	high	0
	intermediate	50
	sparse	0
Leaf colour	Light green	0
	Green	50
	Dark green	0
Leaf shape	Ovate	50
	Lanceolate	0
No. of flowers/ axil	1	50
	2& more	0
Flower position	Pendent	37
	Intermediate	0
	Erect	13
Corolla colour	White	50
	Light yellow	0
Anther colour	Blue	39
	Purple	11
Stigma exsertion	Exserted	38
	Same level	0
	Inserted	12

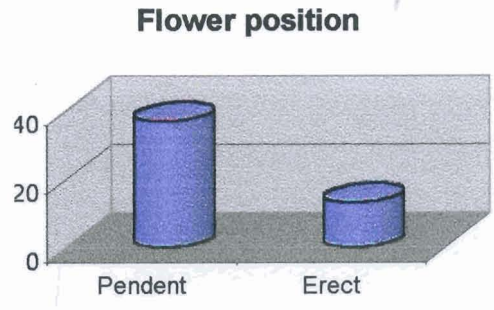
Continued-

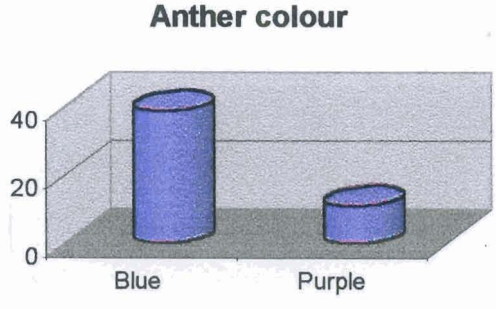
Table 31 cont. Morphological characters of somaclones of Round Ornamental

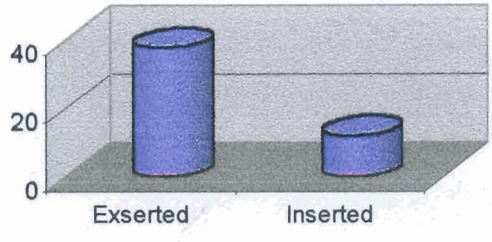
Characters	Expression	No. of plants
Calyx margin	Dentate	0
	Intermediate	50
	Sparse	0
Fruit colour at intermediate stage	Green	50
	Dark green	0
	Light green	0
	Yellowish green	0
Fruit colour at mature stage	Red	50
	Dark red	0
Fruit shape	Elongate	36
	Triangular	14
	Round	0
	Blocky	0
Fruit shape at blossom end	Pointed	5
	Blunt	45
	Sunken	0
	Sunken and pointed	0
Fruit blossom en appendage	Absent	
	Present	0
Fruit surface	Smooth	50
	Semi wrinkled	0
	Wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	Straw	50

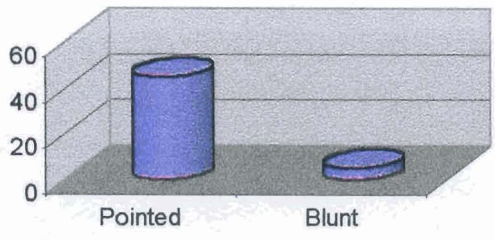
Fig. 21 Frequency distribution of discrete characters in somaclones of Round Ornamental

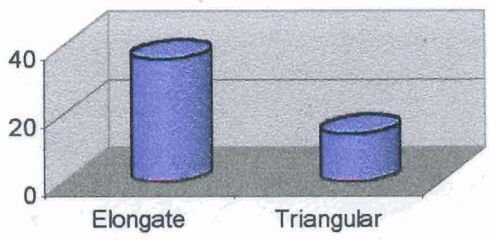












Plant height

Plant height of somaclones of Round Ornamental ranged from 25 – 73cm (Tables 32). R.Orn 2 (73cm) and R.Orn 16 (71cm) were tall plants. R.Orn 3 (25cm), ROrn 4 (29 cm), R.Orn 6 (23cm), R.Orn 22 (26cm), R.Orn 27 (26 cm) and R.Orn 30 (25cm) were short plants. Remaining plants had intermediate height ranging from 34 – 61cm.

Days to flower

Days to flower in somaclones of Round Ornamental ranged from 32 – 58 (Tables 32). R.Orn 16 (32), R.Orn 43 (33), R.Orn 40 (35), R.Orn 42 (36), R.Orn 22 (36), R.Orn 27 (36), R.Orn 32 (37), R.Orn 41 (37), R.Orn 20 (38), R.Orn 25 (38), R.Orn 30 (38), R.Orn 34 (39), R.Orn 49 (39) and R.Orn 50 (39) were early flowering plants and R.Orn 19 (51), R.Orn 44 (51), R.Orn 10(56), R.Orn 29 (56), R.Orn 39 (56), R.Orn 33 (58) and R.Orn 45 (58) were late flowering types. The remaining plants showed intermediate days to flowering.

Days to fruit

Days to fruiting ranged from 45 – 74 (Tables 32). R.Orn 43 (45), R.Orn 49 (45), R.Orn 16 (47), R.Orn 13 (49), R.Orn 22 (48), R.Orn 27 (48), R.Orn 40 (48) and R.Orn 42 (49) were early fruiting. R.Orn 21 (72), R.Orn 26 (72) and R.Orn 11(74) were late fruiting. Rest of the plants belonged to intermediate type.

Table 32 Evaluation of somaclones of Round Ornamental for plant height, days to flower and days to fruit.

Plant no.	Plant height (cm)	Days to flower	Days to fruit
R.Orn – 1	50	42	55
R.Orn – 2	73	44	58
R.Orn – 3	25	45	57
R.Orn – 4	29	49	60
R.Orn – 5	35	50	61
R.Orn – 6	23	41	55
R.Orn – 7	39	46	58
R.Orn – 8	35	42	54
R..orn – 9	35	43	57
R.Orn – 10	56	56	68
R.Orn – 11	54	60	74
R.Orn – 12	61	48	61
R.Orn – 13	48	34	49
R.Orn – 14	56	39	50
R.Orn – 15	63	53	65
R.Orn – 16	71	32	47
R.Orn – 17	49	46	58
R.Orn – 18	53	43	56
R.Orn – 19	59	51	64
R.Orn – 20	54	38	50
R.Orn – 21	42	58	72
R.Orn – 22	26	36	48
R.Orn – 23	34	40	53
R.Orn – 24	41	43	56
R.Orn – 25	42	38	52

R.Orn –Round Ornamental

Continued-

Table 32 cont. – Evaluation of somaclones of Round Ornamental for plant height, days to flower and days to fruit.

Plant no.	Plant height (cm)	Days to flower	Days to fruit
R.Orn – 26	42	58	72
R.Orn – 27	26	36	48
R.Orn – 28	49	46	58
R.Orn – 29	56	48	60
R.Orn – 30	25	38	52
R.Orn – 31	47	41	54
R.Orn – 32	29	37	50
R.Orn – 33	58	43	57
R.Orn – 34	46	39	50
R.Orn – 35	46	42	56
R.Orn – 36	43	47	60
R.Orn – 37	46	44	59
R.Orn – 39	56	43	56
R.Orn – 40	35	35	48
R.Orn – 41	39	37	50
R.Orn – 42	40	36	49
R.Orn – 43	28	33	45
R.Orn – 44	51	49	62
R.Orn – 45	58	48	60
R.Orn – 46	48	46	59
R.Orn – 47	41	48	61
R.Orn – 48	46	41	53
R.Orn – 49	38	32	45
R.Orn - 50	42	39	51
	SD	Mean	CV(%)
Plant height	13.1	44.12	29.6
Days to flower	6.78	43.20	15.6
Days to fruit	9.97	55.34	18.0

Fruit length (cm)

Fruit length ranged from 2.4 – 9.8cm (Table 33). R.Orn 6 (2.4 cm), R.Orn 34 (2.4cm), R.Orn 15 (3.2cm), R.Orn 38 (3.4cm), R.Orn 36 (3.68cm), R.Orn 42 (3.8cm) and R.Orn 35 (3.89 cm) had short fruits and R.Orn 28 (9.1cm), R.Orn 49 (9.12cm), R.Orn 39 (9.2cm), R.Orn 1 (9.4cm), R.Orn 31 (9.4cm), R.Orn 45 (9.43), R.Orn 47 (9.56cm), R.Orn 2 (9.5cm), R.Orn 21 (9.5cm), R.Orn 47 (9.56cm) R.Orn 3 (9.5cm), R.Orn 4 (9.8cm), R.Orn 13 (9.8cm), R.Orn 22 (9.8 cm) and R.Orn 40 (9.8cm) had long fruits.

Fruit width (cm)

Fruit width ranged from 1.04 – 2.8cm (Table 33). R.Orn 49 (1.04cm), R.Orn 38 (1.05cm), R.Orn 36 (1.06cm), R.Orn 39 (1.06cm), R.Orn 42 (1.07cm), R.Orn 46 (1.07cm), R.Orn 19 (1.1cm), R.Orn 22 (1.1cm), R.Orn 31(1.1cm), R.Orn 32 (1.1cm), R.Orn 21 (1.2cm), R.Orn 25 (1.2cm) and R.Orn 35 (1.2cm) had small fruit width and R.Orn 27 (2.5cm), R.,orn 7 (2.8cm) and R.Orn 23 (2.8 cm) had larger fruit width.

Fruit weight (g)

Fruit weight ranged from 1.63 – 7.9g (Table 33). R.Orn 46 (1.63g), R.Orn 49 (1.76g), R.Orn –1 (1.8g), R.Orn 5 (1.8g) and R.Orn 10 (1.9) had low fruit weight and R.Orn 16 (7.3g), R.Orn 10 (7.6g), R.Orn 26 (7.6g) and R.Orn 24 (7.9g) had high fruit weight.

Table 33 Evaluation of somaclones of Round Ornamental for fruit length, fruit width and fruit weight.

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
R.Orn – 1	9.4	1.4	1.8
R.Orn – 2	9.5	2.0	3.3
R.Orn – 3	9.5	1.1	2.7
R.Orn – 4	9.8	1.6	3.03
R.Orn – 5	7.5	1.27	1.8
R.Orn – 6	2.4	1.28	4.5
R.Orn – 7	4.5	2.8	4.1
R.Orn – 8	8.5	1.0	3.98
R.Orn – 9	6.4	2.3	7.6
R.Orn – 10	7.5	1.4	1.9
R.Orn – 11	4.6	2.6	4.6
R.Orn – 12	7.8	1.3	2.0
R.Orn – 13	9.8	1.5	3.2
R.Orn – 15	3.2	1.3	4.8
R.Orn – 16	6.8	2.1	7.3
R.Orn – 17	6.5	2.0	6.8
R.Orn – 18	7.9	1.2	2.2
R.Orn – 19	8.3	1.1	3.6
R.Orn – 20	8.1	1.3	3.2
R.Orn – 21	9.5	1.2	3.3
R.Orn – 22	9.8	1.1	2.8
R.Orn – 23	4.3	2.8	4.4
R.Orn – 24	6.8	2.1	7.9
R.Orn – 25	7.2	1.2	2.1

R.Orn- Round Ornamental

Continued-

Table 33 cont. Evaluation of somaclones of Round Ornamental for fruit length, fruit width and fruit weight.

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
R.Orn – 26	6.3	2.1	7.6
R.Orn – 27	4.6	2.5	4.45
R.Orn – 28	9.1	1.34	1.99
R.Orn – 29	7.56	1.34	1.98
R.Orn – 30	6.4	1.98	7.34
R.Orn – 31	9.4	1.1	1.86
R.Orn – 32	8.94	1.1	3.6
R.Orn – 33	5.3	1.4	2.3
R..orn –34	2.4	1.8	4.2
R.Orn – 35	3.89	1.2	3.98
R.Orn – 36	3.68	1.06	2.98
R.Orn – 37	5.8	1.23	2.43
R.Orn – 38	3.4	1.05	2.68
R.Orn – 39	9.2	1.06	2.01
R.Orn – 40	9.8	1.31	2.35
R.Orn – 41	6.9	1.45	6.45
R.Orn – 42	3.8	1.07	2.76
R.Orn – 43	4.9	1.4	4.3
R.Orn – 44	5.6	1.2	2.64
R.Orn – 45	9.43	1.5	2.67
R.Orn – 46	8.5	1.07	1.63
R.Orn – 47	9.56	1.23	2.4
R.Orn – 48	8.64	1.12	1.86
R.Orn – 49	9.12	1.04	1.76
R.Orn - 50	6.85	1.4	7.3

	SD	Mean	CV(%)
Fruit length	2.25	7.03	32.0
Fruit width	0.529	1.44	36.7
Fruit weight	1.80	2.77	64.0

Yield /plant (g)

Yield /plant ranged from 58 – 165g (Table 34). R.Orn 45 (58g), R.Orn 46 (66g), R.Orn 47 (74g) and R.Orn 24 (79g) gave low yield and R.Orn 2 (111g), R.Orn 10 (113g), R.Orn 11 (120g), R.Orn 21 (134g), R.Orn 9 (160g) and R.Orn 13 (165g) gave high yield.

Seed size (cm)

Size of the seed ranged from 0.12 – 0.40cm (Table 34). R.Orn 48(0.12cm), R.Orn 25 (0.13cm) and R.Orn 49 (0.15) had small seed size. R.Orn 5 (0.36cm), R.Orn 29 (0.36cm) and R.Orn 9 (0.40cm) had large seed size.

Seed number

Seeds/fruit ranged from 72-134 (Table 34). R.Orn 1 (72) and R.Orn 28 (79) had less number of seeds and R.Orn 37 (125), R.Orn 46 (125), R.Orn 10 (125), R.Orn 50 (132) and R.Orn 49 (134) had more number of seeds.

Table 34 Evaluation of somaclones of Round Ornamental for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
R.Orn – 1	108	0.35	72
R.Orn – 2	111	0.30	110
R.Orn – 3	106	0.28	100
R.Orn – 4	112	0.31	105
R.Orn – 5	105	0.36	105
R.Orn – 6	99	0.31	112
R.Orn – 7	112	0.28	112
R.Orn – 8	109	0.29	113
R.Orn – 9	160	0.40	110
R.Orn – 10	113	0.30	125
R.Orn – 11	120	0.32	88
R.Orn – 12	134	0.28	95
R.Orn – 13	165	0.35	100
R.Orn – 15	98	0.29	113
R.Orn – 16	69	0.31	108
R.Orn – 17	84	0.29	118
R.Orn – 18	98	0.27	127
R.Orn – 19	115	0.37	98
R.Orn – 20	108	0.21	112
R.Orn – 21	134	0.26	110
R.Orn – 22	85	0.30	99
R.Orn – 23	98	0.32	115
R.Orn – 24	79	0.26	109
R.Orn – 25	88	0.13	106

R.Orn- Round Ornamental

Continued-

Table 34 cont. Evaluation of somaclones of Round Ornamental for yield/plant, seed size and seed number

Plant no.	Yield/ plant (g)	Seed size (cm)	Seed no.
R.Orn – 26	79	0.34	96
R.Orn – 27	88	0.27	84
R.Orn – 28	94	0.33	79
R.Orn – 29	113	0.36	89
R.Orn – 30	123	0.28	103
R.Orn – 31	107	0.26	116
R.Orn – 32	86	0.30	95
R.Orn – 33	97	0.29	97
R..orn –34	120	0.32	96
R.Orn – 35	134	0.31	99
R.Orn – 36	126	0.30	109
R.Orn – 37	93	0.27	125
R.Orn – 38	109	0.31	113
R.Orn – 39	124	0.25	118
R.Orn – 40	116	0.24	116
R.Orn – 41	112	0.21	121
R.Orn – 42	118	0.32	96
R.Orn – 43	108	0.23	113
R.Orn – 44	93	0.33	109
R.Orn – 45	58	0.26	114
R.Orn – 46	66	0.26	125
R.Orn – 47	74	0.19	105
R.Orn – 48	83	0.12	114
R.Orn – 49	92	0.15	134
R.Orn - 50	118	0.28	132

	SD	Mean	CV%
Yield /plant	21.7	103.82	20.9
Seed size	0.094	0.256	36.7
Seed no.	12.95	107.3	12.0

Colour value

Colour value ranged from 46.4 to123 ASTA (Table 35). R.Orn 1 (46.45) and R.Orn 18 (49) were plants with low colour values and R.Orn 8 (100), R.Orn 41 (110), R.Orn 45 (110), R.Orn 2 (111), R.Orn 31 (112), R.Orn 38 (113), R.Orn 10 (113), R.Orn 46 (113),

R.Orn 12 (114), R.Orn 48 (115), R.Orn 32 (116), R.Orn 11 (120) and R.Orn 47 (123) were plants with high colour values.

Table 35 Evaluation of somaclones of Round Ornamental for colour value

Plant no.	Colour value (ASTA)	Plant No.	Colour value (ASTA)
R.Orn – 1	46.45	R.Orn – 26	58
R.Orn – 2	111	R.Orn – 27	78
R.Orn – 3	59	R.Orn – 28	79
R.Orn – 4	47	R.Orn – 29	106
R.Orn – 5	68	R.Orn – 30	96
R.Orn – 6	98	R.Orn – 31	112
R.Orn – 7	54	R.Orn – 32	116
R.Orn – 8	100	R.Orn – 33	65
R.Orn – 9	98	R..orn –34	78
R.Orn – 10	113	R.Orn – 35	74
R.Orn – 11	120	R.Orn – 36	69
R.Orn – 12	114	R.Orn – 37	79
R.Orn – 13	69	R.Orn – 38	113
R.Orn – 14	76	R.Orn – 39	89
R.Orn –15	84	R.Orn – 40	97
R.Orn –16	56	R.Orn – 41	110
R .orn –17	54	R.Orn – 42	86
R.Orn – 18	49	R.Orn – 43	97
R.Orn – 19	59	R.Orn – 44	109
R.Orn – 20	63	R.Orn – 45	110
R.Orn – 21	67	R.Orn – 46	113
R.Orn – 22	68	R.Orn – 47	123
R.Orn –23	78	R.Orn – 48	115
R.Orn – 24	93	R.Orn – 49	99
R.Orn – 25	96	R.Orn - 50	107

	SD	Mean	CV%
Colour value	22.5	86.3	26.07

Evaluation of somaclones of PBC 535

Morphological characters of somaclones of PBC 535 were observed (Table 36). Variation was found in plant growth habit and leaf shape (Fig.22). Plant growth habit was erect in 37 plants (74%) and compact in 13 plants (26%). Leaf shape was ovate in

35 plants (70%) and lanceolate in 15 plants (30). No variation was found in other morphological characters.

Table 36 Morphological characters of somaclones of PBC 535

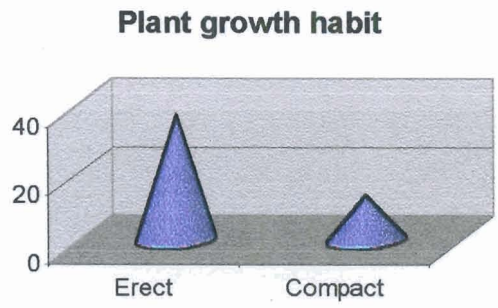
Characters	Expression	No. of plants
Stem shape	Cylindrical	50
Stem pubescence	Dense	0
	Intermediate	0
	Sparse /nil	50
Plant growth habit	Erect	37
	Intermediate	0
	Compact	13
Branching habit	High	0
	Intermediate	50
	Sparse	0
Leaf colour	Light green	0
	Green	50
	Dark green	0
Leaf shape	Ovate	35
	Lanceolate	15
Flowers/axil	1	50
	2 and more	0
Flower position	Pendent	50
	Intermediate	0
	Erect	0
Corolla colour	White	50
	Light yellow	0
Anther colour	Blue	50
	Purple	0
Stigma exsertion	Exserted	50
	Same level	0
	Inserted	0
Calyx margin	Dentate	0
	Intermediate	50
	Sparse	0
Fruit colour at intermediate stage	Green	0
	Dark green	50
	Light green	0
	Yellowish green	0
Fruit colour at mature stage	Red	50
	Dark red	0

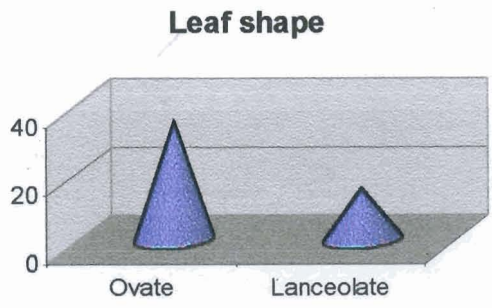
Continued-

Table 36 cont. Morphological characters of somaclones of PBC 535

Characters	Expression	No. of plants
Fruit shape	Elongate	50
	Triangular	0
	Round	0
	Blocky	0
Fruit shape at blossom end	Pointed	50
	Blunt	0
	Sunken	0
	Sunken and pointed	0
Fruit blossom appendage	Absent	50
	Present	0
Fruit surface	Smooth	0
	Semi wrinkled	50
	Wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	Straw	50

Fig. 22 Frequency distribution of discrete characters in somaclones of PBC 535





Plant height

Plant height ranged from 33 – 65cm (Table 37). PBC 535 4(33cm), PBC 535 29 (33cm), PBC 535 13 (38cm), PBC 535 48 (38cm) and PBC 535 17 (39cm) were short plants. PBC 535 21 (60), PBC 535 25 (61cm), PBC 535 7 (61cm), PBC 535 40 (61cm), PBC 535 37 (62cm), PBC 535 19 (62cm), PBC 535 16 (63cm), PBC 535 14 (64cm) and PBC 535 12 (65cm) were tall plants.

Days to flower

Days to flower ranged from 36 – 54 days (Tables 37). PBC 535 19 (35), PBC 535 10 (36), PBC 535 37 (36), PBC 535 48 (36), PBC 535 29 (37), PBC 535 9 (38), PBC 11 (38), PBC 535 17 (38), PBC 535 22 (38) and PBC 535 26 (38) were early flowering plants and PBC 535 7 (52), PBC 535 36 (52) and PBC 535 8 (54) were late flowering.

Days to fruit

Days to fruit ranged from 45 –70 days (Table 37). PBC 535 48 (45), PBC 535 37 (48), PBC 535 19 (48) and PBC 535 29 (49) were early fruiting PBC 535 30 (63), PBC 535 36 (64) and PBC 535 8 (70), were late fruiting.

Fruit length (cm)

Fruit length ranged from 6.8 – 13.5cm (Table 38). PBC 535 34 (6.8cm), PBC 535 37 (7.5cm), PBC 535 35 (7.8cm), PBC 535 23 (7.9cm) and PBC 535 49 (7.98cm) had small fruits and PBC 535 4 (13.0cm), PBC 535 10 (13cm), PBC 535 30 (13.1cm), PBC 535 28 (13.3cm) and PBC 535 47 (13.4cm) had long fruits.

Table 37 Evaluation of somaclones of PBC 535 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 535 - 1	45	41	52
PBC 535 - 2	43	44	56
PBC 535 - 3	36	50	62
PBC 535 - 4	33	43	55
PBC 535 - 5	43	41	56
PBC 535 - 6	30	43	57
PBC 535 - 7	61	52	62
PBC 535 - 8	48	54	70
PBC 535 - 9	54	38	51
PBC 535 - 10	56	36	50
PBC 535 - 11	58	38	50
PBC 535 - 12	65	45	59
PBC 535 - 13	38	46	60
PBC 535 - 14	64	48	61
PBC 535 - 15	58	49	62
PBC 535 - 16	63	48	60
PBC 535 - 17	39	38	50
PBC 535 - 18	53	48	63
PBC 535 - 19	62	35	48
PBC 535 - 20	59	46	59
PBC 535 - 21	60	43	54
PBC 535 - 22	58	38	52
PBC 535 - 23	49	39	51
PBC 535 - 24	57	43	56
PBC 535 - 25	61	41	53

Continued-

Table 37 cont. Evaluation of somaclones of PBC 535 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 535 – 26	54	38	50
PBC 535 – 27	58	41	54
PBC 535 – 28	45	44	55
PBC 535 – 29	33	37	49
PBC 535 – 30	56	50	63
PBC 535 – 31	45	43	55
PBC 535 – 32	52	40	51
PBC 535 – 33	51	46	59
PBC 535 – 34	56	49	60
PBC 535 – 35	52	40	53
PBC 535 – 36	49	52	64
PBC 535 – 37	62	36	48
PBC 535 – 38	57	39	50
PBC 535 – 39	59	42	54
PBC 535 – 40	61	48	60
PBC 535 – 41	55	47	59
PBC 535 – 42	51	44	55
PBC 535 – 43	61	39	50
PBC 535 – 44	51	52	63
PBC 535 – 45	59	43	55
PBC 535 – 46	47	41	52
PBC 535 – 47	58	42	53
PBC 535 – 48	38	36	45
PBC 535 – 49	52	39	50
PBC 535 - 50	58	42	55

	SD	Mean	CV%
Plant height	9.115	51.8	17.5
Days to flower	4.819	43.2	11
Days to fruit	7.93	49.3	16

Fruit width (cm)

Fruit width ranged from 0.7 – 2.5 cm (Table 38). PBC 535 8 (0.7cm), PBC 535 9 (1.0 cm), PBC 535 7 (1.0cm), PBC 535 19 (1.05 cm), PBC 535 47 (1.06 cm), PBC 535 30 (1.08cm), PBC 535 25 (1.09 cm), PBC 535 36 (1.09cm) and PBC 535 41 (1.09) were plants with small fruit width. PBC 535 23 (2.5cm) had the maximum fruit width.

Fruit weight (g)

Fruit weight ranged from 1.0 – 4.6g (Table 38). PBC 535 8 (1.0g), PBC 535 9 (1.2g), PBC 535 17 (1.3g), PBC 535 34 (1.3g), PBC 535 39 (1.4g), PBC 535 41 (1.4g) and PBC 535 47 (1.45g) were lines with low fruit weight and PBC 535 2 (3.6g), PBC 535 3 (4.6g) and PBC 535 5 (4.6g) were plants with large fruit weight.

Table 38 Evaluation of somaclones of PBC 535 for fruit length, fruit weight and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 535 - 1	11.6	1.2	2.8
PBC 535 - 2	11.6	1.3	3.6
PBC 535 - 3	11.8	1.2	4.6
PBC 535 - 4	13.0	1.2	1.8
PBC 535 - 5	12.0	1.3	4.6
PBC 535 - 6	11.2	1.3	3.5
PBC 535 - 7	10.5	1.0	1.65
PBC 535 - 8	11.8	0.7	1.0
PBC 535 - 9	12.5	1.0	1.2
PBC 535 - 10	13	1.2	1.6
PBC 535 - 11	12.4	1.4	1.8
PBC 535 - 12	9.5	1.2	1.7
PBC 535 - 13	12	1.6	2.3
PBC 535 - 14	8	1.1	1.78
PBC 535 - 15	8.8	1.3	2.1
PBC 535 - 16	10.2	1.1	1.82
PBC 535 - 17	11.1	1.3	1.3
PBC 535 - 18	10.5	1.4	1.6
PBC 535 - 19	11.3	1.05	1.8
PBC 535 - 20	10.05	1.6	1.9
PBC 535 - 21	9.9	1.3	1.67
PBC 535 - 22	8.84	1.23	1.98
PBC 535 - 23	7.9	2.5	2.3
PBC 535 - 24	8.75	1.4	1.98
PBC 535 - 25	9.23	1.09	2.01

Table 38 cont. Evaluation of somaclones of PBC 535 for fruit length, fruit weight and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 535 – 26	10.5	1.3	1.8
PBC 535 – 27	9.5	1.2	1.9
PBC 535 – 28	13.3	1.4	3.2
PBC 535 – 29	12.1	1.3	2.89
PBC 535 – 30	13.1	1.08	1.67
PBC 535 – 31	9.3	1.2	2.1
PBC 535 – 32	12.1	1.08	2.01
PBC 535 – 33	8.78	1.3	1.5
PBC 535 – 34	6.8	1.08	1.3
PBC 535 – 35	7.8	1.3	1.8
PBC 535 – 36	6.89	1.09	1.5
PBC 535 – 37	7.5	1.3	1.8
PBC 535 – 38	8.9	1.1	1.9
PBC 535 – 39	8.9	1.09	1.4
PBC 535 – 40	9.3	1.12	1.67
PBC 535 – 41	9.5	1.09	1.43
PBC 535 – 42	8.98	1.08	1.83
PBC 535 – 43	9.9	1.34	2.1
PBC 535 – 44	12.3	1.4	2.9
PBC 535 – 45	11.9	1.3	1.98
PBC 535 – 46	10.5	0.98	1.67
PBC 535 – 47	13.4	1.06	1.45
PBC 535 – 48	8.56	1.2	2.1
PBC 535 – 49	7.98	1.1	1.98
PBC 535 - 50	9.2	1.09	2.1

	SD	Mean	CV%
Fruit length	2.110	10.4	20.2
Fruit width	0.259	1.21	21.4
Fruit weight	0.770	2.058	37.4

Yield /plant (g)

Yield / plant ranged from 50.5 – 148 g (Table 39). PBC 535 2 (47.53g), PBC 535 1 (50.5g), PBC 535 31 (58g), PBC 535 17 (68g) and PBC 535 30 (68g) had low yield. PBC 535 29 (133g), PBC 535 8 (134g), PBC 535 23 (134g), PBC 535 36 (136g), PBC 535 42 (138g), PBC 535 9 (142 g), PBC 535 35 (145g) and PBC 535 5 (148g) were high yielding.

Seed size (cm)

Seed size ranged from 0.26 – 0.38cm (Table 39). PBC 535 24 (0.26cm), PBC 535 34 (0.26cm) PBC 535 17 (0.26cm), PBC 535 19 (0.28cm), PBC 535 10 (0.29cm) and PBC 535 42 (0.29cm) had small seed size and PBC 535 27 (0.36cm), PBC 535 5 (0.36cm), PBC 535 26 (0.37cm) and PBC 535 49 (0.38cm) had large seed size.

Seed number

Seed number ranged from 89 – 146 (Table 39). PBC 535 27 (89), PBC 535 19 (99), PBC 535 20 (99) and PBC 535 17 (100) had low seed number and PBC 535 31 (139), PBC 535 3 (140), PBC 535 34 (143) and PBC 535 35 (146) had high seed number.

Table 39 Evaluation of somaclones of PBC 535 for yield/plant, seed size and seed size

Plant no.	Yield / plant (g)	Seed size	Seed no.
PBC 535 - 1	50.5	0.30	100
PBC 535 - 2	47.53	0.33	132
PBC 535 - 3	67.34	0.41	140
PBC 535 - 4	112.5	0.36	111
PBC 535 - 5	148	0.36	116
PBC 535 - 6	96.5	0.36	98
PBC 535 - 7	128	0.32	115
PBC 535 - 8	134	0.30	108
PBC 535 - 9	142	0.36	113
PBC 535 - 10	121	0.297	116
PBC 535 - 11	128	0.33	118
PBC 535 - 12	109	0.34	115
PBC 535 - 13	87	0.31	98
PBC 535 - 14	100	0.30	113
PBC 535 - 15	129	0.32	115
PBC 535 - 16	132	0.31	123
PBC 535 - 17	68	0.26	100
PBC 535 - 18	79	0.34	112
PBC 535 - 19	95	0.289	99
PBC 535 - 20	103	0.31	99
PBC 535 - 21	111	0.32	118
PBC 535 - 22	123	0.35	100
PBC 535 - 23	134	0.32	116
PBC 535 - 24	75	0.26	120
PBC 535 - 25	83	0.31	107

Table 39 cont. Evaluation of somaclones of PBC 535 for fruit length, fruit weight and fruit weight

Plant no.	Yield / plant (g)	Seed size	Seed no.
PBC 535 – 26	112	0.37	115
PBC 535 – 27	86	0.36	89
PBC 535 – 28	116	0.32	135
PBC 535 – 29	133	0.34	124
PBC 535 – 30	68	0.34	123
PBC 535 – 31	58	0.32	139
PBC 535 – 32	116	0.34	129
PBC 535 – 33	132	0.32	132
PBC 535 – 34	128	0.26	143
PBC 535 – 35	145	0.36	146
PBC 535 – 36	136	0.32	113
PBC 535 – 37	65	0.31	123
PBC 535 – 38	78	0.33	115
PBC 535 – 39	88	0.31	112
PBC 535 – 40	93	0.32	120
PBC 535 – 41	137	0.30	118
PBC 535 – 42	138	0.29	129
PBC 535 – 43	86	0.34	128
PBC 535 – 44	122	0.32	132
PBC 535 – 45	114	0.31	108
PBC 535 – 46	120	0.28	123
PBC 535 – 47	96	0.32	120
PBC 535 – 48	112	0.31	109
PBC 535 – 49	123	0.38	113
PBC 535 - 50	90	0.32	112

	SD	Mean	CV%
Yield /plant	29.5	103.6	28.4
Seed size	0.03	0.323	9.2
Seed no.	12.52	117.8	10.6

Colour value (ASTA)

Colour value ranged from 54.54 – 153.5 ASTA (Table 40). PBC 535 3 (47.34 ASTA), PBC 535 4 (53.17 ASTA), PBC 535 2 (54.54 ASTA) and PBC 535 9 (59.0ASTA) had low colour value and PBC 535 27 (120.2 ASTA), PBC 535 5 (120.75 ASTA), PBC 535

30 (120.40 ASTA), PBC 535 18 (122.0 ASTA), PBC 535 40 (123.40ASTA) and PBC 535 1 (153.5 ASTA) had high colour value.

Table 40 Evaluation of somaclones of PBC 535 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
PBC 535 - 1	153.5	PBC 535 - 26	98.45
PBC 535 - 2	54.54	PBC 535 - 27	120.20
PBC 535 - 3	47.34	PBC 535 - 28	113.50
PBC 535 - 4	53.17	PBC 535 - 29	96.45
PBC 535 - 5	120.75	PBC 535 - 30	120.40
PBC 535 - 6	52.30	PBC 535 - 31	86.34
PBC 535 - 7	103.04	PBC 535 - 32	76.20
PBC 535 - 8	129.10	PBC 535 - 33	58.30
PBC 535 - 9	59.00	PBC 535 - 34	78.34
PBC 535 - 10	91.00	PBC 535 - 35	84.10
PBC 535 - 11	73.03	PBC 535 - 36	93.10
PBC 535 - 12	85.98	PBC 535 - 37	109.30
PBC 535 - 13	112.83	PBC 535 - 38	113.20
PBC 535 - 14	108.50	PBC 535 - 39	115.30
PBC 535 - 15	78.23	PBC 535 - 40	123.40
PBC 535 - 16	104.80	PBC 535 - 41	85.30
PBC 535 - 17	96.45	PBC 535 - 42	96.30
PBC 535 - 18	122.20	PBC 535 - 43	98.40
PBC 535 - 19	96.67	PBC 535 - 44	87.40
PBC 535 - 20	79.78	PBC 535 - 45	100.40
PBC 535 - 21	93.23	PBC 535 - 46	68.90
PBC 535 - 22	108.30	PBC 535 - 47	76.30
PBC 535 - 23	112.22	PBC 535 - 48	105.30
PBC 535 - 24	109.30	PBC 535 - 49	116.35
PBC 535 - 25	112.20	PBC 535 - 50	95.34

	SD	Mean	CV%
Colour value	22.51	95.47	23.5

Evaluation of somaclones of PBC 375

Morphological characters of PBC 375 somaclones are presented in Table 41. Variation was found in plant growth habit and leaf shape (Fig.23). Plant growth habit was erect in 16 plants (32%) and compact in 44 (68%). Leaf shape was ovate in 35 plants (70%) and lanceolate in 15 (30%) plants.

Plant height

Plant height ranged from 43 – 76 cm (Table 42). PBC 375 13 (43cm), PBC 375 42 (45), PBC 375 14 (48cm), PBC 375 21 (48) were short plants and PBC 375 1 (70cm), PBC 375 41 (74cm), PBC 375 4 (75cm), PBC 375 15 (75cm) and PBC 375 3 (78cm) were tall plants.

Days to flower

Days to flower ranged from 33- 49 days (Table 42). PBC 375 36 (31), PBC 375 6 (33), PBC 375 37 (33), PBC 375 16 (34), PBC 375 29 (35), PBC 375 8 (36), PBC 375 28 (36) and PBC 375 50 (36) were early flowering plants while PBC 375 14 (46), PBC 375 18 (46), PBC 375 40 (46), PBC 375 41 (47), PBC 375 9 (48), PBC 375 25 (48), PBC 375 42 (48), PBC 375 5 (49), PBC 375 15 (49) and PBC 375 43 (49) were late flowering.

Days to fruit

Days to fruit ranged from 42-63 (Table 42). PBC 375 36 (42), PBC 375 6 (46), PBC 375 37 (47), PBC 375 16 (48), PBC 375 28 (48), PBC 375 50 (48), PBC 375 8 (49) and PBC 375 29 (49) were early fruiting. PBC 375 15 (60), PBC 375 25 (60), PBC 375 43 (60), PBC 375 5 (62) and PBC 375 9 (63) were late fruiting.

Table 41 Morphological characters of somaclones of PBC 375

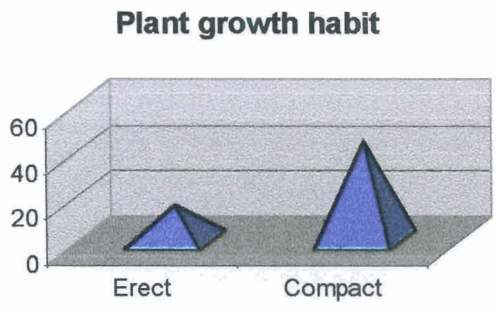
Characters	Expression	No. of plants
Stem shape	Cylindrical	50
Stem pubescence	Dense	0
	Intermediate	0
	Sparse /nil	50
Plant growth habit	Erect	16
	Intermediate	0
	Compact	44
Branching habit	High	0
	Intermediate	50
	Sparse	0
Leaf colour	Light green	0
	Green	50
	Dark green	0
Leaf shape	Ovate	35
	Lanceolate	15
No. of flowers/axil	1	50
	2& more	0
Flower position	Pendent	50
	Intermediate	0
	Erect	0
Corolla colour	White	50
	Light yellow	0
Anther colour	Blue	0
	Purple	50
Stigma exsertion	Exserted	50
	Same level	0
	Inserted	0
Calyx margin	Dentate	0
	Intermediate	50
	Sparse	0
Fruit colour at intermediate stage	Green	50
	Dark green	0
	Light green	0
	Yellowish green	0
Fruit colour at mature stage	Red	50
	Dark red	0

Continued-

Table 41 cont. Morphological characters of somaclones of PBC 375

Character	Expression	No. of plants
Fruit shape	Elongate	50
	Triangular	0
	Round	0
	Blocky	0
Fruit shape at blossom end	Pointed	50
	Blunt	0
	Sunken	0
	Sunken and pointed	0
Fruit blossom appendage	Absent	50
	Present	0
Fruit surface	Smooth	50
	Semi wrinkled	0
	Wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	Straw	50

Fig. 23 – Frequency of occurrence of forms of discrete characters in somaclones of PBC 375



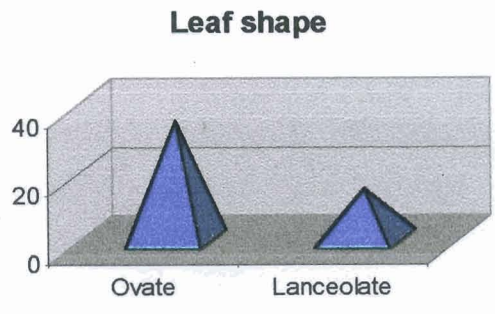


Table 42 Evaluation of somaclones of PBC 375 for plant height, days to flower, days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 375 – 1	70	39	51
PBC 375 – 2	50	40	50
PBC 375 – 3	78	42	54
PBC 375 – 4	75	38	51
PBC 375 – 5	50	49	62
PBC 375 – 6	60	33	46
PBC 375 – 7	68	38	53
PBC 375 – 8	65	36	49
PBC 375 – 9	64	48	63
PBC 375 – 10	63	41	53
PBC 375 – 11	52	43	58
PBC 375 – 12	57	45	59
PBC 375 – 13	43	44	56
PBC 375 – 14	48	46	58
PBC 375 – 15	75	49	60
PBC 375 – 16	63	34	48
PBC 375 – 17	62	39	51
PBC 375 – 18	60	46	58
PBC 375 – 19	58	39	50
PBC 375 – 20	55	44	56
PBC 375 – 21	48	43	56
PBC 375 – 22	67	42	53
PBC 375 – 23	65	41	54
PBC 375 – 24	66	44	58
PBC 375 – 25	71	48	60

Continued-

Table 42 cont. Evaluation of somaclones of PBC 375 for plant height, days to flower, days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 375 – 26	76	38	50
PBC 375 – 27	72	38	51
PBC 375 – 28	56	36	48
PBC 375 – 29	67	35	49
PBC 375 – 30	64	43	56
PBC 375 – 31	62	42	54
PBC 375 – 32	50	40	52
PBC 375 – 33	53	39	52
PBC 375 – 34	64	42	55
PBC 375 – 35	66	45	56
PBC 375 – 36	62	31	42
PBC 375 – 37	61	33	47
PBC 375 – 38	58	43	54
PBC 375 – 39	63	41	54
PBC 375 – 40	61	46	59
PBC 375 – 41	74	47	59
PBC 375 – 42	45	48	57
PBC 375 – 43	54	49	60
PBC 375 – 44	63	43	55
PBC 375 – 45	62	42	55
PBC 375 – 46	60	41	54
PBC 375 – 47	59	43	56
PBC 375 – 48	58	42	56
PBC 375 – 49	55	40	53
PBC 375 – 50	67	36	48
	SD	Mean	CV%
Plant height	7.95	61.26	12.9
Days to flower	4.597	41.75	11.0
Days to fruit	4.42	54.09	8.1

Fruit length (cm)

Fruit length ranged from 7.8 – 16.2 cm (Tables 43). PBC 375 16 (7.8cm), PBC 375 47 (7.8cm), PBC 375 2 (8cm), PBC 375 8 (8.2cm), PBC 375 9 (8.3cm), PBC 375 17 (8.3cm), PBC 375 25 (8.3cm), PBC 375 30 (8.45cm), PBC 375 14 (8.5cm), PBC 375 32 (8.74cm), PBC 375 45 (8.78cm) and PBC 375 46 (8.98cm) had short fruits and PBC 375

37 (15.3cm), PBC 375 35 (15.3 cm), PBC 375 22 (15.4cm), PBC 375 5 (16cm), PBC 375 23 (16.0) and PBC 375 36 (16.2cm) had long fruits.

Fruit width (cm)

Fruit width ranged from 1.08cm – 2.6cm (Table 43). PBC 375 16 (1.08 cm), PBC 375 18 (1.08cm), PBC 375 17 (1.11cm), PBC 375 15 (1.12cm), PBC 375 43 (1.12) and PBC 375 14 (1.13cm) had low fruit weight. PBC 375 37 (2.45cm), PBC 375 50 (2.45cm) PBC 375 49 (2.56cm), PBC 375 24 (2.56cm) and PBC 375 8 (2.6cm) had high fruit width.

Fruit weight (g)

Fruit weight ranged from 1.83 –5.5g (Table 43). PBC 375 47 (1.83g), PBC 375 46 (1.85g), PBC 375 45 (1.89g), PBC 375 25 (1.98g) and PBC 375 42 (1.98g), had low fruit weight and PBC 375 7 (3.23g), PBC 375 24 (3.23g), PBC 375 21 (3.24g), PBC 375 14 (3.25g), PBC 375 10 (3.32g), PBC 375 28 (3.32g), PBC 375 1 (3.33g), PBC 375 2 (3.4g), PBC 375 8 (3.65g) and PBC 375 3 (5.5g) had high fruit weight.

Yield / plant (g)

Yield / plant ranged from 92 – 192g (Table 44). PBC 375 22 (92g), PBC 375 21 (93g), PBC 375 37 (98g), PBC 375 38 (99g), PBC 375 49 (99g) and PBC 375 50 (100g) gave low fruit yield and PBC 375 1 (167g), PBC 375 4 (173g) and PBC 375 6 (192g) gave high fruit yield.

Table 43 Evaluation of somaclones of PBC 375 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 375 – 1	9.5	1.22	3.33
PBC 375 – 2	8	1.23	3.4
PBC 375 – 3	10.4	1.33	5.5
PBC 375 – 4	9.5	1.4	2.75
PBC 375 – 5	16	2.1	3.1
PBC 375 – 6	12	1.3	2.86
PBC 375 – 7	10.2	2.4	3.23
PBC 375 – 8	8.2	2.6	3.65
PBC 375 – 9	8.3	2.3	2.78
PBC 375 – 10	12.3	1.76	3.32
PBC 375 – 11	11.2	1.89	2.78
PBC 375 – 12	10.2	2.13	2.56
PBC 375 – 13	9.4	2.5	2.67
PBC 375 – 14	8.5	1.13	3.25
PBC 375 – 15	10.2	1.12	3.21
PBC 375 – 16	7.8	1.08	2.78
PBC 375 – 17	8.3	1.11	2.31
PBC 375 – 18	9.4	1.08	3.21
PBC 375 – 19	10.3	1.56	2.75
PBC 375 – 20	9.2	1.43	3.12
PBC 375 – 21	14.3	1.23	3.24
PBC 375 – 22	15.4	2.2	3.15
PBC 375 – 23	16.0	2.3	2.56
PBC 375 – 24	13.2	2.56	3.23
PBC 375 – 25	8.3	2.32	1.98

Continued-

Table 43 cont. Evaluation of somaclones of PBC 375 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 375 – 26	12.1	1.56	2.78
PBC 375 – 27	11.4	2.32	3.12
PBC 375 – 28	10.3	2.13	3.32
PBC 375 – 29	9.87	2.0	2.56
PBC 375 – 30	8.45	1.86	2.13
PBC 375 – 31	9.34	1.98	2.34
PBC 375 – 32	8.74	1.56	2.12
PBC 375 – 33	10.3	1.75	2.56
PBC 375 – 34	13.5	2.21	2.75
PBC 375 – 35	15.3	2.08	2.52
PBC 375 – 36	16.2	2.21	2.34
PBC 375 – 37	15.3	2.45	2.45
PBC 375 – 38	12.1	2.31	2.65
PBC 375 – 39	10.86	2.14	2.74
PBC 375 – 40	9.45	1.34	2.43
PBC 375 – 41	9.32	1.22	2.42
PBC 375 – 42	10.2	1.26	1.98
PBC 375 – 43	9.35	1.12	2.2
PBC 375 – 44	10.2	1.87	2.1
PBC 375 – 45	8.78	1.56	1.89
PBC 375 – 46	8.98	1.23	1.85
PBC 375 – 47	7.8	1.22	1.83
PBC 375 – 48	12.4	2.34	2.22
PBC 375 – 49	11.9	2.56	2.12
PBC 375 – 50	12.3	2.45	2.54
	SD	Mean	CV%
Fruit length	2.416	10.63	22.7
Fruit width	0.505	1.80	28.0
Fruit weight	0.678	2.296	29.5

Seed size (cm)

Seed size ranged from 0.21– 0.36cm (Table 44). PBC 375 6 (0.21cm), PBC 375 5 (0.22cm), PBC 375 34 (0.22cm), PBC 375 23 (0.23cm), PBC 375 25 (0.23cm), PBC 375 27 (0.23cm), PBC 375 24 (0.25cm) and PBC 375 38 (0.25cm) had small seed size and

PBC 375 15 (0.34cm), PBC 375 16 (0.34cm), PBC 375 49 (0.34cm), PBC 375 28 (0.36cm) and PBC 375 40 (0.36cm) had large seed size.

Seed number

Seed number ranged from 82 – 143 (Table 44). PBC 375 3 (82), PBC 375 35 (89), PBC 375 22 (95), PBC 375 21 (96), PBC 375 20 (98), PBC 375 36 (98) and PBC 375 42 (99) had low number of seeds and PBC 375 33 (130), PBC 375 29 (135), PBC 375 46 (138), PBC 375 50 (139), PBC 375 45 (142), PBC 375 45 (142), PBC 375 44 (143), PBC 375 44 (143) and PBC 375 5 (145) had more number of seeds.

Table 44 Evaluation of somaclones of PBC 375 for yield/plant, seed size and seed number

Plant no.	Yield/plant (g)	Seed size (cm)	Seed no.
PBC 375 – 1	167	0.32	120
PBC 375 – 2	145	0.31	134
PBC 375 – 3	150	0.29	82
PBC 375 – 4	173	0.26	132
PBC 375 – 5	183	0.22	145
PBC 375 – 6	192	0.21	100
PBC 375 – 7	154	0.30	122
PBC 375 – 8	153	0.28	112
PBC 375 – 9	126	0.29	104
PBC 375 – 10	104	0.32	110
PBC 375 – 11	116	0.31	126
PBC 375 – 12	122	0.32	132
PBC 375 – 13	132	0.26	125
PBC 375 – 14	140	0.25	111
PBC 375 – 15	145	0.34	123
PBC 375 – 16	100	0.34	112
PBC 375 – 17	113	0.32	110
PBC 375 – 18	121	0.32	127
PBC 375 – 19	120	0.32	128
PBC 375 – 20	106	0.29	98
PBC 375 – 21	93	0.26	96
PBC 375 – 22	92	0.25	95
PBC 375 – 23	136	0.23	128
PBC 375 – 24	156	0.25	132
PBC 375 – 25	134	0.23	110

Continued-

Table 44 cont. Evaluation of somaclones of PBC 375 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
PBC 375 – 26	156	0.32	120
PBC 375 – 27	122	0.23	113
PBC 375 – 28	108	0.36	123
PBC 375 – 29	134	0.31	135
PBC 375 – 30	156	0.28	112
PBC 375 – 31	124	0.34	121
PBC 375 – 32	122	0.31	127
PBC 375 – 33	125	0.29	130
PBC 375 – 34	132	0.22	111
PBC 375 – 35	123	0.32	89
PBC 375 – 36	108	0.34	98
PBC 375 – 37	98	0.19	106
PBC 375 – 38	99	0.25	124
PBC 375 – 39	112	0.29	105
PBC 375 – 40	128	0.36	117
PBC 375 – 41	124	0.32	107
PBC 375 – 42	128	0.31	99
PBC 375 – 43	135	0.30	113
PBC 375 – 44	136	0.33	143
PBC 375 – 45	140	0.35	142
PBC 375 – 46	112	0.29	138
PBC 375 – 47	134	0.30	128
PBC 375 – 48	114	0.31	100
PBC 375 – 49	99	0.34	125
PBC 375 – 50	100	0.30	139
	SD	Mean	CV%
Yield /plant	22.9	128.94	17.7
Seed size	0.041	0.293	13.9
Seed no.	13.95	118.38	11.7

Colour value

Colour value ranged from 74 – 156 ASTA units (Table 45). PBC 375 6 (74 ASTA), PBC 375 28 (78.45 ASTA), PBC 375 10 (87 ASTA) and PBC 375 41 (98.45 ASTA) had low colour value and PBC 375 22 (146.35 ASTA), PBC 375 2 (155.3 ASTA), PBC 375

21 (155.34 ASTA), PBC 375 49 (156.32 ASTA), PBC 375 31 (156.34 ASTA) and PBC 375 47 (156.5 ASTA) had high colour value.

Table 45 Evaluation of somaclones of PBC 375 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
PBC 375 – 1	111	PBC 375 – 26	126.75
PBC 375 – 2	155.3	PBC 375 – 27	112.34
PBC 375 – 3	134.6	PBC 375 – 28	78.45
PBC 375 – 4	105.6	PBC 375 – 29	132.23
PBC 375 – 5	107.34	PBC 375 – 30	126.45
PBC 375 – 6	74.00	PBC 375 – 31	156.34
PBC 375 – 7	121.00	PBC 375 – 32	134.45
PBC 375 – 8	114.2	PBC 375 – 33	126.78
PBC 375 – 9	122.3	PBC 375 – 34	113.45
PBC 375 – 10	87 .00	PBC 375 – 35	128.42
PBC 375 – 11	113.42	PBC 375 – 36	112.34
PBC 375 – 12	120.2	PBC 375 – 37	109.23
PBC 375 – 13	95.34	PBC 375 – 38	132.24
PBC 375 – 14	100.23	PBC 375 – 39	145.34
PBC 375 – 15	98.23	PBC 375 – 40	140.30
PBC 375 – 16	124.56	PBC 375 – 41	98.45
PBC 375 – 17	132.32	PBC 375 – 42	121.2
PBC 375 – 18	128.45	PBC 375 – 43	125.56
PBC 375 – 19	111.35	PBC 375 – 44	132.21
PBC 375 – 20	126.34	PBC 375 – 45	107.20
PBC 375 – 21	155.34	PBC 375 – 46	143.21
PBC 375 – 22	146. 35	PBC 375 – 47	156.5
PBC 375 – 23	135.56	PBC 375 – 48	132.22
PBC 375 – 24	123.45	PBC 375 – 49	156.32
PBC 375 – 25	110.45	PBC 375 – 50	144.23

	SD	Mean	CV%
Colour value	19.7	122.8	16.0

Evaluation of somaclones of PBC 385

Morphological characters of somaclones of PBC 385 were observed (Table. 46). Variation was found in stem pubescence and anther colour (Fig.24)). Stem pubescence

was intermediate in 24 plants (48%) and stem pubescence was absent in 26 plants (52%) plants. Anther colour was blue in 19 plants (38%) and purple in 31 (62%) plants.

Table 46– Morphological characters of somaclones of PBC 385

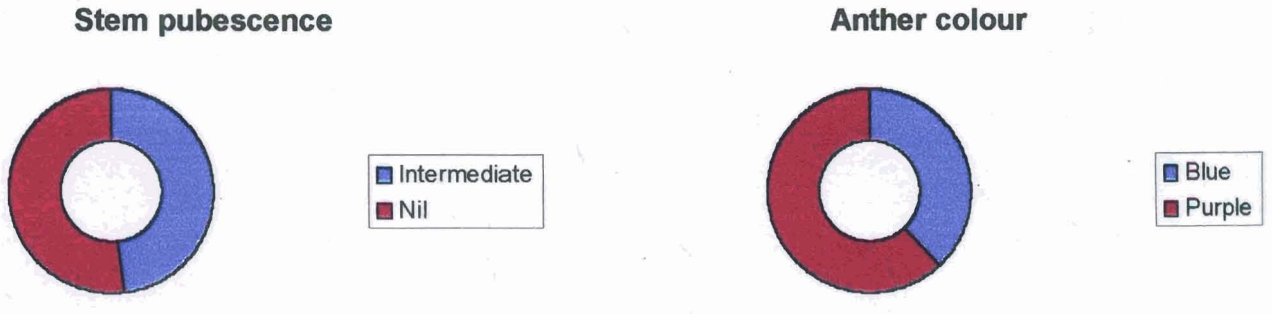
Characters	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	24
	sparse /nil	26
Plant growth habit	erect	50
	intermediate	0
	compact	0
Branching habit	high	0
	intermediate	50
	sparse	0
Leaf colour	light green	0
	green	50
	dark green	0
Leaf shape	ovate	50
	lanceolate	0
No.of flowers/axil	1	50
	2 and more	0
Flower position	pendent	50
	intermediate	0
	erect	0
Corolla colour	white	50
	light yellow	0
Anther colour	blue	19
	purple	31
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
	sparse	0
Fruit colour at intermediate stage	green	50
	dark green	0
	light green	0
	yellowish green	0
Fruit colour at mature stage	red	50
	dark red	0

Continued-

Table 46 cont. Morphological characters of somaclones of PBC 385

Characters	Expression	No. of plants
Fruit shape	Elongate	50
	Triangular	0
	Round	0
	Blocky	0
Fruit shape at blossom end	Pointed	50
	Blunt	0
	Sunken	0
	Sunken and pointed	0
Fruit blossom appendage	Absent	50
	Present	0
Fruit surface	Smooth	0
	Semi wrinkled	50
	Wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	Straw	50

Fig. 24 Frequency of occurrence of forms of descriptor states in somaclones of PBC 385.



Plant height (cm)

Plant height ranged from 40 – 78 cm (Table 47). PBC 385 2 (40cm), PBC 385 4 (45cm) and PBC 385 3 (50cm) were short plants. PBC 385 14 (72cm), PBC 385 42 (72cm), PBC 385 25 (73cm), PBC 385 19 (74cm), PBC 385 21 (74cm), PBC 385 22 (76cm) and PBC 385 13 (78cm) were tall plants.

Days to flower

Days to flower ranged from 33 – 52 cm (Table 47). PBC 385 50 (33), PBC 385 17 (34), PBC 385 7 (35) and PBC 385 47 (35) were early flowering. PBC 385 46 (49), PBC 385 6 (50), PBC 385 14 (51) and PBC 385 13 (52) were late flowering.

Days to fruit

Days to fruit ranged from 45 – 60 (Table 47). PBC 385 50 (45), PBC 385 17 (46), PBC 385 9 (48), PBC 385 38 (48), PBC 385 61 (48), PBC 385 7 (49), PBC 385 8 (49), PBC 385 18 (49) and PBC 385 49 (49), were early fruiting. PBC 385 32 (60), PBC 385 46 (60), PBC 385 6 (60), PBC 385 13 (62) and PBC 385 14 (62) were late fruiting.

Fruit length (cm)

Fruit length ranged from 7.56 – 15.3 cm (Table 48). PBC 385 21 (7.56cm), PBC 385 6 (7.6 cm), PBC 385 10 (7.8 cm) and PBC 385 46 (7.83cm) had short fruits while PBC 385 33 (14.2 cm), PBC 385 1 (15cm), PBC 385 27 (15.2 cm) and PBC 385 26 (15.3cm) had long fruits.

Table 47 Evaluation of somaclones of PBC 385 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 385 – 1	60	38	50
PBC 385 – 2	40	40	53
PBC 385 – 3	50	39	53
PBC 385 – 4	45	40	50
PBC 385 – 5	63	42	53
PBC 385 – 6	60	50	60
PBC 385 – 7	55	35	49
PBC 385 – 8	60	37	49
PBC 385 – 9	55	36	48
PBC 385 – 10	62	45	56
PBC 385 – 11	67	42	54
PBC 385 – 12	63	43	54
PBC 385 – 13	78	52	62
PBC 385 – 14	72	51	62
PBC 385 – 15	68	43	55
PBC 385 – 16	58	38	50
PBC 385 – 17	64	34	46
PBC 385 – 18	65	38	49
PBC 385 – 19	74	41	53
PBC 385 – 20	71	43	55
PBC 385 – 21	74	48	58
PBC 385 – 22	76	45	56
PBC 385 – 23	71	42	54
PBC 385 – 24	70	43	55
PBC 385 – 25	73	41	53

Continued-

Table 47 cont. Evaluation of somaclones of PBC 385 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 385 – 26	65	38	50
PBC 385 – 27	68	40	54
PBC 385 – 28	73	41	53
PBC 385 – 29	58	43	57
PBC 385 – 30	55	44	59
PBC 385 – 31	65	39	50
PBC 385 – 32	71	48	60
PBC 385 – 33	73	45	58
PBC 385 – 34	67	43	57
PBC 385 – 35	68	41	53
PBC 385 – 36	66	40	53
PBC 385 – 37	63	39	52
PBC 385 – 38	63	37	48
PBC 385 – 39	59	45	58
PBC 385 – 40	56	42	54
PBC 385 – 41	59	46	57
PBC 385 – 42	72	49	59
PBC 385 – 43	64	43	55
PBC 385 – 44	63	40	52
PBC 385 – 45	62	48	59
PBC 385 – 46	60	49	60
PBC 385 – 47	61	35	48
PBC 385 – 48	64	38	52
PBC 385 – 49	64	37	49
PBC 385 – 50	61	33	45

	SD	Mean	CV%
Plant height	7.61	63.84	11.9
Days to flower	4.50	41.8	10.7
Days to fruit	10.6	46.7	22.6

Fruit width (cm)

Fruit width ranged from 1– 2.22cm (Table 48). PBC 385 22 (1.0cm), PBC 385 16 (1.04cm), PBC 385 34 (1.09cm), PBC 385 39 (1.09 cm), PBC 385 10 (1.1cm), PBC 385 20 (1.10), PBC 385 32 (1.11cm), PBC 385 38 (1.13cm) and PBC 385 35 (1.14cm) had low fruit width and PBC 385 31 (1.72cm), PBC 385 7 (1.78cm), PBC 385 15 (1.78cm), PBC 385 33 (1.78cm), PBC 385 45 (2.01cm), PBC 385 44 (2.08cm) and PBC 385 46 (2.22cm) had high fruit width.

Fruit weight (g)

Fruit weight ranged from 1.34 – 2.91 g (Table 48). PBC 385 38 (1.28 g), PBC 385 17 (1.34 g), PBC 385 29 (1.34 g), PBC 385 34 (1.36g), PBC 385 21 (1.38g) and PBC 385 37 (1.38 g) had low fruit weight and PBC 385 8 (2.5 g), PBC 385 9 (2.63g) and PBC 385 47 (2.91 g) had high fruit weight.

Yield/plant (g)

Yield /plant ranged from 103 – 173g (Table 49). PBC 385 22 (103g), PBC 385 25 (105g), PBC 385 23 (108g) and PBC 385 24 (109g) were low yielding. PBC 385 30 (163g), PBC 385 43 (168g), PBC 385 31 (172g) and PBC 385 9 (173g) were high yielding.

Seed size (cm)

Seed size ranged from 0.26 – 0.38 cm (Table 49). PBC 385 27 (0.21cm), PBC 385 26 (0.23 cm), PBC 385 12 (0.26 cm), PBC 385 41 (0.26cm), PBC 385 42 (0.27cm), PBC 385 11 (0.29 cm) and PBC 385 40 (0.29cm) had small seed size. PBC 385 22 (0.36cm), PBC 385 31 (0.37 cm), PBC 385 9 (0.38 cm) and PBC 385 32 (0.38 cm) had large seed size.

Table 48 Evaluation of somaclones of PBC 385 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 385 – 1	15	1.2	2.1
PBC 385 – 2	11.5	1.2	1.8
PBC 385 – 3	13.7	1.5	2.1
PBC 385 – 4	11.5	1.2	1.75
PBC 385 – 5	8	1.7	1.82
PBC 385 – 6	7.6	1.2	2.1
PBC 385 – 7	12	1.78	1.8
PBC 385 – 8	10	1.3	2.5
PBC 385 – 9	10.5	1.3	2.63
PBC 385 – 10	7.8	1.1	2.12
PBC 385 – 11	12.9	1.2	2.11
PBC 385 – 12	10.7	1.5	2.10
PBC 385 – 13	12.3	2.0	2.13
PBC 385 – 14	11.2	1.56	2.06
PBC 385 – 15	9.45	1.78	2.14
PBC 385 – 16	8.23	1.04	2.12
PBC 385 – 17	9.23	1.23	1.34
PBC 385 – 18	11.10	1.33	1.65
PBC 385 – 19	13.1	1.12	1.85
PBC 385 – 20	10.4	1.10	1.56
PBC 385 – 21	7.56	1.21	1.38
PBC 385 – 22	8.23	1.00	1.87
PBC 385 – 23	8.12	1.24	1.99
PBC 385 – 24	10.1	1.20	2.13
PBC 385 – 25	12.3	1.34	2.16

Continued-

Table 48 cont. Evaluation of somaclones of PBC 385 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 385 – 26	15.3	1.32	2.3
PBC 385 – 27	15.2	1.22	2.1
PBC 385 – 28	11.3	1.56	2.2
PBC 385 – 29	10.34	1.54	1.34
PBC 385 – 30	12.1	1.38	2.13
PBC 385 – 31	11.8	1.72	2.08
PBC 385 – 32	13.23	1.11	2.16
PBC 385 – 33	14.2	1.78	1.76
PBC 385 – 34	10.5	1.09	1.36
PBC 385 – 35	9.45	1.14	1.59
PBC 385 – 36	9.23	1.29	1.45
PBC 385 – 37	10.34	1.24	1.38
PBC 385 – 38	9.34	1.13	1.28
PBC 385 – 39	9.21	1.09	1.67
PBC 385 – 40	10.34	1.24	1.76
PBC 385 – 41	11.23	1.34	1.83
PBC 385 – 42	12.10	1.21	2.12
PBC 385 – 43	13.20	1.12	2.32
PBC 385 – 44	14.13	2.08	2.31
PBC 385 – 45	8.57	2.01	2.22
PBC 385 – 46	7.83	2.22	2.18
PBC 385 – 47	9.23	1.67	2.91
PBC 385 – 48	10.22	1.21	1.98
PBC 385 – 49	11.2	1.13	1.89
PBC 385 – 50	8.34	1.14	1.76

	SD	Mean	CV%
Fruit length	2.10	10.9	19.2
Fruit width	0.338	1.284	26.3
Fruit weight	0.452	1.77	25.5

Seed number

Seed number ranged from 79 – 135 (Table 49). PBC 385 26 (99), PBC 385 29 (98), PBC 385 46 (105) and PBC 385 49 (108) had low seed number. PBC 385 16 (130), PBC 385 35 (131), PBC 385 17 (132), PBC 385 15 (135) had high seed number.

Table 49 Evaluation of somaclones of PBC 385 for yield/plant, seed size and seed number

Plant no.	Yield/plant (g)	Seed size	Seed no.
PBC 385 – 1	120	0.30	112
PBC 385 – 2	128	0.31	114
PBC 385 – 3	110	0.32	121
PBC 385 – 4	115	0.34	124
PBC 385 – 5	125	0.31	123
PBC 385 – 6	136	0.31	125
PBC 385 – 7	127	0.34	79
PBC 385 – 8	120	0.31	126
PBC 385 – 9	173	0.38	124
PBC 385 – 10	121	0.34	128
PBC 385 – 11	123	0.29	125
PBC 385 – 12	110	0.26	126
PBC 385 – 13	116	0.30	124
PBC 385 – 14	113	0.31	122
PBC 385 – 15	112	0.32	135
PBC 385 – 16	110	0.34	130
PBC 385 – 17	112	0.34	132
PBC 385 – 18	123	0.35	130
PBC 385 – 19	145	0.32	129
PBC 385 – 20	156	0.34	122
PBC 385 – 21	116	0.35	112
PBC 385 – 22	103	0.36	110
PBC 385 – 23	108	0.31	113
PBC 385 – 24	109	0.34	109
PBC 385 – 25	105	0.32	110

Continued-

Table 49 cont. Evaluation of somaclones of PBC 385 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size	Seed no.
PBC 385 – 26	138	0.23	99
PBC 385 – 27	146	0.21	112
PBC 385 – 28	153	0.34	110
PBC 385 – 29	143	0.32	98
PBC 385 – 30	163	0.35	113
PBC 385 – 31	172	0.37	112
PBC 385 – 32	144	0.38	115
PBC 385 – 33	132	0.31	119
PBC 385 – 34	129	0.32	122
PBC 385 – 35	126	0.34	131
PBC 385 – 36	120	0.36	128
PBC 385 – 37	126	0.30	110
PBC 385 – 38	125	0.34	105
PBC 385 – 39	120	0.32	108
PBC 385 – 40	136	0.29	118
PBC 385 – 41	145	0.26	112
PBC 385 – 42	152	0.27	118
PBC 385 – 43	168	0.34	123
PBC 385 – 44	143	0.31	114
PBC 385 – 45	114	0.32	116
PBC 385 – 46	125	0.32	105
PBC 385 – 47	133	0.34	111
PBC 385 – 48	156	0.31	115
PBC 385 – 49	142	0.33	108
PBC 385 – 50	152	0.32	114
	SD	Mean	CV%
Yield/plant	19.11	132.42	14.4
Seed size	0.033	0.319	0.103
Seed no	8.654	1 17.4	7.3

Colour value (ASTA)

Colour value ranged from 70.24 – 205 ASTA (Table 50). PBC 385 6 (70.24 ASTA), PBC 385 3 (86.2ASTA), PBC 385 12 (86.5 ASTA) and PBC 385 9 (89.7 ASTA) were lines with low colour value and PBC 385 15 (200ASTA), PBC 385 38 (203.2ASTA) and PBC 385 39 (205ASTA) were lines with high colour value.

Table 50 Evaluation of somaclones of PBC 385 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
PBC 385 – 1	140.2	PBC 385 – 26	146
PBC 385 – 2	168.5	PBC 385 – 27	162
PBC 385 – 3	86.2	PBC 385 – 28	158.45
PBC 385 – 4	104.9	PBC 385 – 29	143.14
PBC 385 – 5	124.5	PBC 385 – 30	165.34
PBC 385 – 6	70.24	PBC 385 – 31	172.3
PBC 385 – 7	110.41	PBC 385 – 32	135.6
PBC 385 – 8	130.24	PBC 385 – 33	145.5
PBC 385 – 9	89.7	PBC 385 – 34	165.3
PBC 385 – 10	94.2	PBC 385 – 35	175.45
PBC 385 – 11	91.6	PBC 385 – 36	187.3
PBC 385 – 12	86.5	PBC 385 – 37	198.3
PBC 385 – 13	123.76	PBC 385 – 38	203.2
PBC 385 – 14	132.23	PBC 385 – 39	205
PBC 385 – 15	200	PBC 385 – 40	156
PBC 385 – 16	169	PBC 385 – 41	178.3
PBC 385 – 17	120	PBC 385 – 42	180.34
PBC 385 – 18	1223	PBC 385 – 43	176.23
PBC 385 – 19	121	PBC 385 – 44	186.3
PBC 385 – 20	134	PBC 385 – 45	123.4
PBC 385 – 21	132	PBC 385 – 46	167.3
PBC 385 – 22	115	PBC 385 – 47	186.34
PBC 385 – 23	117	PBC 385 – 48	184.5
PBC 385 – 24	125	PBC 385 – 49	165.34
PBC 385 – 25	156	PBC 385 – 50	145.6
	SD	Mean	CV%
Colour value	39.07	139.2	28.06

Evaluation of somaclones of PBC 066

Morphological characters of somaclones of PBC 066 were observed (Table 51). Variation was found in stem pubescence, plant growth habit, leaf colour and fruit colour at intermediate stages (Fig.25)). Twenty-four plants (48%) were found to have intermediate pubescence and 26 plants (52%) had sparse or nil pubescence. Plant growth habit was erect in 23 plants (46%) and intermediate in 27 plants (54%). Leaf colour was

green in 24 plants (48%), dark green in 26 plants (52%). Fruit colour at intermediate stage was green in 23 plants (46%) and dark green in 27 plants (54%).

Table 51 Morphological characters of somaclones of PBC 066

Character	Expression	No. plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	24
	sparse /nil	26
Plant growth habit	erect	23
	intermediate	27
	compact	0
Branching habit	high	0
	intermediate	50
	sparse	0
Leaf colour	light green	0
	green	24
	dark green	26
Leaf shape	ovate	50
	lanceolate	0
No.of flowers/axil	1	50
	2 and more	0
Flower position	pendent	50
	intermediate	0
	erect	0
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
	sparse	0
Fruit colour at intermediate stage	green	23
	dark green	27
	light green	0
	yellowish green	0
Fruit colour at mature stage	red	0
	dark red	50

Continued-

Table 51 cont. Morphological characters of somaclones of PBC 066

Characters	Expression	No. of plants
Fruit shape	elongate	50
	triangular	0
	round	0
	blocky	0
Fruit shape at blossom end	pointed	50
	blunt	0
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

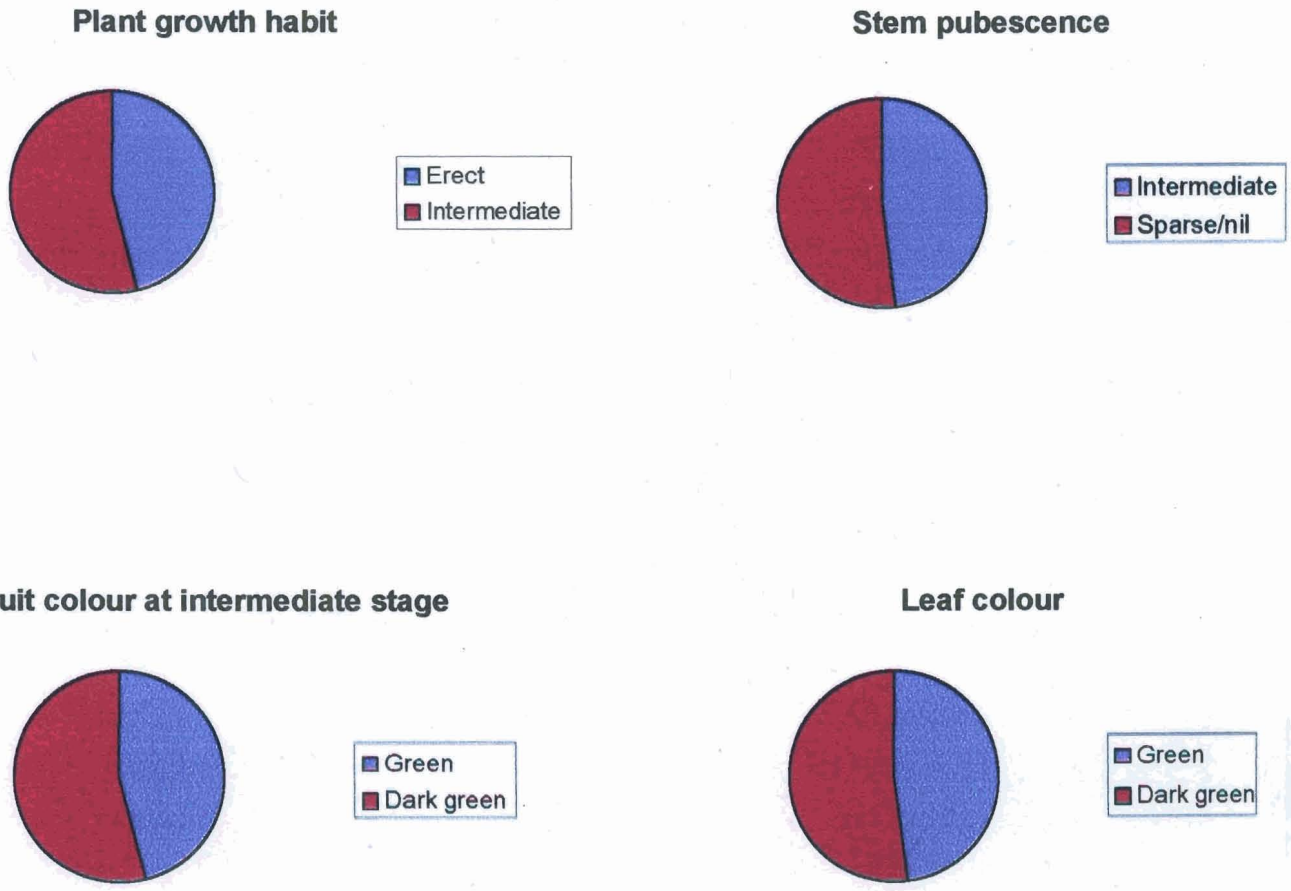
Plant height (cm)

Plant height ranged from 45 – 66cm (Table 52). PBC 066 1(45cm), PBC 066 6 (45cm), PBC 066 35 (45cm), PBC 066 5 (46cm) and PBC 066 29 (46cm) were short plants. PBC 066 46 (60cm), PBC 066 10 (61 cm), PBC 066 25 (61cm), PBC 066 24 (62cm), PBC 066 26 (61cm), PBC 066 37 (61cm), PBC 066 38 (62cm), PBC 066 13 (64cm) and PBC 066 39 (66cm) were tall plants

Days to flower

Days to flower ranged from 32 – 49 (Table 52). PBC 066 1 (32), PBC 066 19 (32), PBC 066 26 (32), PBC 066 46 (32), PBC 066 5 (33), PBC 066 39 (33) and PBC 066 47 (33) were early flowering. PBC 066 23 (48), PBC 066 41 (48) and PBC 066 43 (49) were late flowering.

Fig.25 Frequency of occurrence of forms of discrete characters of somaclones of PBC 066



Days to fruiting

Days to fruiting ranged from 45 – 63 (Table 52). PBC 066 26 (43), PBC 066 1 (45), PBC 066 19 (45), PBC 066 39 (45) and PBC 066 46 (45) were early flowering. PBC 066 23 (60), PBC 066 24 (60), PBC 066 43 (60) and PBC 066 50 (63) were late flowering.

Table 52 Evaluation of somaclones of PBC 066 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 066 – 1	45	32	45
PBC 066 – 2	48	38	50
PBC 066 – 3	50	40	53
PBC 066 – 4	52	45	56
PBC 066– 5	46	33	48
PBC 066 – 6	45	41	53
PBC 066 – 7	48	45	57
PBC 066 – 8	49	39	53
PBC 066 – 9	50	41	54
PBC 066 – 10	61	39	52
PBC 066 – 11	56	42	56
PBC 066 – 12	59	38	53
PBC 066 – 13	64	35	49
PBC 066 – 14	53	43	56
PBC 066 – 15	51	42	56
PBC 066 – 16	57	40	53
PBC 066 – 17	48	38	50
PBC 066 – 18	49	36	46
PBC 066 – 19	56	32	45
PBC 066 – 20	55	39	53
PBC 066 – 21	52	43	58
PBC 066 – 22	50	42	54
PBC 066 – 23	51	48	60
PBC 066 – 24	62	47	60
PBC 066 – 25	61	45	58

Continued-

Table 52 cont. Evaluation of somaclones of PBC 066 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
PBC 066 – 26	61	32	43
PBC 066 – 27	56	34	46
PBC 066 – 28	58	38	50
PBC 066 – 29	46	40	50
PBC 066 – 30	49	45	58
PBC 066 – 31	53	34	46
PBC 066 – 32	55	42	55
PBC 066 – 33	54	36	48
PBC 066 – 34	48	38	50
PBC 066 – 35	45	41	53
PBC 066 – 36	54	42	55
PBC 066 – 37	61	41	53
PBC 066 – 38	62	36	48
PBC 066 – 39	66	33	45
PBC 066 – 40	54	45	57
PBC 066 – 41	52	48	59
PBC 066 – 42	57	43	55
PBC 066 – 43	58	49	60
PBC 066 – 44	59	37	49
PBC 066 – 45	58	36	48
PBC 066 – 46	60	32	45
PBC 066 – 47	53	33	49
PBC 066 – 48	56	39	52
PBC 066 – 49	59	42	55
PBC 066 – 50	51	41	63

	SD	Mean	CV%
Plant height	5.55	54.01	10.2
Days to flower	4.507	39.6	11.38
Days to fruit	4.789	52.4	9.0

Fruit length (cm)

Fruit length ranged from 8.3 – 14.0cm (Table 53). PBC 066 47 (8.3cm), PBC 066 14 (9.86cm), PBC 066 32 (8.9cm), PBC 066 31 (9.3cm) had short fruits and PBC 066 7 (13cm), PBC 066 10 (13.1cm), PBC 066 26 (13.1cm), PBC 066 43 (13.1cm), PBC 066

45 (13.1cm), PBC 066 16 (13.2cm), PBC 066 18 (13.2cm), PBC 066 38 (13.2cm), PBC 066 40 (13.6cm), PBC 066 3 (14cm), PBC 066 28 (14.0cm), PBC 066 42 (14.0cm) and PBC 066 35 (14.1cm), had long fruits.

Fruit width (cm)

Fruit width ranged from 0.8 – 4.0cm (Table 53). PBC 066 7 (0.8cm), PBC 066 35 (1.1cm), PBC 066 5 (1.2cm), PBC 066 27 (1.3cm), PBC 066 34 (1.3cm) and PBC 066 8 (1.33cm) had low fruit width and PBC 066 22 (3.56cm), PBC 066 24 (3.56cm), PBC 066 23 (4.0cm), PBC 066 25 (4.0cm), PBC 066 31(4.0cm) and PBC 066 40 (4.0cm) had high fruit width.

Fruit weight (g)

Fruit weight ranged from 8.34 – 13.56g (Table 53). PBC 066 14 (8.34g), PBC 066 31 (9.21g), PBC 066 2 (9.45g) and PBC 066 17 (9.45g) had low fruit weight and PBC 066 25 (13.2g), PBC 066 27 (13.21g), PBC 066 8 (13.23g), PBC 066 42 (13.23g), PBC 066 12 (13.24g) and PBC 066 28 (13.56g) had high fruit weight.

Yield/plant (g)

Yield/plant ranged from 138-238g (Table 54). PBC 066 38 (138g), PBC 066 37 (145g), PBC 066 39 (145g) and PBC 066 31 (148g) were low in yield. PBC 066 17 (220g), PBC 066 19 (223g), PBC 066 22 (224g), PBC 066 34 (228g), PBC 066 5 (230g), PBC 066 29 (230g) and PBC 066 20 (238g), were high in yield.

Table 53 Evaluation of somaclones of PBC 066 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 066 – 1	12	1.6	10.1
PBC 066 – 2	11	1.4	9.45
PBC 066 – 3	14	1.3	10.26
PBC 066 – 4	11.5	1.5	11.23
PBC 066– 5	11.8	1.2	10.56
PBC 066 – 6	12.1	1.3	10.76
PBC 066 – 7	13	0.8	10.87
PBC 066 – 8	12.8	1.33	13.23
PBC 066 – 9	12.9	1.47	11.45
PBC 066 – 10	13.1	2.3	12.34
PBC 066 – 11	11.3	1.56	11.34
PBC 066 – 12	13.2	2.1	13.24
PBC 066 – 13	12.3	1.45	11.87
PBC 066 – 14	9.86	1.32	8.34
PBC 066 – 15	11.2	2.6	11.44
PBC 066 – 16	13.2	3.2	12.36
PBC 066 – 17	10.56	3.1	9.45
PBC 066 – 18	13.2	3.4	10.56
PBC 066 – 19	11.5	2.75	10.4
PBC 066 – 20	12.2	2.24	12.4
PBC 066 – 21	11.33	1.67	11.2
PBC 066 – 22	12.12	3.56	11.34
PBC 066 – 23	10.86	4.00	12.3
PBC 066 – 24	11.34	3.56	10.3
PBC 066 – 25	10.23	4.0	13.2

Continued-

Table 53 cont. Evaluation of somaclones of PBC 066 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
PBC 066 – 26	13.1	1.4	12.65
PBC 066 – 27	12.1	1.3	13.21
PBC 066 – 28	14.0	1.6	13.56
PBC 066 – 29	11.8	2.6	10.34
PBC 066 – 30	10.6	3.1	10.23
PBC 066 – 31	9.3	4.0	9.21
PBC 066 – 32	8.9	3.3	7.34
PBC 066 – 33	11.9	1.5	10.84
PBC 066 – 34	12.3	1.3	12.32
PBC 066 – 35	14.1	1.1	14.21
PBC 066 – 36	12.3	2.4	12.12
PBC 066 – 37	11.6	2.6	10.34
PBC 066 – 38	13.2	3.2	12.35
PBC 066 – 39	10.4	3.3	10.12
PBC 066 – 40	13.6	4.0	12.89
PBC 066 – 41	11.0	2.5	10.56
PBC 066 – 42	14.0	3.1	13.23
PBC 066 – 43	13.1	2.7	12.86
PBC 066 – 44	11.3	1.6	11.23
PBC 066 – 45	12.7	1.9	12.13
PBC 066 – 46	13.1	2.0	11.67
PBC 066 – 47	8.3	2.2	12.34
PBC 066 – 48	11.6	2.3	11.12
PBC 066 – 49	12.5	2.4	12.35
PBC 066 – 50	12.7	1.5	12.12
	SD	Mean	CV%
Fruit length	3.17	10.98	28.8
Fruit width	0.90	2.25	40
Fruit weight	1.392	11.47	12.1

Seed size (cm)

Seed size ranged from 0.27- 0.42cm (Table 54). PBC 066 41 (0.27cm), PBC 066 33 (0.27cm), PBC 066 24 (0.28cm), PBC 066 11 (0.29cm), PBC 066 21 (0.29cm) and PBC 066 26 (0.29cm) had small seed size. PBC 066 6 (0.40cm), PBC 066 14 (0.40cm), PBC

066 29 (0.40cm), PBC 066 34 (0.41cm), PBC 066 3 (0.41cm), PBC 066 13 (0.42cm) and PBC 066 50 (0.42cm) had large seed size.

Seed number

Seed number ranged from 80 – 120 (Table 54). PBC 066 26 (80), PBC 066 2 (80), PBC 066 6 (82), PBC 066 10 (83), PBC 066 1 (85) and PBC 066 50 (85) had small seed number. PBC 066 12 (112), PBC 066 39 (112), PBC 066 21 (113), PBC 066 23 (115), PBC 066 41 (115), PBC 066 43 (115) and PBC 066 42 (120) had large number of seeds.

Table 54 Evaluation of somaclones of PBC 066 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
PBC 066 – 1	210	0.35	85
PBC 066 – 2	150	0.35	80
PBC 066 – 3	185	0.41	90
PBC 066 – 4	200	0.36	95
PBC 066– 5	230	0.38	96
PBC 066 – 6	175	0.40	82
PBC 066 – 7	180	0.38	88
PBC 066 – 8	191	0.39	91
PBC 066 – 9	168	0.33	93
PBC 066 – 10	201	0.32	83
PBC 066 – 11	168	0.29	100
PBC 066 – 12	173	0.30	112
PBC 066 – 13	169	0.42	76
PBC 066 – 14	185	0.40	88
PBC 066 – 15	198	0.39	94
PBC 066 – 16	200	0.41	92
PBC 066 – 17	220	0.36	99
PBC 066 – 18	211	0.34	102
PBC 066 – 19	223	0.38	87
PBC 066 – 20	238	0.32	96
PBC 066 – 21	212	0.29	113
PBC 066 – 22	224	0.34	108
PBC 066 – 23	219	0.31	115
PBC 066 – 24	178	0.28	94
PBC 066 – 25	169	0.38	86

Continued-

Table 54 cont. Evaluation of somaclones of PBC 066 for fruit length, fruit width and fruit weight

Plant no.	Yield/plant (g)	Seed size (cm)	Seed no.
PBC 066 – 26	165	0.29	80
PBC 066 – 27	187	0.31	89
PBC 066 – 28	193	0.34	84
PBC 066 – 29	230	0.40	93
PBC 066 – 30	156	0.32	95
PBC 066 – 31	148	0.35	88
PBC 066 – 32	168	0.34	95
PBC 066 – 33	210	0.27	99
PBC 066 – 34	228	0.41	100
PBC 066 – 35	196	0.39	101
PBC 066 – 36	162	0.33	92
PBC 066 – 37	145	0.36	94
PBC 066 – 38	138	0.31	95
PBC 066 – 39	145	0.34	112
PBC 066 – 40	152	0.31	110
PBC 066 – 41	159	0.27	115
PBC 066 – 42	178	0.36	120
PBC 066 – 43	213	0.34	115
PBC 066 – 44	221	0.32	93
PBC 066 – 45	174	0.30	89
PBC 066 – 46	163	0.34	95
PBC 066 – 47	189	0.32	94
PBC 066 – 48	198	0.35	93
PBC 066 – 49	211	0.38	86
PBC 066 – 50	213	0.42	85
	SD	Mean	CV%
Fruit yield/plant	26.44	187.98	14.0
Seed size	0.040	0.34	11.7
Seed no.	10.35	95.14	10.8

Colour value (ASTA)

Colour value ranged from 132 – 248ASTA (Table 55). PBC 066 2 (132.45ASTA), PBC 066 11 (132ASTA), PBC 066 26 (132ASTA) and PBC 066 27 (143ASTA) had low colour value. PBC 066 15 (220.05ASTA), PBC 066 16 (213ASTA), PBC 066 49

(211.67ASTA), PBC 066 50 (218.5ASTA), PBC 066 17 (242.16ASTA), PBC 066 35 (224.5ASTA) and PBC 066 36 (231.4 ASTA) had high colour value.

Table 55 Evaluation of somaclones of PBC 066 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
PBC 066 – 1	152.25	PBC 066 – 26	132
PBC 066 – 2	132.45	PBC 066 – 27	143
PBC 066 – 3	154	PBC 066 – 28	168.2
PBC 066 – 4	145.24	PBC 066 – 29	176.3
PBC 066– 5	156.21	PBC 066 – 30	189.5
PBC 066 – 6	160.35	PBC 066 – 31	194.2
PBC 066 – 7	178.4	PBC 066 – 32	145.35
PBC 066 – 8	220.20	PBC 066 – 33	189.5
PBC 066 – 9	200.31	PBC 066 – 34	211.3
PBC 066 – 10	164	PBC 066 – 35	224.5
PBC 066 – 11	132	PBC 066 – 36	231.4
PBC 066 – 12	220.21	PBC 066 – 37	216.14
PBC 066 – 13	156	PBC 066 – 38	213.4
PBC 066 – 14	188.64	PBC 066 – 39	199.35
PBC 066 – 15	200.05	PBC 066 – 40	168.5
PBC 066 – 16	213.6	PBC 066 – 41	176.43
PBC 066 – 17	242.16	PBC 066 – 42	192.3
PBC 066 – 18	189	PBC 066 – 43	188.2
PBC 066 – 19	193	PBC 066 – 44	165.3
PBC 066 – 20	211.142	PBC 066 – 45	153.2
PBC 066 – 21	212.14	PBC 066 – 46	172.34
PBC 066 – 22	184.2	PBC 066 – 47	183.2
PBC 066 – 23	198.1	PBC 066 – 48	198.3
PBC 066 – 24	200.03	PBC 066 – 49	211.67
PBC 066 – 25	167.12	PBC 066 – 50	218.5
	SD	Mean	CV%
Colour value	49.6	140.08	35.4

Evaluation of seedling progeny of somaclones

Evaluation of seedling progeny of somaclones of PBC 385

Morphological characters of somaclones of PBC 385 were observed (Table 56). Variation was found in stem pubescence, plant growth habit, leaf colour, flower position, fruit colour at intermediate stage and fruit shape (Fig. 26). Stem pubescence was dense in 5 plants (10%, Fig. 27,a), intermediate in 18 plants (36%) and sparse/nil in 27 (54%) plants. Plant growth habit was erect in 23 plants (46%) and intermediate in 27 (54%) plants. Leaf colour was green in 24 plants (48%) and dark green in 26 plants (52%). Flower position was pendent in 45 plants (90%) and erect in 5plants (10%). Fruit colour at intermediate stage was green in 23 plants (46%) and dark green in 27 plants (54%). Fruit shape was elongate in 32 plants (64%) and triangular in 18 plants (36%, Fig 27, b and c). Clustering of fruits (8%, Fig. 28,b) and erect fruit habit (10%, Fig 28,c) was observed in some plants

Plant height (cm)

Plant height ranged from 50 (385 8-3) to 83 cm (385 8-20) among the seedling progeny of 385 8 somaclone (Table 57) and ranged from 50 (385 7-9, 385 7-11, 385 7-19) to 85 cm (385 7-12) among the seedling progeny of 385 7 somaclone (Table 58, Fig 29,a).

Days to flower

Days to flower ranged from 39 (385 8-15) to 45 (385 8-4, 385 8-8, 385 8-20) among the seedling progeny of 385 8 somaclone (Table 57) and ranged from 40 (385 7-3, 385 7–4, 385 7-12, 385 7–13, 385 7-14, 385 7-18, 385 7-25) to 46 (385 7-23) among seedling progeny of 385 7 somaclone (Table58).

Table 56 Morphological characters of seedling progeny of somaclones of PBC 385.

Characters	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	5
	intermediate	18
	sparse /nil	27
Plant growth habit	erect	23
	intermediate	27
	compact	0
Branching habit	high	0
	intermediate	50
	sparse	0
Leaf colour	light green	0
	green	24
	dark green	26
Leaf shape	ovate	50
	lanceolate	0
No. of flowers/axil	1	50
	2 and more	0
Flower position	pendent	45
	intermediate	0
	erect	5
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
	sparse	0
Fruit colour at intermediate stage	green	23
	dark green	27
	light green	0
	yellowish green	0
Fruit colour at mature stage	red	0
	dark red	50

Table 56 cont. Morphological characters of seedling progeny of somaclones of PBC 385

Characters	Expression	No. of plants
Fruit shape	elongate	32
	triangular	18
	round	0
	blocky	0
Fruit shape at blossom end	pointed	50
	blunt	0
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

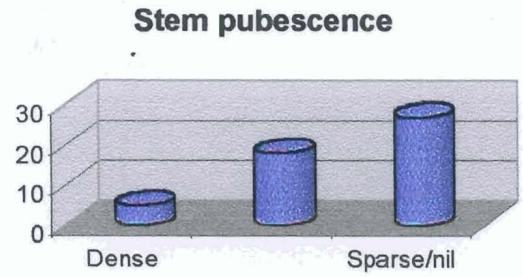
Days to fruit

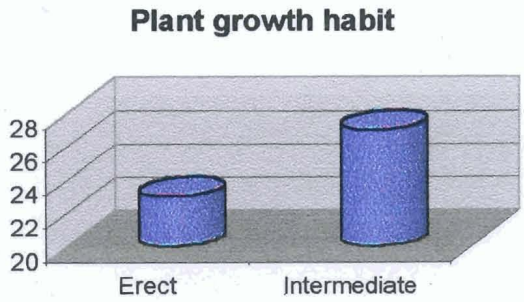
Days to fruit ranged from 51 (385 8-10, 385 8-18, 385 8-23) to 59 (385 8-3) among seedling progeny of 385 8 somaclone (Table57) and ranged from 51 (385 7-12, 385 7-13, 385 7-14) to 59 9(385 7-8) among seedling progeny of 385 7 somaclone (Table 58).

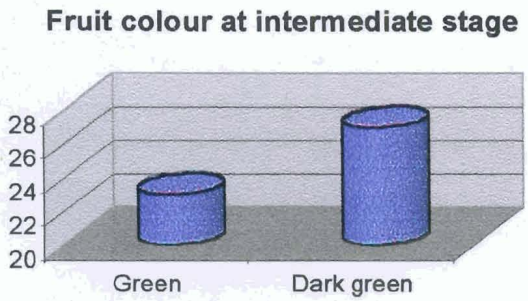
Fruit length (cm)

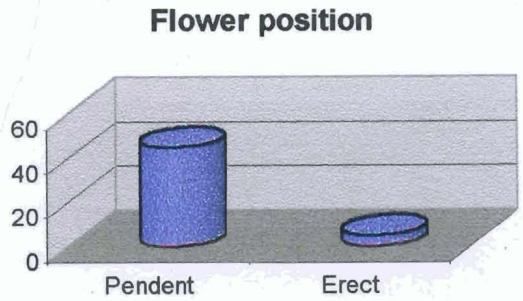
Fruit length ranged from 6.2 (385 8-2) to 14.2cm(385 8-24) among the seedling progeny of somaclone 385 8 (Table 59, Fig. 28 and 29) and ranged from 6.5 (385 7-17) to 9.3cm (385 7-20) among the seedling progeny of somaclone 385 7 (Table 60, Fig.29.b).

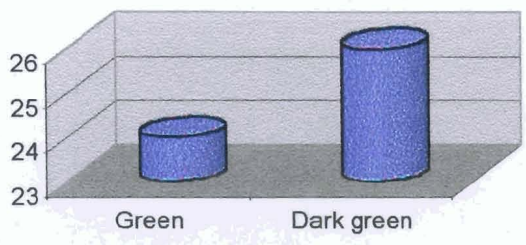
Fig. 26 Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of PBC 385

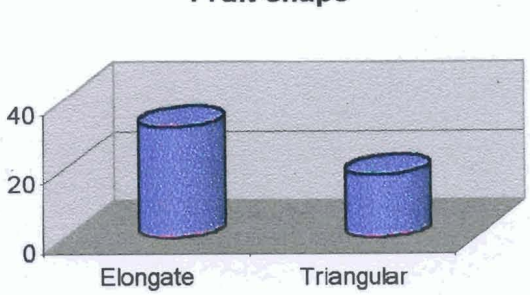






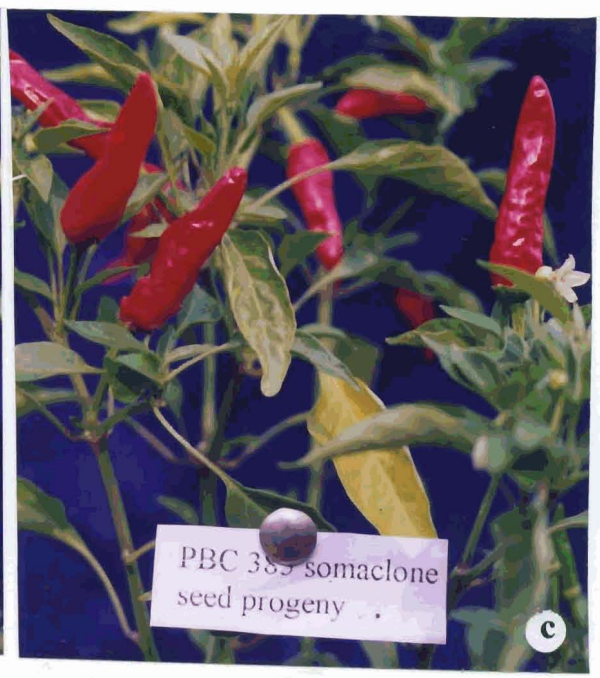


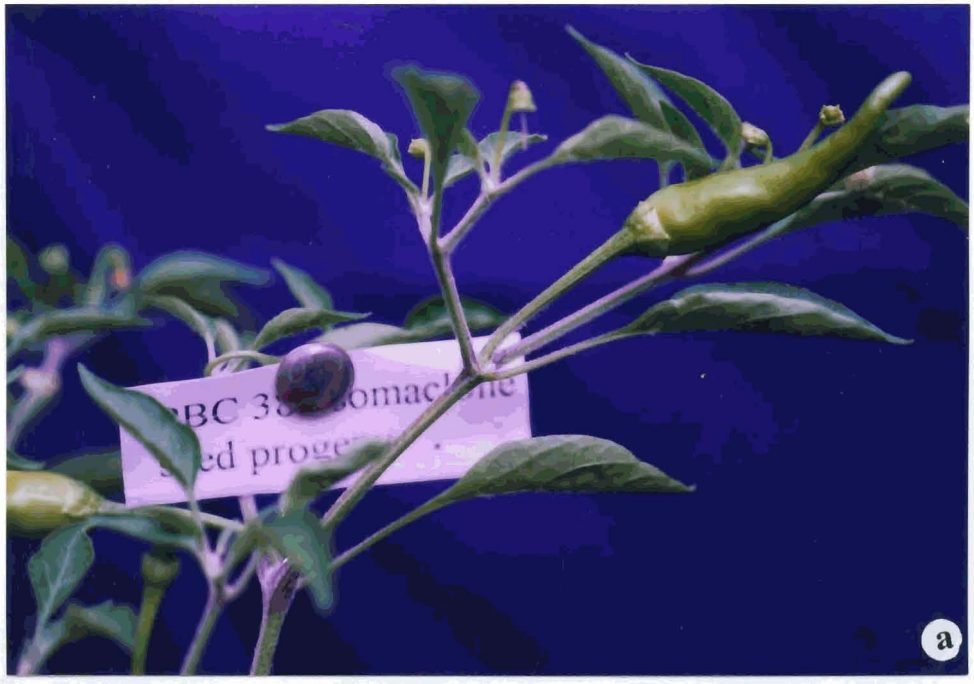





PBC 385
a


PBC 385 somaclone
seed progeny
b


PBC 385 somaclone
seed progeny
c


a


b

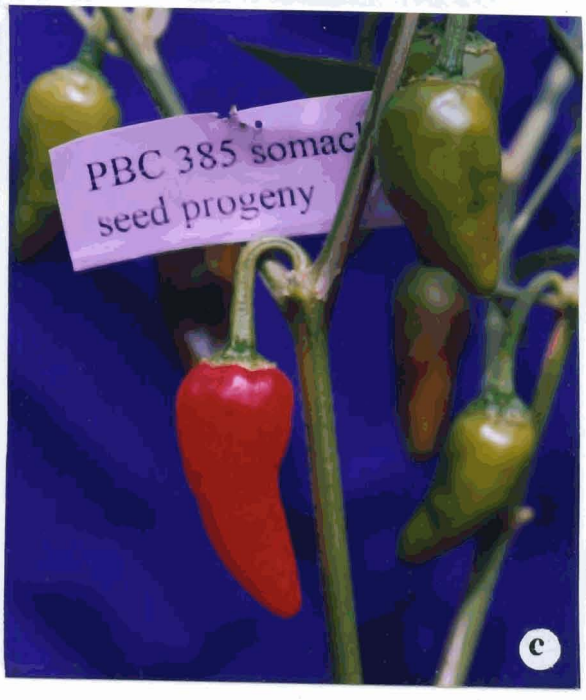
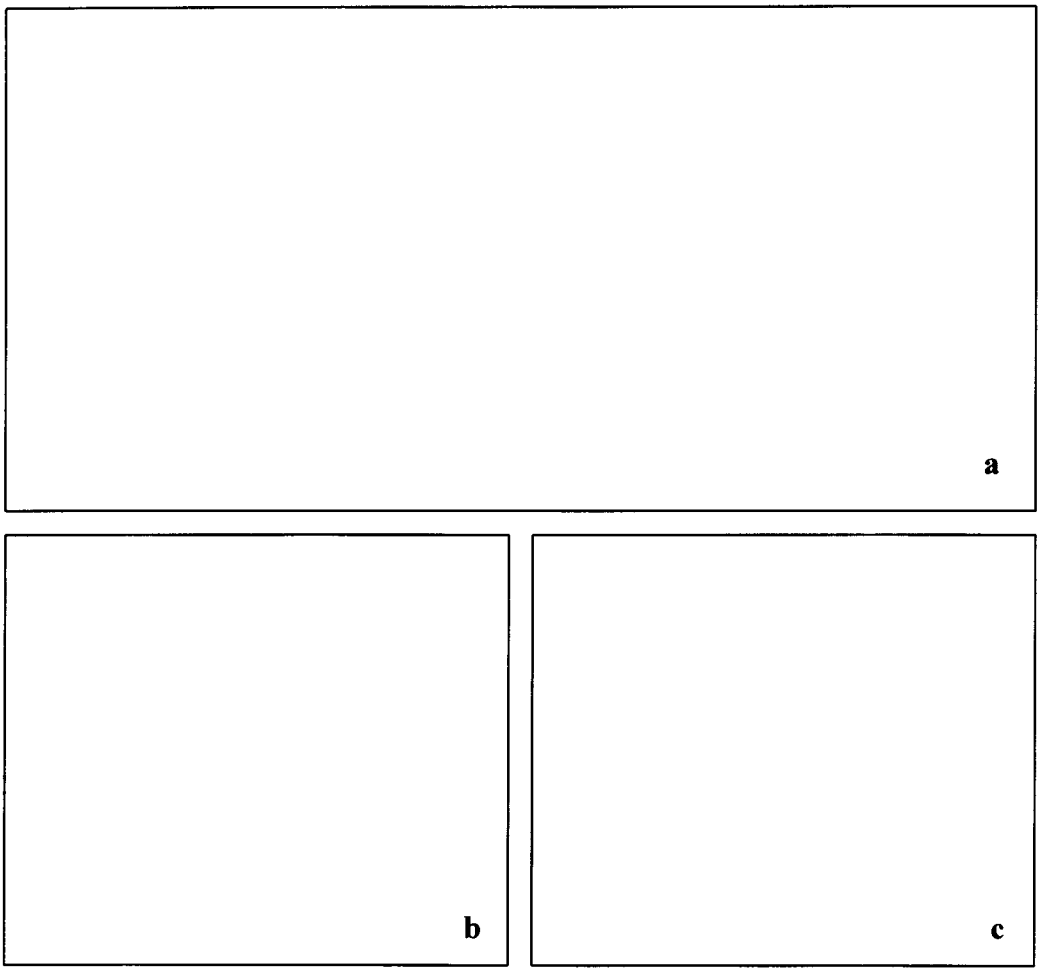

PBC 385 somac
seed progeny
c

Fig. 27 Variations in the somaclone seed progeny of PBC 385.

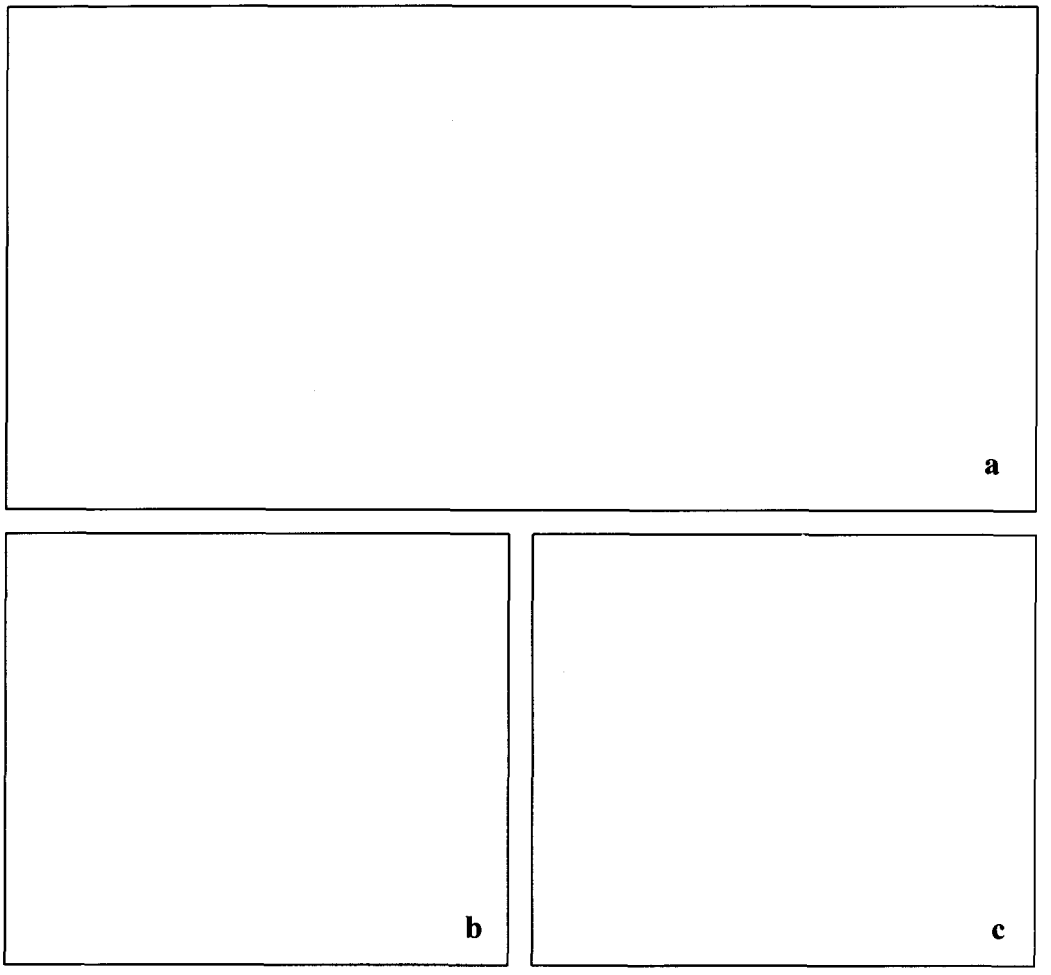


a PBC 385 parent plant showing pendent, elongate fruits.

b PBC 385 somaclone seedling progeny plant showing clustering of fruits.

c PBC 385 somaclone seedling progeny showing short erect fruits.

Fig. 28 Variations in the somaclone seed progeny of PBC 385.



a PBC 385 somaclone seedling progeny showing dense pubescence.

b PBC 385 somaclone seedling progeny showing short triangular fruits.

c PBC 385 somaclone seedling progeny showing short blocky fruits.

Table 57 Evaluation of seedling progeny of somaclones of PBC 385 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
385 8-1	67	40	58
385 8-2	69	43	54
385 8-3	50	44	59
385 8-4	68	45	58
385 8-5	52	40	53
385 8-6	56	41	54
385 8-7	65	43	55
385 8-8	68	45	57
385 8-9	67	42	53
385 8-10	69	42	51
385 8-11	82	41	53
385 8-12	62	40	56
385 8-13	68	41	56
385 8-14	73	40	54
385 8-15	71	39	56
385 8-16	65	43	54
385 8-17	66	41	52
385 8-18	74	40	51
385 8-19	81	46	58
385 8-20	83	45	56
385 8-21	82	42	54
385 8-22	56	42	54
385 8-23	64	40	51
385 8-24	61	40	53
385 8-25	71	45	58
	SD	Mean	CV%
Plant height	8.80	67.96	12.
Days to flowe	2.04	42.0	4.8
Days to fruit	2.164	54.92	3.9

Table 58 Evaluation of seedling progeny of somaclones of PBC 385 for plant height, days to flower and days to fruit

Plant no.	Plant height	Days to flower	Days to fruit
385 7-1	55	44	56
385 7-2	60	43	57
385 7-3	55	40	52
385 7-4	77	40	52
385 7-5	60	41	53
385 7-6	60	42	54
385 7-7	64	45	56
385 7-8	65	47	59
385 7-9	50	44	56
385 7-10	63	43	55
385 7-11	50	42	54
385 7-12	85	40	51
385 7-13	60	40	51
385 7-14	70	40	51
385 7-15	55	44	54
385 7-16	80	42	56
385 7-17	56	41	54
385 7-18	58	40	52
385 7-19	50	42	54
385 7-20	68	42	54
385 7-21	63	45	56
385 7-22	60	45	57
385 7-23	67	46	58
385 7-24	59	43	56
385 7-25	68	40	52
	SD	Mean	CV%
Plant height	8.92	61.92	14.4
Days to flower	2.12	42.44	4.9
Days to fruit	6.60	48.7	13.5

Fruit width (cm)

Fruit width ranged from 1.0 (385 8-9) to 2.22cm(385 8-22) among the seedling progeny of somaclone 385 8 (Table 59) and ranged from 1.1 (385 7-20) to 2.0cm(385 7- 11) among seedling progeny of somaclone 385 7 (Table 60).

Fruit weight (g)

Fruit weight ranged from 1.34 (385 8-17) to 2.91g (385 8-23) among the seedling progeny of somaclone 385 8 (Table 59) and ranged from 1.12 (385 7-11) to 2.68g (385 7-19) among seedling progeny of somaclone 385 7 (Table 60).

Fruit yield/plant (g)

Fruit yield / plant ranged from 98 (385 8-8) to 134g (385 8-6) among seedling progeny of somaclone 385 8 (Table 61) and ranged from 96 (385 7-10) to 125g (385 7-24) among seedling progeny of somaclone 385 7 (Table 62).

Seed size (cm)

Seed size ranged from 0.30 (385 8-13) to 0.40 (385 8-12) among seedling progeny of somaclone 385 8 (Table 61) and ranged from 0.20 (385 7-13) to 0.41cm (385 7-20) among seedling progeny of somaclone 385 7 (Table 62).

Seed number

Seed number ranged from 60 (385 8-24) to 116 (385 8-1) among seedling progeny of somaclone 385 8 (Table 61) and ranged from 50 (385 7-11) to 100 (385 7-15) among seedling progeny of somaclone 385 7 (Table 62).

Table 59 Evaluation of seedling progeny of somaclones of PBC 385 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
385 8-1	13.4	1.2	2.13
385 8-2	6.2	1.5	2.21
385 8-3	13.34	1.3	1.56
385 8-4	14.1	1.2	2.32
385 8-5	10.3	1.1	1.67
385 8-6	13.6	1.2	2.45
385 8-7	11.7	1.3	2.13
385 8-8	14.0	1.3	2.0
385 8-9	10.2	1.0	1.65
385 8-10	11.2	1.3	2.5
385 8-11	8.4	1.3	1.63
385 8-12	9.0	1.1	2.12
385 8-13	13.6	1.2	2.11
385 8-14	12.5	1.5	2.10
385 8-15	13.7	1.22	2.1
385 8-16	10.4	1.56	2.2
385 8-17	12.4	1.54	1.34
385 8-18	11.0	1.38	2.13
385 8-19	12.3	1.72	2.08
385 8-20	13.4	2.08	2.31
385 8-21	12.2	2.01	2.22
385 8-22	11.8	2.22	2.18
385 8-23	10.5	1.67	2.91
385 8-24	14.2	1.21	1.98
385 8-25	12.1	1.13	1.89

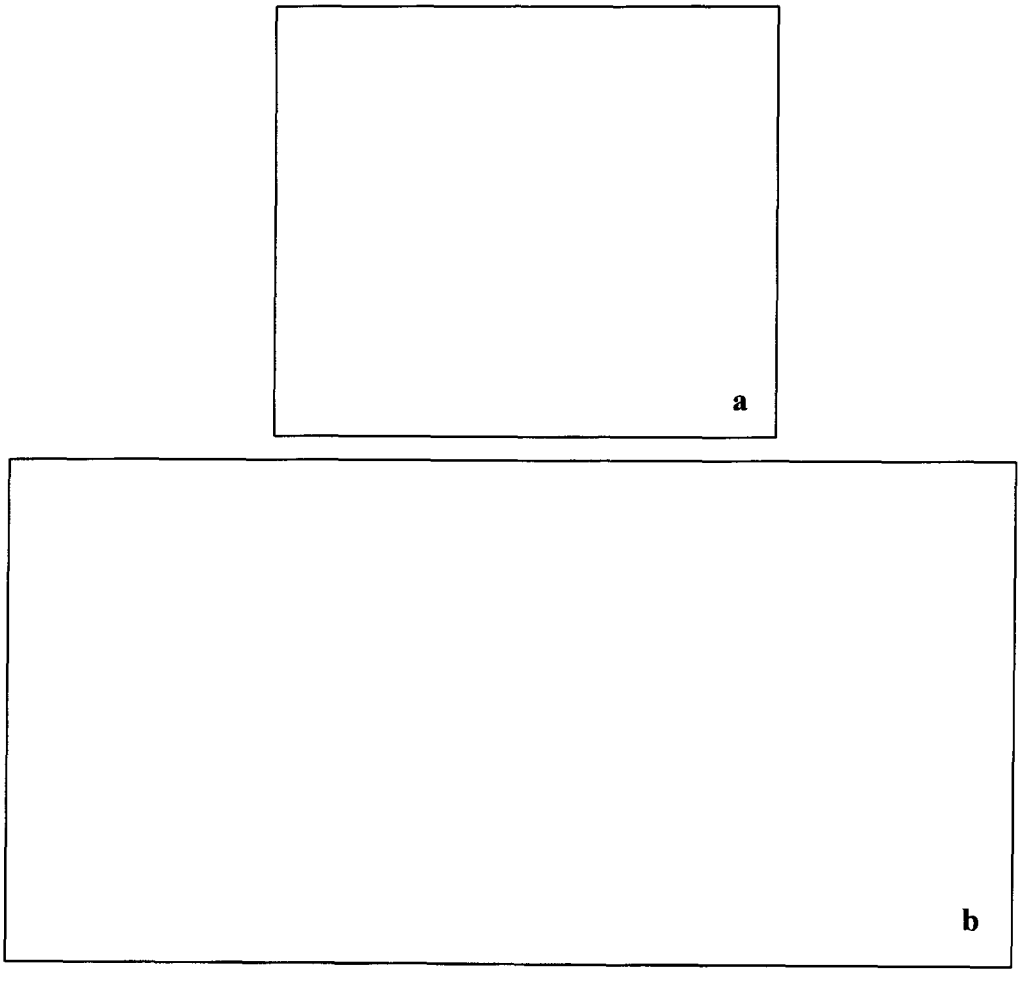
	SD	Mean	CV%
Fruit length	1.99	11.83	16.8
Fruit width	0.307	1.401	21.9
Fruit weight	0.438	1.728	25.3

Table 60 Evaluation of seedling progeny of somaclones of PBC 385 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
385 7-1	9.1	1.3	2.0
385 7-2	14	1.3	2.13
385 7-3	10	1.6	1.45
385 7-4	7.7	1.8	1.89
385 7-5	9	1.8	1.99
385 7-6	8.8	1.4	2.13
385 7-7	9.1	1.2	2.34
385 7-8	8.1	1.1	2.08
385 7-9	8.3	1.3	2.34
385 7-10	9.0	1.9	1.98
385 7-11	7.0	1.7	1.12
385 7-12	8.4	2.0	1.80
385 7-13	8.8	1.7	1.67
385 7-14	9.0	1.5	1.94
385 7-15	7.3	1.7	2.43
385 7-16	9.0	1.3	2.16
385 7-17	6.5	1.4	2.22
385 7-18	12.5	1.3	2.35
385 7-19	8.6	1.6	2.68
385 7-20	9.3	1.1	2.31
385 7-21	8.3	1.2	2.26
385 7-22	8.5	1.3	2.54
385 7-23	8.86	1.4	2.13
385 7-24	6.8	1.6	2.25
385 7-25	7.8	1.5	2.18

	SD	Mean	CV%
Fruit length	1.53	8.80	17.3
Fruit width	0.252	1.487	16.9
Fruit weight	0.334	2.09	15.9

Fig. 29 Variations in the somaclone seed progeny of PBC 385.



a Variation in plant height among the somaclone seedling progeny of PBC 385.

b Variation in fruit length among the seedling progeny of PBC 385.


a


PBC 385 somaclone
seed progeny
b

Table 61 Evaluation of seedling progeny of somaclones of PBC 385 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
385 8-1	128	0.3	116
385 8-2	115	0.32	100
385 8-3	112	0.30	104
385 8-4	123	0.33	101
385 8-5	133	0.30	112
385 8-6	134	0.31	114
385 8-7	126	0.32	103
385 8-8	98	0.30	104
385 8-9	86	0.33	100
385 8-10	84	0.31	113
385 8-11	110	0.30	112
385 8-12	112	0.40	92
385 8-13	98	0.30	98
385 8-14	123	0.32	88
385 8-15	122	0.32	115
385 8-16	112	0.34	114
385 8-17	111	0.35	112
385 8-18	123	0.37	104
385 8-19	112	0.33	113
385 8-20	130	0.30	110
385 8-21	126	0.34	110
385 8-22	120	0.31	100
385 8-23	118	0.34	112
385 8-24	115	0.31	60
385 8-25	110	0.34	65

	SD	Mean	CV%
Yield/plant	13.26	115.4	11.4
Seed size	0.024	0.322	7.7
Seed number	12.12	104.45	11.6

Table 62 Evaluation of seedling progeny of somaclones of PBC 385 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
385 7-1	110	0.30	75
385 7-2	112	0.40	50
385 7-3	123	0.40	54
385 7-4	124	0.40	60
385 7-5	116	0.40	56
385 7-6	118	0.40	55
385 7-7	112	0.35	58
385 7-8	111	0.30	50
385 7-9	98	0.33	50
385 7-10	96	0.30	60
385 7-11	113	0.35	50
385 7-12	115	0.30	52
385 7-13	116	0.20	50
385 7-14	109	0.32	98
385 7-15	106	0.34	100
385 7-16	114	0.32	96
385 7-17	110	0.30	54
385 7-18	88	0.28	52
385 7-19	85	0.40	93
385 7-20	82	0.41	51
385 7-21	116	0.30	76
385 7-22	118	0.31	86
385 7-23	123	0.31	50
385 7-24	125	0.32	84
385 7-25	123	0.36	99

	S.D	Mean	CV%
Yield/plant	12.27	110.5	11.1
Seed size	0.08	0.32	26.4
Seed number	20.9	62.76	33.3

Colour value (ASTA)

Colour value ranged from 84.23 (385 8-15) to 170.34ASTA (385 8-20) among seedling progeny of somaclone 385 8 and ranged from 91.4 (385 7-13) to 168.34 (385 7 7-12) among the seedling progeny of somaclone 385 7 (Table 63).

Table 63 Evaluation of seedling progeny of somaclones of PBC 385 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
385 8-1	156.8	385 7-1	123.56
385 8-2	145.23	385 7-2	135.42
385 8-3	132.34	385 7-3	145.67
385 8-4	110.3	385 7-4	132.23
385 8-5	112.5	385 7-5	116.13
385 8-6	114.56	385 7-6	100.34
385 8-7	123.34	385 7-7	130.45
385 8-8	154.45	385 7-8	128.23
385 8-9	116.76	385 7-9	109.95
385 8-10	123.45	385 7-10	137.5
385 8-11	113.46	385 7-11	170.2
385 8-12	112.46	385 7-12	168.34
385 8-13	108.45	385 7-13	91.4
385 8-14	98.46	385 7-14	112.3
385 8-15	84.23	385 7-15	135.6
385 8-16	123.45	385 7-16	126.45
385 8-17	145.6	385 7-17	82.28
385 8-18	143.6	385 7-18	113.45
385 8-19	168.8	385 7-19	112.46
385 8-20	170.34	385 7-20	145.65
385 8-21	134.6	385 7-21	134.67
385 8-22	135.6	385 7-22	116.53
385 8-23	128.2	385 7-23	135.67
385 8-24	116.8	385 7-24	123.45
385 8-25	112.23	385 7-25	138.67

	SD	Mean	CV%
Colour value (385 8 seedling progeny)	22.36	129.02	17.3
Colour value (385 7 seedling progeny)	18.8	124.9	15.0

Evaluation of seedling progeny of somaclones of PBC 375

Morphological characters of seedling progeny of PBC 375 were observed (Table 64). Variation was found in stem pubescence, plant growth habit, branching habit, leaf

colour, flower position, fruit colour at intermediate stage and fruit shape at blossom end (Fig. 30). Stem pubescence was dense in 5 plants (10%), (Fig. 30, Fig 31 c), and sparse/nil in 45 plants (90%). Plant growth habit was erect in 33 plants (66%) and intermediate in 17 plants (34%). Branching habit was high in 9 plants (18%), intermediate in 20 (40%) and sparse in 21 plants (42%). Leaf colour was light green in 10 plants (20%) and green in 40 plants (80%). Flower position was pendent in 31 plants (62%) and intermediate in 19 plants (38%). Fruit colour at intermediate stage was green in 35 plants (70%) and yellowish green in 15 plants (30%). Fruit shape at blossom end was pointed in 45 plants (90%) and blunt in 5 plants (10%). Clustering of fruits was also observed among 5% of the plants (Fig.31, b).

Plant height (cm)

Plant height ranged from 44 (PBC 375 3-4) to 75cm (PBC 375 3-20) among seedling progeny of somaclone PBC 375 3 (Table 65).

Days to flower

Days to flower ranged from 36 (PBC 375 3-21) to 48 (PBC 375 3-20) among the seedling progeny of somaclone PBC 375 3 (Table 65).

Days to fruit

Days to fruit ranged from 49 (PBC 375 3-21) to 63 (PBC 375 3-20) among the seedling progeny of somaclone PBC 375 3 (Table 65).

Table 64 Morphological characters of seedling progeny of somaclones of PBC 375

Character	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	5
	intermediate	0
	sparse /nil	45
Plant growth habit	erect	33
	intermediate	0
	compact	0
Branching habit	high	9
	intermediate	20
	sparse	21
Leaf colour	light green	10
	green	40
	dark green	0
Leaf shape	ovate	50
	lanceolate	0
No. of flowers/axil	1	50
	2 and more	0
Flower position	pendent	31
	intermediate	19
	erect	0
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
Fruit colour at intermediate stage	green	35
	dark green	0
	light green	0
	yellowish green	15
Fruit colour at mature stage	red	50
	dark red	0

Continued -

Table 64 cont. Morphological characters of seedling progeny of somaclones of PBC 375

Character	Expression	No. of plants
Fruit shape	elongate	50
	triangular	0
	round	0
	blocky	0
Fruit shape at blossom end	pointed	45
	blunt	5
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

Fruit length (cm)

Fruit length ranged from 10.2 (PBC 375 3-1) to 16.2cm (PBC 375 3-14) among the seedling progeny of somaclone PBC 375 3 (Table 66).

Fruit width (cm)

Fruit width ranged from 1.14 (PBC375 3-44) to 2.31cm (PBC 375 3-50) among seedling progeny of somaclone PBC 375 3 (Table 66).

Fruit weight (g)

Fruit weight ranged from 2.2 (375 3-5) to 12.3g (375 3-37) among the seedling progeny of somaclone PBC 375 3 (Table 66).

Fruit yield (g)

Fruit yield ranged from 122 (PBC 375 3-33) to 178g (PBC 375 3-31) among the seedling progeny of somaclone PBC 375 3 (Table 67).

Seed size (cm)

Seed size ranged from 0.20 (PBC 375 3-4) to 0.45cm(PBC 375 3-14) among the seedling progeny of somaclone PBC 375 3 (Table 67).

Seed number

Seed number ranged from 60 (PBC 375 3-33) to 100 (PBC 375 3-43) among seedling progeny of somaclone PBC 375 3 (Table 67).

Colour value (ASTA)

Colour value ranged from 78 (PBC 375 3-3) to 242 ASTA (PBC 375 3-7) among seedling progeny of somaclone PBC 375 3 (Table 68)

Fig. 30 Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of PBC 375

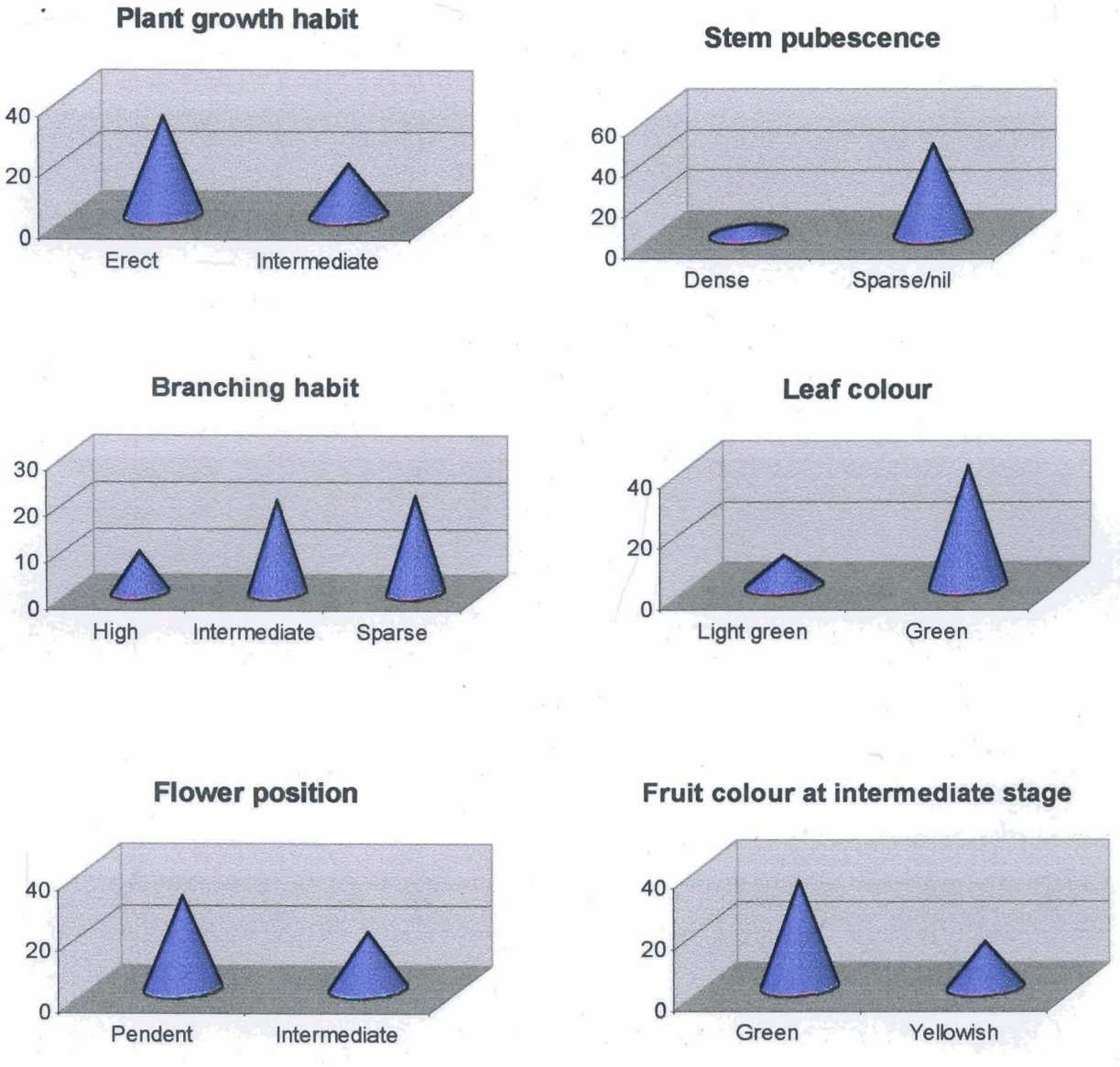
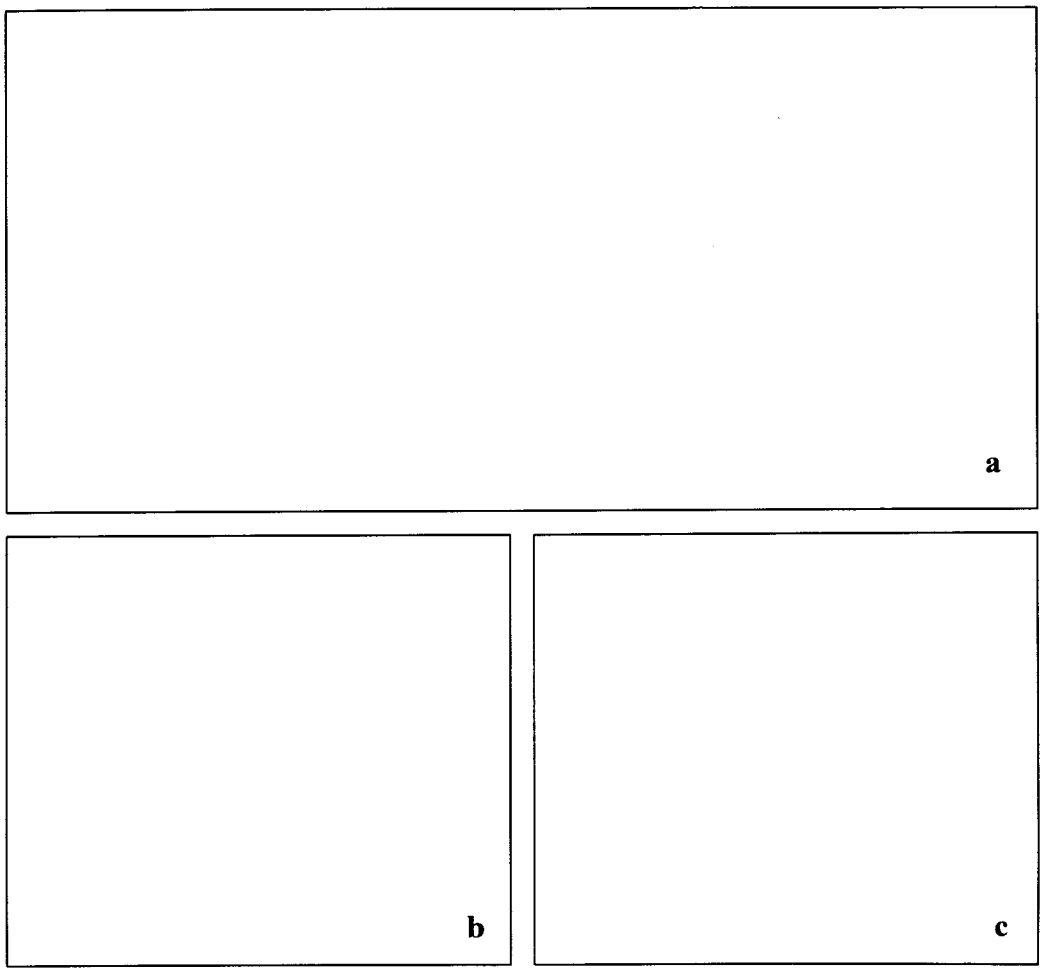


Fig. 31 Variations in the somaclone seed progeny of PBC 375.



a PBC 375 parent plant showing pendent, elongate fruits.

b PBC 375 somaclone seedling progeny plant showing clustering of fruits.

c PBC 375 somaclone seedling progeny showing dense stem pubescence.


a


PBC 375 somaclo
seed progeny
b

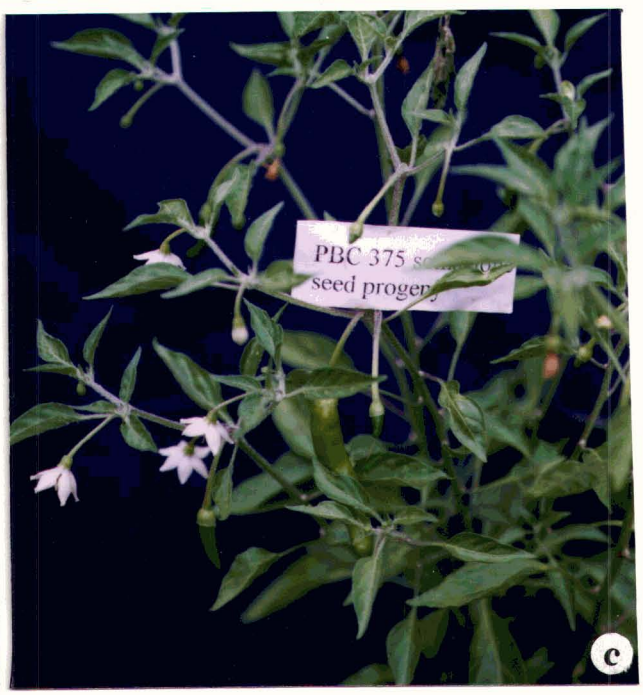

PBC 375
seed proge
c

Table 65 Evaluation of seedling progeny of somaclones of PBC 375 for plant height, days to flower and days to fruit

Plant no.	Plant height	Days to flower	Days to fruit
375 3 – 1	67	39	53
375 3 – 2	60	41	54
375 3 – 3	73	44	56
375 3 – 4	44	42	54
375 3 – 5	54	41	54
375 3 – 6	68	46	59
375 3 – 7	56	41	53
375 3 – 8	72	40	53
375 3 – 9	50	43	56
375 3 – 10	60	41	53
375 3 – 11	65	40	52
375 3 – 12	72	42	54
375 3 – 13	74	45	58
375 3 – 14	65	42	54
375 3 – 15	56	40	53
375 3 – 16	55	44	56
375 3 – 17	46	41	53
375 3 – 18	67	47	59
375 3 –19	69	43	56
375 3 – 20	75	48	63
375 3 – 21	63	36	49
375 3 – 22	62	39	50
375 3 – 23	60	41	54
375 3 – 24	54	40	53
375 3 – 25	52	46	59

Table 65 cont. Evaluation of seedling progeny of somaclones of PBC 375 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
375 3 – 26	68	35	48
375 3 – 27	73	38	50
375 3 – 28	71	48	60
375 3 – 29	66	46	58
375 3 – 30	63	43	55
375 3 – 31	58	39	53
375 3 – 32	55	42	55
375 3 – 33	52	44	58
375 3 – 34	61	48	59
375 3 – 35	60	46	58
375 3 – 36	57	43	54
375 3 – 37	53	41	54
375 3 – 38	51	49	60
375 3 – 39	65	46	57
375 3 – 40	63	42	56
375 3 – 41	62	41	54
375 3 – 42	69	36	49
375 3 – 43	64	39	53
375 3 – 44	61	40	53
375 3 – 45	67	42	54
375 3 – 46	61	44	58
375 3 – 47	73	42	56
375 3 – 48	52	43	55
375 3 – 49	69	44	58
375 3 – 50	74	44	56
	SD	Mean	CV%
Plant height	8.82	61.56	14.3
Days to flower	10.73	39	27.5
Days to fruit	3.17	54.7	5.7

Table 66 Evaluation of seedling progeny of somaclones of PBC 375 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
375 3 – 1	10.2	1.3	2.8
375 3 – 2	12.5	1.2	2.2
375 3 – 3	10.8	1.2	3.1
375 3 – 4	11.3	1.4	2.5
375 3 – 5	11.5	1.3	2.2
375 3 – 6	12.2	2.0	3.21
375 3 – 7	13.5	1.2	3.56
375 3 – 8	15.4	2.2	3.67
375 3 – 9	11.5	2.0	10.78
375 3 – 10	7.6	1.4	4.67
375 3 – 11	12.0	1.8	4.45
375 3 – 12	13.5	1.8	6.6
375 3 – 13	12.5	1.7	3.57
375 3 – 14	16.2	2.0	3.68
375 3 – 15	14.0	2.2	5.12
375 3 – 16	14.0	1.8	5.68
375 3 – 17	13.0	1.2	7.34
375 3 – 18	13.2	1.2	4.78
375 3 –19	14.5	1.9	5.63
375 3 – 20	12.5	1.2	5.34
375 3 – 21	15.3	1.3	6.03
375 3 – 22	11.5	1.5	4.68
375 3 – 23	16.1	1.3	7.23
375 3 – 24	12.4	1.3	5.34
375 3 – 25	14.3	1.3	7.68

Table 66 cont. Evaluation of seedling progeny of somaclones of PBC 375 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
375 3 – 26	12.45	1.4	3.2
375 3 – 27	10.34	2.2	4.5
375 3 – 28	14.56	2.1	5.2
375 3 – 29	11.34	1.34	7.3
375 3 – 30	16.12	1.56	8.5
375 3 – 31	11.67	1.46	6.8
375 3 – 32	12.34	1.42	3.6
375 3 – 33	13.25	1.50	4.5
375 3 – 34	10.45	1.63	3.6
375 3 – 35	12.34	1.72	4.2
375 3 – 36	15.34	1.63	6.9
375 3 – 37	11.45	1.72	12.3
375 3 – 38	14.23	1.83	10.45
375 3 – 39	12.45	1.64	5.67
375 3 – 40	13.23	1.43	8.45
375 3 – 41	11.94	1.25	7.23
375 3 – 42	10.26	2.22	5.61
375 3 – 43	13.24	2.1	4.67
375 3 – 44	14.56	1.14	5.86
375 3 – 45	13.28	1.43	8.63
375 3 – 46	14.67	1.32	5.67
375 3 – 47	12.13	1.20	8.40
375 3 – 48	11.56	2.35	4.64
375 3 – 49	13.24	2.06	3.68
375 3 – 50	12.45	2.31	5.63
	SD	Mean	CV%
Fruit length	1.71	12.8	13.3
Fruit width	36.1	1.63	22.14
Fruit weight	2.32	5.68	40.8

Table 67 Evaluation of seedling progeny of somaclones of PBC 375 for fruit yield/plant, seed size and seed number

Plant no.	Fruit yield / plant (g)	Seed size (cm)	Seed no.
375 3 – 1	164	0.34	78
375 3 – 2	166	0.25	63
375 3 – 3	154	0.30	68
375 3 – 4	173	0.20	72
375 3 – 5	183	0.30	78
375 3 – 6	145	0.40	86
375 3 – 7	123	0.30	93
375 3 – 8	134	0.40	74
375 3 – 9	156	0.40	70
375 3 – 10	147	0.32	78
375 3 – 11	149	0.43	82
375 3 – 12	168	0.38	88
375 3 – 13	164	0.35	84
375 3 – 14	149	0.45	64
375 3 – 15	143	0.38	86
375 3 – 16	129	0.40	93
375 3 – 17	139	0.38	81
375 3 – 18	140	0.35	86
375 3 –19	153	0.36	93
375 3 – 20	152	0.42	67
375 3 – 21	136	0.32	63
375 3 – 22	147	0.36	64
375 3 – 23	143	0.41	65
375 3 – 24	132	0.40	61
375 3 – 25	162	0.46	64

Table 67 cont. Evaluation of seedling progeny of somaclones of PBC 375 for yield/plant, seed size and seed number

Plant no.	Fruit yield /plant (g)	Seed size (cm)	Seed no.
375 3 – 26	145	0.32	75
375 3 – 27	125	0.34	72
375 3 – 28	165	0.42	74
375 3 – 29	157	0.28	70
375 3 – 30	168	0.29	69
375 3 – 31	178	0.32	73
375 3 – 32	123	0.33	71
375 3 – 33	122	0.38	60
375 3 – 34	146	0.32	62
375 3 – 35	158	0.39	64
375 3 – 36	168	0.31	61
375 3 – 37	159	0.26	83
375 3 – 38	165	0.29	85
375 3 – 39	154	0.38	89
375 3 – 40	143	0.36	86
375 3 – 41	153	0.37	92
375 3 – 42	163	0.31	98
375 3 – 43	175	0.34	100
375 3 – 44	149	0.34	85
375 3 – 45	152	0.32	94
375 3 – 46	143	0.36	93
375 3 – 47	154	0.38	75
375 3 – 48	143	0.37	81
375 3 – 49	142	0.31	88
375 3 – 50	136	0.30	84
	SD	Mean	CV%
Fruit yield/plant	15.04	152.8	9.8
Seed size	0.072	0.339	21.2
Seed number	11.48	77.48	14.8

Table 68 Evaluation of seedling progeny of somaclones of PBC 375 for colour value

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
375 3 – 1	113.4	375 3 – 26	145.54
375 3 – 2	127.7	375 3 – 27	136.23
375 3 – 3	78.45	375 3 – 28	98.45
375 3 – 4	122.5	375 3 – 29	179.48
375 3 – 5	138.23	375 3 – 30	200.34
375 3 – 6	159.67	375 3 – 31	234.13
375 3 – 7	242.5	375 3 – 32	240.65
375 3 – 8	119.4	375 3 – 33	156.30
375 3 – 9	123.45	375 3 – 34	143.23
375 3 – 10	135.67	375 3 – 35	142.30
375 3 – 11	115.67	375 3 – 36	110.50
375 3 – 12	86.45	375 3 – 37	96.34
375 3 – 13	98.23	375 3 – 38	134.5
375 3 – 14	93.41	375 3 – 39	189.34
375 3 – 15	124.6	375 3 – 40	192.68
375 3 – 16	110.45	375 3 – 41	213.46
375 3 – 17	124.56	375 3 – 42	225.64
375 3 – 18	138.94	375 3 – 43	167.82
375 3 –19	168.98	375 3 – 44	175.30
375 3 – 20	176.34	375 3 – 45	165.23
375 3 – 21	156.8	375 3 – 46	214.70
375 3 – 22	143.23	375 3 – 47	122.5
375 3 – 23	125.6	375 3 – 48	87.65
375 3 – 24	112.5	375 3 – 49	113.40
375 3 – 25	145.6	375 3 – 50	127.8
	SD	Mean	CV%
	48.9	140.9	34.06

Evaluation of somaclones of PBC 066

Morphological characters of seedling progeny of PBC066 were observed (Table 69). Variation was observed in plant growth habit, branching habit, leaf colour, stigma exsertion, and fruit colour at intermediate stage (Fig.32). Plant growth habit was erect in 31 plants (62%), intermediate in 9 plants (18%) and compact in 10 plants (20%). Branching habit was intermediate in 26 plants (52%) and sparse in 24 plants (48%).

Leaf colur was light in 6 plants (12%0 and green in 44 plants (88%). Stigma was exserted in 47 plants (94%) and inserted in 3 plants (6%). Fruit colour at intermediate stage was green in 41 plants (82%), dark green in 6 plants (12%) and light green in 3 plants (6%). Fruit shape at blosssom end was pointed in 46 plants (92%) and blunt in 4 plants (8%).

Table 69 Morphological characters of seedling progeny of somaclones of PBC 066.

Characters	Expression	No .of plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	0
	sparse /nil	50
Plant growth habit	erect	31
	intermediate	9
	compact	10
Branching habit	high	0
	intermediate	26
	sparse	24
Leaf colour	light green	6
	green	44
	dark green	0
Leaf shape	ovate	50
	lanceolate	0
No.of flowers/axil	1	50
	2 and more	0
Flower position	pendent	50
	intermediate	0
	erect	0
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	47
	same level	0
	inserted	3
Calyx margin	dentate	0
	intermediate	50
Fruit colour at intermediate stage	green	41
	dark green	6
	light green	3
	yellowish green	0
Fruit colour at mature stage	red	50
	dark red	0

Table 69 cont. Morphological characters of seedling progeny of somaclones of PBC 066

Characters	Expression	No. of plants
Fruit shape	elongate	50
	triangular	0
	round	0
	blocky	0
Fruit shape at blossom end	pointed	46
	blunt	4
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

Plant height (cm)

Plant height ranged from 42 (PBC 066 1-34) to 83cm (PBC 066 1-41) among the seedling progeny of somaclone PBC 0661 (Table 70, Fig. 33, b).

Days to flower

Days to flower ranged from 33 (PBC 066-17) to 50 (PBC 066-14) among the seedling progeny of somaclone PBC 066 1 (Table 70).

Days to fruit

Days to fruit ranged from 46 (PBC 066 1-6 and PBC 066 1-17) to 63 (PBC 0661-38) among the seedling progeny of somaclone PBC 0661 (Table 70).

Fig. 32 – Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of PBC 066

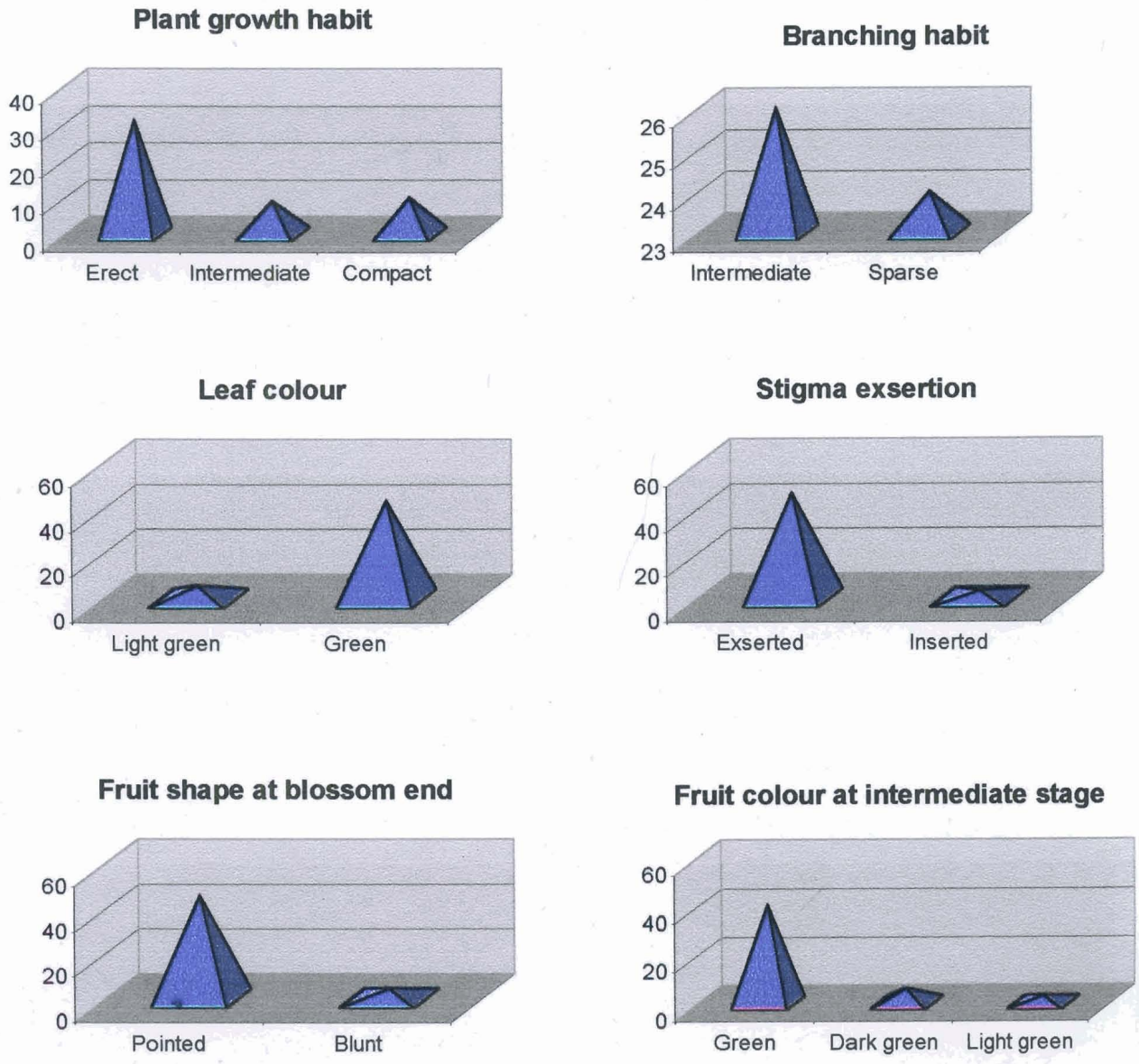


Table 70 Evaluation of seedling progeny of somaclones of PBC 066 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
066 1 – 1	60	34	47
066 1 – 2	53	36	49
066 1 – 3	63	39	50
066 1 – 4	52	43	56
066 1 – 5	67	40	53
066 1 – 6	55	44	46
066 1 – 7	69	41	53
066 1 – 8	43	48	62
066 1 – 9	71	38	52
066 1 – 10	42	39	54
066 1 – 11	71	38	53
066 1 – 12	46	45	57
066 1 – 13	60	46	59
066 1 – 14	60	50	62
066 1 – 15	53	42	54
066 1 – 16	44	35	47
066 1 – 17	60	33	46
066 1 – 18	58	36	49
066 1 – 19	63	45	59
066 1 – 20	47	46	58
066 1 – 21	71	49	62
066 1 – 22	60	43	56
066 1 – 23	56	39	53
066 1 – 24	48	43	55
066 1 – 25	62	41	52

Table 70 cont. Evaluation of seedling progeny of somaclones of PBC 066 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
066 1 – 26	58	36	49
066 1 – 27	60	45	58
066 1 – 28	63	48	61
066 1 – 29	74	38	53
066 1 – 30	56	39	54
066 1 – 31	52	40	53
066 1 – 32	48	42	54
066 1 – 33	71	43	55
066 1 – 34	42	39	52
066 1 – 35	46	38	52
066 1 – 36	60	37	49
066 1 – 37	55	45	58
066 1 – 38	63	48	63
066 1 – 39	54	49	60
066 1 – 40	73	46	58
066 1 – 41	83	49	50
066 1 – 42	72	39	51
066 1 – 43	56	42	54
066 1 – 44	62	47	59
066 1 – 45	54	44	57
066 1 – 46	56	43	54
066 1 – 47	53	39	50
066 1 – 48	69	36	48
066 1 – 49	65	43	58
066 1 – 50	69	45	58
	SD	Mean	CV%
Plant height	9.643	58.5	16.4
Days to flower	11.2	50.5	22.4
Days to fruit	4.108	54.72	7.5

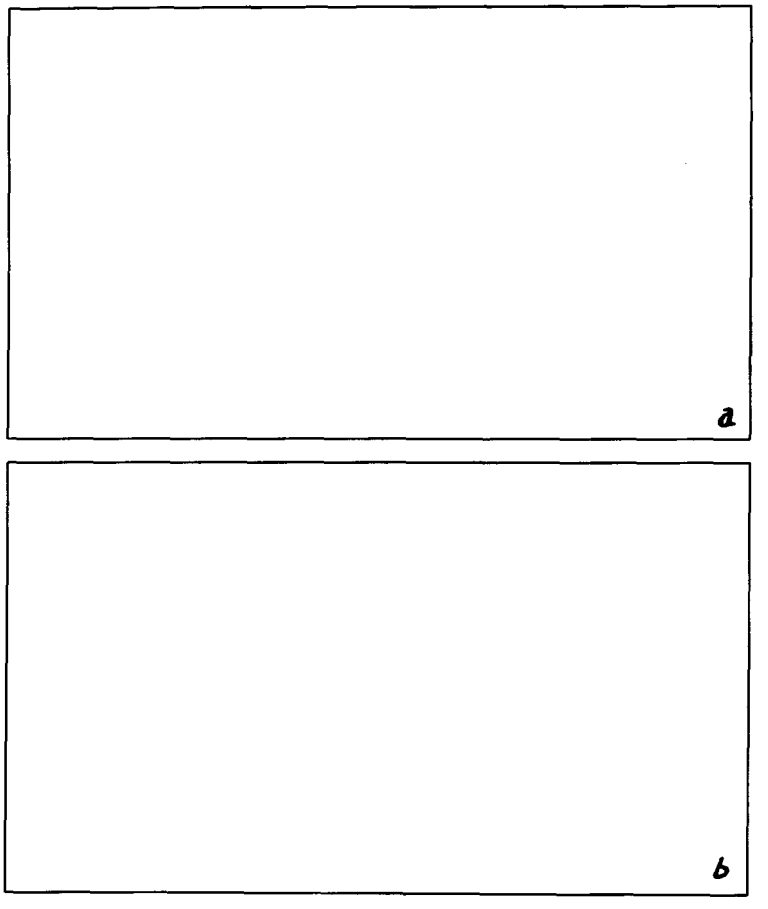
Fruit length (cm)

Fruit length ranged from 12.0 (PBC 066 1) to 16.0cm (PBC 066 1- 4, PBC 0661-11) among the seedling progeny of somaclone PBC 066 1 (Table 71).

Fruit width (cm)

Fruit width ranged from 0.88 (PBC 066 1-31) to 2.56cm (PBC 066 1-33) among the seedling progeny of somaclone PBC 066 1 (Table 71).

Fig. 33 Variations in the somaclone seed progeny of PBC 066.



a PBC 066 parent plant showing pendent fleshy fruits.

b Variation in plant height among the seedling progeny of PBC 066.


PBC 066
a


b

Fruit weight (g)

Fruit weight ranged from 2.60 (PBC 0661-12) to 10.34g (PBC 0661-49) among the seedling progeny of somaclone PBC 0661 (Table 71).

Table 71 Evaluation of seedling progeny of somaclones of PBC 066 for fruit length, fruit width and fruit weight.

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
066 1 – 1	12.0	1.80	7.30
066 1 – 2	14.5	1.70	5.54
066 1 – 3	13.0	1.80	5.43
066 1 – 4	16.0	2.5	3.74
066 1 – 5	12.2	2.2	6.60
066 1 – 6	12.0	2.0	6.12
066 1 – 7	14.0	2.0	7.1
066 1 – 8	14.2	2.0	9.0
066 1 – 9	13.0	2.2	10.2
066 1 – 10	14.5	2.5	5.54
066 1 – 11	16.0	2.5	6.90
066 1 – 12	12.2	1.9	2.60
066 1 – 13	13.1	1.9	6.40
066 1 – 14	14.0	2.0	6.60
066 1 – 15	13.4	2.1	8.30
066 1 – 16	12.5	2.3	3.40
066 1 – 17	13.7	2.4	8.31
066 1 – 18	14.6	1.8	8.34
066 1 – 19	12.8	2.1	8.80
066 1 – 20	11.6	1.8	9.10
066 1 – 21	13.1	1.8	8.50
066 1 – 22	14.2	2.3	8.60
066 1 – 23	13.6	1.4	7.30
066 1 – 24	12.6	1.2	7.90
066 1 – 25	13.1	1.1	8.50

Table 71 cont. Evaluation of seedling progeny of somaclones of PBC 066 for fruit length, fruit length and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
066 1 – 26	12.3	1.6	8.60
066 1 – 27	13.0	1.47	10.2
066 1 – 28	11.5	1.34	9.23
066 1 – 29	14.0	1.30	9.45
066 1 – 30	12.1	1.20	8.56
066 1 – 31	11.5	0.88	6.40
066 1 – 32	13.2	1.56	8.20
066 1 – 33	9.8	2.56	7.56
066 1 – 34	12.1	3.45	9.45
066 1 – 35	10.3	2.35	8.23
066 1 – 36	13.10	1.45	7.87
066 1 – 37	9.96	3.20	8.67
066 1 – 38	11.34	4.10	9.23
066 1 – 39	10.50	3.20	9.76
066 1 – 40	9.50	2.10	8.43
066 1 – 41	13.10	1.76	10.25
066 1 – 42	11.50	1.56	8.46
066 1 – 43	10.40	2.34	9.45
066 1 – 44	12.56	2.10	8.54
066 1 – 45	11.34	1.89	7.56
066 1 – 46	13.20	1.34	6.85
066 1 – 47	10.35	1.20	8.23
066 1 – 48	13.24	2.13	9.12
066 1 – 49	10.68	1.89	10.34
066 1 – 50	12.65	1.45	9.86
	SD	Mean	CV%
Fruit length	1.41	12.75	11.1
Fruit breadth	0.526	1.89	27.8
Fruit weight	1.718	7.883	21.8

Yield/plant (g)

Yield/plant ranged from 143 (PBC 066 1-20) to 256g (PBC 066 1-43) among the seedling progeny of somaclone PBC 066 1(Table 72).

Seed size (cm)

Seed size ranged from 0.27 (PBC 066 1-50) to 0.42cm (PBC 0661-37) among the seedling progeny of somaclone PBC 066 1 (Tables 72).

Seed number

Seed number ranged from 76 (PBC 066 1-36) to 129 (PBC 066 1-6) among the seedling progeny of somaclone PBC 066 1 (Table 72).

Table 72 Evaluation of seedling progeny of somaclones of PBC 066 for yield / plant, seed size and seed number

Plant no.	Yield / plant (g)	Seed size (cm)	Seed no.
066 1 – 1	156.5	0.40	110
066 1 – 2	210.45	0.34	111
066 1 – 3	185.67	0.38	100
066 1 – 4	200.12	0.35	123
066 1 – 5	230.10	0.40	105
066 1 – 6	175.80	0.36	129
066 1 – 7	180.00	0.40	114
066 1 – 8	191.90	0.30	100
066 1 – 9	168.34	0.32	118
066 1 – 10	201.62	0.30	123
066 1 – 11	167.69	0.35	120
066 1 – 12	187.00	0.39	119
066 1 – 13	156.34	0.36	112
066 1 – 14	145.32	0.33	119
066 1 – 15	213.23	0.36	114
066 1 – 16	176.34	0.31	120
066 1 – 17	193.12	0.42	100
066 1 – 18	165.20	0.40	112
066 1 – 19	150.13	0.40	100
066 1 – 20	143.21	0.30	110
066 1 – 21	230.45	0.40	107
066 1 – 22	196.46	0.38	112
066 1 – 23	167.34	0.36	100
066 1 – 24	154.12	0.32	112
066 1 – 25	172.21	0.41	113

Table 72 cont. Evaluation of seedling progeny of somaclones of PBC 066 for yield / plant, seed size and seed number

Plant no.	Yield / plant (g)	Seed size (cm)	Seed no.
066 1 – 26	212.00	0.31	98
066 1 – 27	154.67	0.40	86
066 1 – 28	187.56	0.40	100
066 1 – 29	145.43	0.38	112
066 1 – 30	163.25	0.36	96
066 1 – 31	172.38	0.38	95
066 1 – 32	185.65	0.35	85
066 1 – 33	198.36	0.31	89
066 1 – 34	211.45	0.38	108
066 1 – 35	213.46	0.37	110
066 1 – 36	201.13	0.42	76
066 1 – 37	185.12	0.41	88
066 1 – 38	173.21	0.41	89
066 1 – 39	125.65	0.30	100
066 1 – 40	200.00	0.33	113
066 1 – 41	219.58	0.36	112
066 1 – 42	243.54	0.35	114
066 1 – 43	256.31	0.30	115
066 1 – 44	251.63	0.35	120
066 1 – 45	186.40	0.33	118
066 1 – 46	165.20	0.29	120
066 1 – 47	154.20	0.30	113
066 1 – 48	168.98	0.31	116
066 1 – 49	150.32	0.30	100
066 1 – 50	138.45	0.27	115
	SD	Mean	CV%
Yield/plant	29.8	183.6	16.2
Seed size	0.081	0.33	24.5
Seed number	12.8	103.52	12.3

Colour value (ASTA)

Colour value ranged from 121.35 (PBC 066 1- 48) to 224.60 ASTA (PBC 066 1- 8) among the seedling progeny of PBC 066 1(Table 73).

Table 73 Evaluation of seedling progeny of somaclones of PBC 066 for colour value.

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
066 1 – 1	131.67	066 1 – 26	148.76
066 1 – 2	156.78	066 1 – 27	153.27
066 1 – 3	167.45	066 1 – 28	161.23
066 1 – 4	123.89	066 1 – 29	153.21
066 1 – 5	200.13	066 1 – 30	142.18
066 1 – 6	163.1	066 1 – 31	162.31
066 1 – 7	154.23	066 1 – 32	135.80
066 1 – 8	224.60	066 1 – 33	123.45
066 1 – 9	122.32	066 1 – 34	146.66
066 1 – 10	202.13	066 1 – 35	165.32
066 1 – 11	124.56	066 1 – 36	122.31
066 1 – 12	220.9	066 1 – 37	121.45
066 1 – 13	134.56	066 1 – 38	152.13
066 1 – 14	146.78	066 1 – 39	153.16
066 1 – 15	153.20	066 1 – 40	169.21
066 1 – 16	162.34	066 1 – 41	183.56
066 1 – 17	111.44	066 1 – 42	193.45
066 1 – 18	153.23	066 1 – 43	155.67
066 1 – 19	142.57	066 1 – 44	168.13
066 1 – 20	137.89	066 1 – 45	123.14
066 1 – 21	142.13	066 1 – 46	156.12
066 1 – 22	155.68	066 1 – 47	162.31
066 1 – 23	172.34	066 1 – 48	121.35
066 1 – 24	152.13	066 1 – 49	137.89
066 1 – 25	140.16	066 1 – 50	143.18
	SD	Mean	CV%
Colour value	32.3	151.4	21.35

Evaluation of seedling progeny of somaclones of PBC 535

Morphological characters of seedling progeny of somaclones of PBC 535 were observed (Table 74). Variation was found in branching habit, leaf colour and fruit colour at intermediate stage (Fig.34). Branching habit was high in 4 plants (8%), intermediate in 38 plants (76%) and sparse in 8 plants (16%). Leaf colour was light green in 4 plants (8%), green in 38 plants (76%) and dark green in 8 plants (16%). Fruit colour at intermediate stage was green in 31 plants (62%), dark green in 15 plants

(30%) and yellowish green in 4 plants (8%). Fruit was erect in 5% of the plants (Fig.35, c).

Table 74 Morphological characters of seedling progeny of somaclones of PBC 535.

Characters	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	0
	sparse /nil	50
Plant growth habit	erect	50
	intermediate	0
	compact	0
Branching habit	high	4
	intermediate	38
	sparse	8
Leaf colour	light green	4
	green	38
	dark green	8
Leaf shape	ovate	0
	lanceolate	50
No. of flowers/ axil	1	50
	2and more	0
Flower position	pendent	50
	intermediate	0
	erect	0
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
Fruit colour at intermediate stage	green	31
	dark green	25
	light green	0
	yellowish green	4
Fruit colour at mature stage	red	50
	dark red	0

Table 74 cont. Morphological characters of seedling progeny of somaclones of PBC 535

Characters	Expression	No. of plants
Fruit shape	elongate	50
	triangular	0
	round	0
	blocky	0
Fruit shape at blossom end	pointed	50
	blunt	0
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

Plant height (cm)

Plant height ranged from 40 (PBC 535 6-2) to 68 cm (PBC 535 6-15) among the seedling progeny of somaclone PBC 535 6 (Table 75, Fig.35, b).

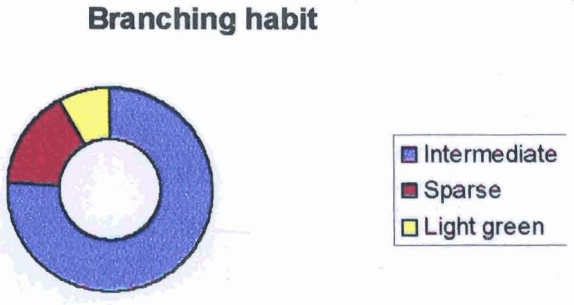
Days to flower

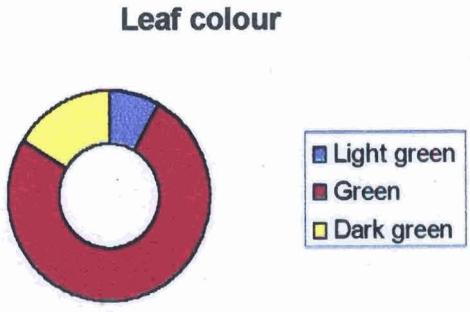
Days to flower ranged from 31 (PBC 535 6-38) to 54 (PBC 535 6-40) among the seedling progeny of somaclone PBC 535 6 (Table 75).

Days to fruit

Days to fruit ranged from 44 (PBC 535 6-38) to 65 (PBC 535 6-40) among the seedling progeny of somaclone PBC 535 6 (Table 75).

Fig.34 Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of PBC 535





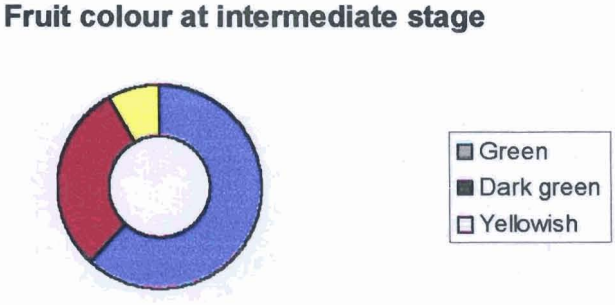


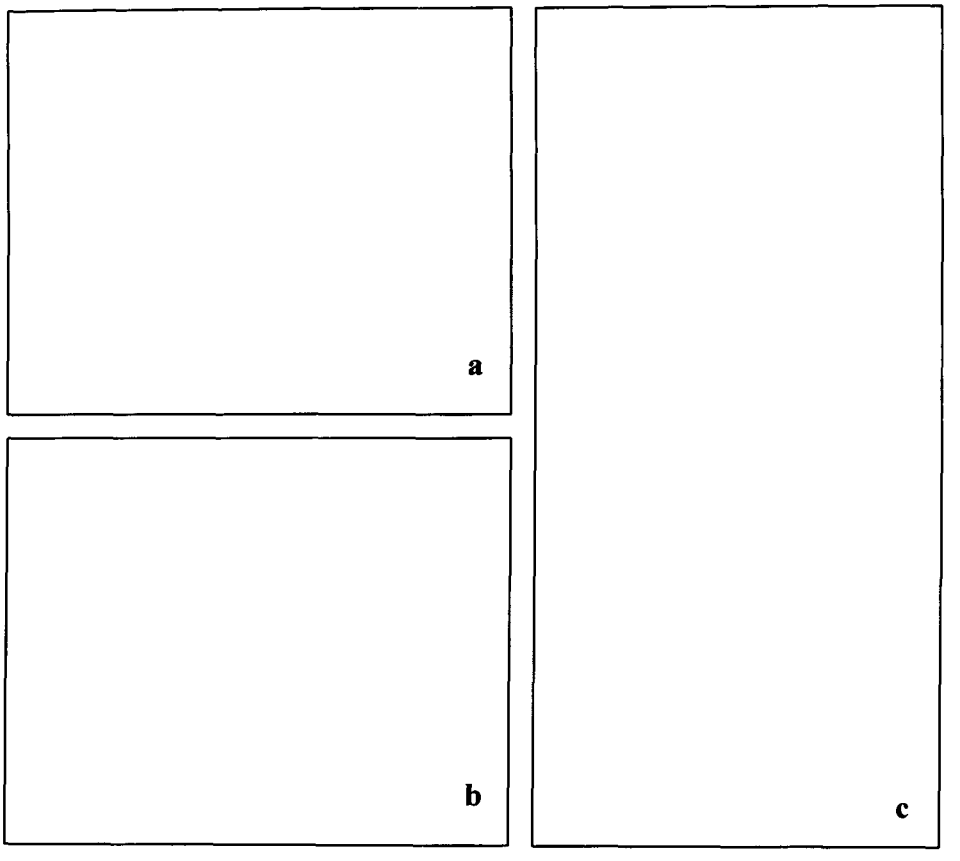
Table 75 Evaluation of seedling progeny of somaclones of PBC 535 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
535 6 – 1	65	44	57
535 6 – 2	40	45	59
535 6 – 3	60	41	53
535 6 – 4	50	43	55
535 6 – 5	60	52	65
535 6 – 6	50	45	58
535 6 – 7	55	38	52
535 6 – 8	63	38	52
535 6 – 9	45	43	55
535 6 – 10	47	52	65
535 6 – 11	47	46	58
535 6 – 12	49	42	55
535 6 – 13	54	41	54
535 6 – 14	67	40	53
535 6 – 15	68	48	60
535 6 – 16	54	46	58
535 6 – 17	55	40	54
535 6 – 18	66	42	55
535 6 – 19	62	49	62
535 6 – 20	63	46	58
535 6 – 21	58	45	58
535 6 – 22	56	41	54
535 6 – 23	64	44	56
535 6 – 24	61	46	59
535 6 – 25	60	49	60

Table 75 cont. Evaluation of seedling progeny of somaclones of PBC 385 for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
535 6 – 26	56	40	53
535 6 – 27	48	41	54
535 6 – 28	54	43	55
535 6 – 29	61	50	62
535 6 – 30	30	53	65
535 6 – 31	35	52	64
535 6 – 32	43	41	52
535 6 – 33	36	44	57
535 6 – 34	45	42	55
535 6 – 35	45	43	54
535 6 – 36	43	36	49
535 6 – 37	65	45	57
535 6 – 38	62	31	44
535 6 – 39	61	45	58
535 6 – 40	55	54	65
535 6 – 41	48	50	63
535 6 – 42	51	40	53
535 6 – 43	49	42	54
535 6 – 44	56	43	55
535 6 – 45	58	41	53
535 6 – 46	64	40	51
535 6 – 47	62	39	50
535 6 – 48	48	37	50
535 6 – 49	52	39	53
535 6 – 50	56	40	53
	SD	Mean	CV%
Plant height	11.2	52.9	21.1
Days to Flower	4.68	43.5	10.7
Days to fruit	4.673	54.6	8.5

Fig. 35 Variation in somaclone seedling progeny of PBC 535.



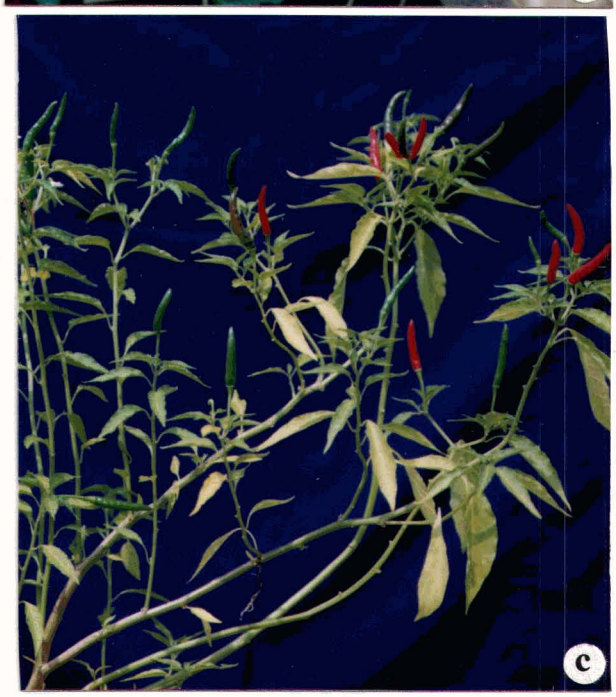
a Parental plant of PBC 535 showing pendent elongate fruits.

b Variation in plant height among the seedling progeny of somaclone PBC 535.

c Somaclone seed progeny of PBC 535 showing erect narrow fruits.


PBC 535
a


b


c

Fruit length (cm)

Fruit length ranged from 10.13 (PBC 535 6-12) to 16.20cm(PBC 535 6-45) among the seedling progeny of somaclone PBC 535 6 (Table 76).

Fruit width (cm)

Fruit width ranged from 1.0 (PBC 535 6-2, PBC 535 6-7) to 2.3cm (PBC 5356-1) among the seedling progeny of somaclone PBC 535 6 (Table 76).

Fruit weight (g)

Fruit weight ranged from 1.12 (PBC 535 6-43) to 4.98g (PBC 535 6-36) among the seedling progeny of somaclone PBC 535 6 (Table 76).

Table 76 Evaluation of seedling progeny of somaclones of PBC 535 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
535 6 – 1	15.2	2.3	2.15
535 6 – 2	16.0	1.0	1.94
535 6 – 3	13.9	1.2	2.64
535 6 – 4	12.5	1.2	2.12
535 6 – 5	16.0	1.2	2.24
535 6 – 6	13.0	2.0	3.24
535 6 – 7	12.0	1.0	5.30
535 6 – 8	13.8	1.7	4.32
535 6 – 9	11.4	1.8	3.78
535 6 – 10	13.1	2.1	3.40
535 6 – 11	12.3	1.86	3.78
535 6 – 12	10.3	1.2	2.86
535 6 – 13	13.2	1.4	3.34
535 6 – 14	12.2	1.2	4.65
535 6 – 15	13.0	1.8	1.85
535 6 – 16	12.0	1.7	4.60
535 6 – 17	12.0	1.8	3.85
535 6 – 18	13.6	1.6	3.55
535 6 – 19	14.2	1.1	1.65
535 6 – 20	16.0	1.2	2.12
535 6 – 21	15.8	1.1	4.56
535 6 – 22	13.2	1.3	3.21
535 6 – 23	13.0	1.4	2.34
535 6 – 24	12.5	1.2	5.12
535 6 – 25	11.8	1.4	1.89

Table 76 cont. Evaluation of seedling progeny of somaclones of PBC 535 for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
535 6 – 26	13.10	2.0	3.10
535 6 – 27	13.26	1.2	2.22
535 6 – 28	12.45	1.4	2.10
535 6 – 29	11.42	1.8	2.65
535 6 – 30	11.15	1.3	1.90
535 6 – 31	14.25	2.1	4.13
535 6 – 32	15.23	2.0	4.23
535 6 – 33	16.10	1.6	5.24
535 6 – 34	13.90	1.3	2.89
535 6 – 35	12.56	1.2	2.54
535 6 – 36	16.00	2.0	4.98
535 6 – 37	13.12	1.7	2.32
535 6 – 38	13.83	1.54	1.87
535 6 – 39	12.10	1.73	2.13
535 6 – 40	13.50	2.0	2.21
535 6 – 41	13.86	1.21	1.56
535 6 – 42	14.20	1.45	1.21
535 6 – 43	11.80	1.70	1.12
535 6 – 44	14.20	1.54	2.31
535 6 – 45	16.20	1.45	4.56
535 6 – 46	13.35	1.36	2.43
535 6 – 47	12.10	1.28	1.76
535 6 – 48	11.85	1.11	1.21
535 6 – 49	14.25	1.75	2.23
535 6 – 50	13.21	2.10	1.78
	SD	Mean	CV%
Fruit length	1.47	13.3	11.0
Fruit width	0.337	1.54	21.8
Fruit weight	1.96	2.84	42.1

Yield /plant (g)

Yield ranged from 59 (PBC 535 6-4) to 148g (PBC 535 6-3) among the seedling progeny of somaclone PBC 535 6 (Table 77).

Seed size (cm)

Seed size ranged from 0.20 (PBC 535 6-5 and PBC 535 6-7) to 0.42cm (PBC 535 6-38) among the seedling progeny of somaclone PBC 535 6 (Table 77).

Seed number

Seed number ranged from 55 (PBC 066 6-4) to 114 (PBC 066 6-35) among the seedling progeny of PBC 5356 (Table 77).

Table 77 Evaluation of seedling progeny of somaclones of PBC 535 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
535 6 – 1	67.89	0.40	65
535 6 – 2	112.50	0.35	60
535 6 – 3	148.60	0.33	58
535 6 – 4	59.26	0.30	55
535 6 – 5	88.95	0.20	65
535 6 – 6	76.34	0.30	65
535 6 – 7	100.56	0.20	110
535 6 – 8	120.45	0.30	100
535 6 – 9	110.34	0.34	87
535 6 – 10	68.45	0.28	98
535 6 – 11	124.69	0.32	112
535 6 – 12	113.60	0.29	76
535 6 – 13	114.50	0.30	75
535 6 – 14	132.40	0.34	88
535 6 – 15	124.35	0.38	89
535 6 – 16	98.45	0.29	96
535 6 – 17	115.36	0.27	94
535 6 – 18	110.23	0.32	107
535 6 – 19	113.13	0.30	114
535 6 – 20	106.12	0.34	109
535 6 – 21	110.34	0.32	107
535 6 – 22	108.21	0.36	115
535 6 – 23	99.34	0.31	113
535 6 – 24	91.13	0.35	105
535 6 – 25	105.36	0.32	95

Table 77 cont. Evaluation of seedling progeny of somaclones of PBC 535 for yield/plant, seed size and seed number

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
535 6 – 26	83.45	0.30	68
535 6 – 27	75.12	0.32	73
535 6 – 28	65.32	0.40	85
535 6 – 29	110.23	0.32	78
535 6 – 30	113.15	0.31	100
535 6 – 31	124.15	0.31	112
535 6 – 32	64.21	0.35	58
535 6 – 33	105.21	0.38	113
535 6 – 34	92.14	0.31	106
535 6 – 35	75.13	0.30	114
535 6 – 36	116.24	0.28	89
535 6 – 37	102.38	0.41	90
535 6 – 38	111.00	0.42	96
535 6 – 39	83.21	0.35	84
535 6 – 40	75.16	0.26	96
535 6 – 41	73.45	0.29	84
535 6 – 42	81.14	0.39	82
535 6 – 43	92.16	0.32	76
535 6 – 44	96.14	0.37	108
535 6 – 45	101.21	0.35	116
535 6 – 46	115.24	0.30	112
535 6 – 47	109.23	0.26	106
535 6 – 48	74.21	0.36	114
535 6 – 49	86.25	0.30	99
535 6 – 50	99.34	0.34	100
	SD	Mean	Range
Yield/plant	26.53	96.66	27.4
Seed size	0.044	0.332	13.4
Seed number	18.0	92.34	19.5

Colour value (ASTA)

Colour value ranged from 91.13 (PBC 535 6-41) to 176.34ASTA (PBC 535 6-21) among the seedling progeny of somaclone PBC 535 6 (Table 78).

Table 78 Performance of seedling progeny of somaclones of PBC 535.

Plant no.	Colour value (ASTA)	Plant no.	Colour value (ASTA)
535 6 – 1	157.86	535 6 – 26	145.63
535 6 – 2	120.34	535 6 – 27	125.35
535 6 – 3	149.3	535 6 – 28	133.65
535 6 – 4	124.56	535 6 – 29	114.54
535 6 – 5	103.56	535 6 – 30	122.80
535 6 – 6	131.10	535 6 – 31	134.65
535 6 – 7	128.56	535 6 – 32	132.86
535 6 – 8	98.45	535 6 – 33	142.30
535 6 – 9	110.34	535 6 – 34	154.32
535 6 – 10	96.45	535 6 – 35	167.89
535 6 – 11	113.45	535 6 – 36	165.21
535 6 – 12	171.18	535 6 – 37	132.40
535 6 – 13	145.56	535 6 – 38	112.10
535 6 – 14	123.40	535 6 – 39	87.89
535 6 – 15	132.14	535 6 – 40	95.34
535 6 – 16	119.17	535 6 – 41	91.13
535 6 – 17	120.15	535 6 – 42	132.50
535 6 – 18	112.34	535 6 – 43	143.52
535 6 – 19	109.12	535 6 – 44	138.98
535 6 – 20	116.54	535 6 – 45	124.35
535 6 – 21	176.34	535 6 – 46	142.15
535 6 – 22	134.65	535 6 – 47	153.21
535 6 – 23	123.89	535 6 – 48	128.13
535 6 – 24	122.54	535 6 – 49	154.13
535 6 – 25	132.32	535 6 – 50	142.31
	SD	Mean	CV%
Colour value	20.46	129.32	15.8

Evaluation of seedling progeny of somaclones of Round Ornamental

Morphological characters of seedling progeny of somaclones of Round Ornamental were observed (Table 79). Variation was found in stem pubescence, branching habit, leaf colour, leaf shape, flower position, fruit colour at intermediate stage, fruit shape and fruit shape at blossom end (Fig. 36 and 37). Stem pubescence was intermediate in 2 plants (4%) and sparse/nil in 48 plants (96%). Plant growth habit was erect in 42 plants (84%), intermediate in 5 plants (10%) and compact in 3 plants (6%). Branching habit was high in 8 plants (16%), intermediate in 34 plants (68%) and sparse in 8 plants

(16%). Leaf colour was light green in 3 plants (6%) and green in 47 plants (94%). Leaf shape was ovate in 31 plants (62%) and lanceolate in 19 plants (38%). Flower position was pendent in 44 plants (88%), intermediate in 4 plants (8%) and erect in 2 plants (4%). Fruit colour at intermediate stage was green in 39 plants (78%), light green in 7 plants (14%) and yellowish green in 4 plants (8%). Fruit shape was elongate in 41 plants (82%, Fig. 38, a and b), triangular in 5 plants (10%, Fig. 39, c), round in 2 plants (4%) and blocky in 2 plants (4% Fig. 38, c). Fruit shape at blossom end was pointed in 45 plants (90%) and blunt in 5 plants (10%). Fruit position was pendent in most plants (88%, Fig. 38 and 39) and erect as in the parent plant, only in 4% of the plants.

Plant height (cm)

Plant height ranged from 30 (Round Ornamental 8-13) to 64cm (Round Ornamental 8-23) among the seedling progeny of somaclone Round Ornamental 8 (Table 80) and ranged from 28cm (Round Ornamental 4-20) to 58cm (Round Ornamental 4-1) among the seedling progeny of somaclone Round Ornamental 4 (Table 81).

Days to flower

Days to flower ranged from 38 (Round Ornamental 8-7) to 46 (Round Ornamental 8-22) among the seedling progeny of somaclone Round Ornamental 8 (Table 80) and ranged from 32 (Round Ornamental 4-12) to 43 (Round Ornamental 4-8) among the seedling progeny of somaclone Round Ornamental 4 (Table 81).

Days to fruit

Days to fruit ranged from 51 (Round Ornamental 8-6) to 58 (Round Ornamental 8-22) among the seedling progeny of somaclone Round Ornamental 8 (Table 80) and ranged from 45 (Round Ornamental 4-12) to 55 (Round Ornamental 4-8) among the seedling progeny of somaclone Round Ornamental 4 (Table 81).

Table 79 Morphological characters of seedling progeny of somaclones of Round Ornamental.

Characters	Expression	No. of plants
Stem shape	cylindrical	50
Stem pubescence	dense	0
	intermediate	2
	sparse /nil	48
Plant growth habit	erect	42
	intermediate	5
	compact	3
Branching habit	high	8
	intermediate	34
	sparse	8
Leaf colour	light green	3
	green	47
	dark green	0
Leaf shape	ovate	31
	lanceolate	19
No. of flowers / axil	1	50
	2 and more	0
Flower position	pendent	44
	intermediate	4
	erect	2
Corolla colour	white	50
	light yellow	0
Anther colour	blue	0
	purple	50
Stigma exsertion	exserted	50
	same level	0
	inserted	0
Calyx margin	dentate	0
	intermediate	50
Fruit colour at intermediate stage	green	39
	dark green	0
	light green	7
	yellowish green	4
Fruit colour at mature stage	red	50
	dark red	0

Table 79 cont. Morphological characters of seedling progeny of somaclones of Round Ornamental.

Characters	Expression	No. of plants
Fruit shape	elongate	41
	triangular	5
	round	2
	blocky	2
Fruit shape at blossom end	pointed	45
	blunt	5
	sunken	0
	sunken and pointed	0
Fruit blossom appendage	absent	50
	present	0
Fruit surface	smooth	50
	semi wrinkled	0
	wrinkled	0
Placenta length	>1/2	50
	<1/2	0
Seed colour	straw	50

Fig. 36 Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of Round Ornamental

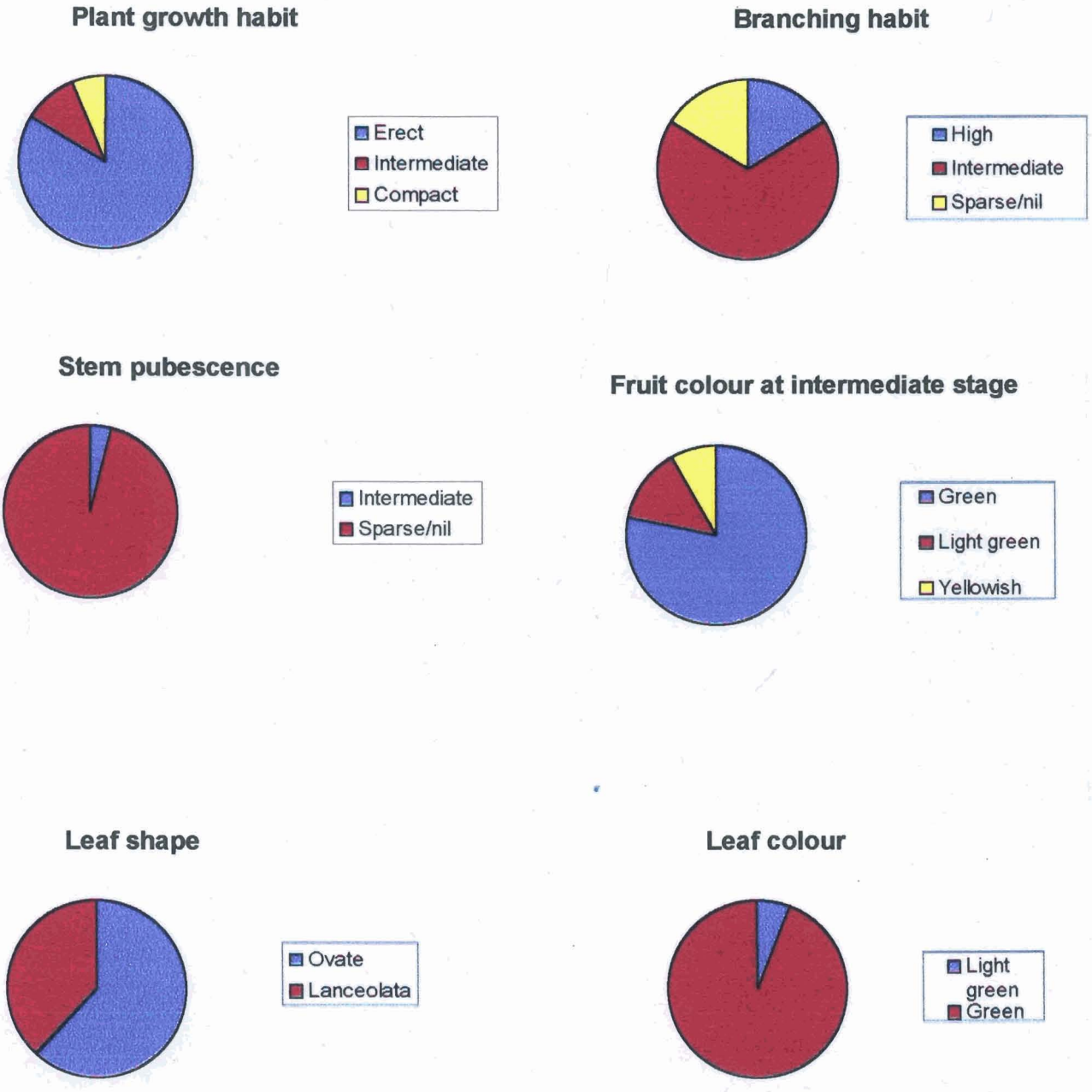
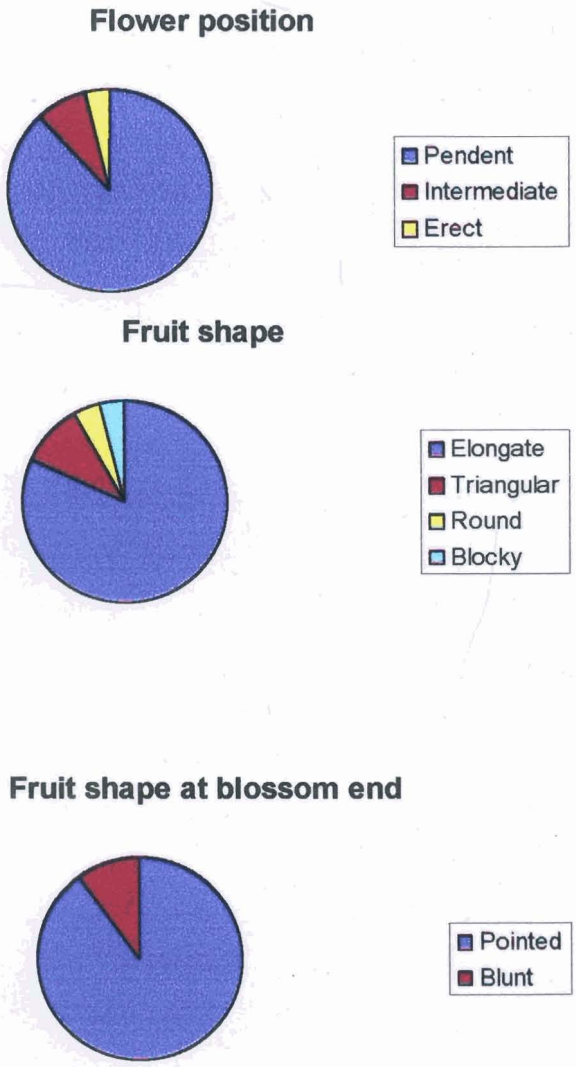


Fig.37 Frequency of occurrence of forms of discrete characters in seedling progeny of somaclones of Round Ornamental

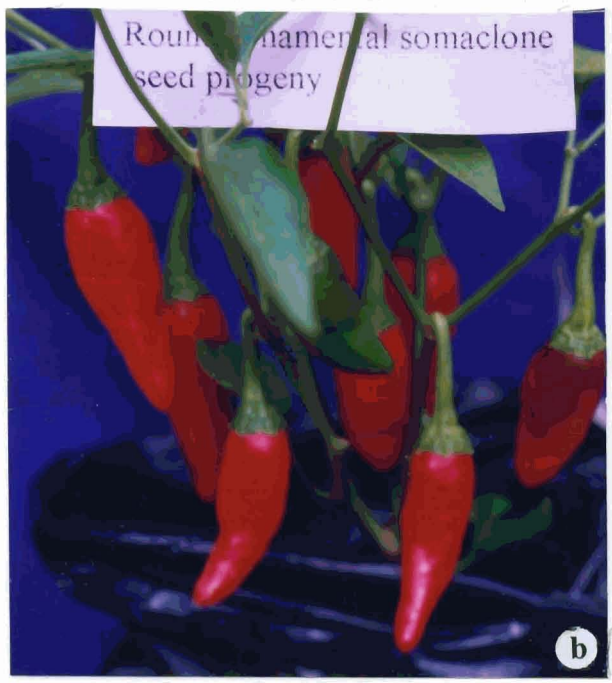



Round ornamental somaclone
seed progeny
a


b


c


Round Ornamental
a


seed progeny
b

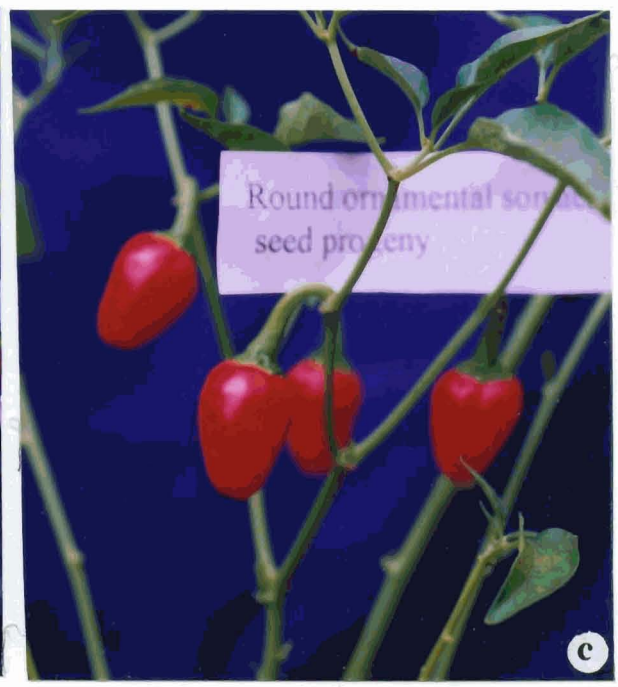
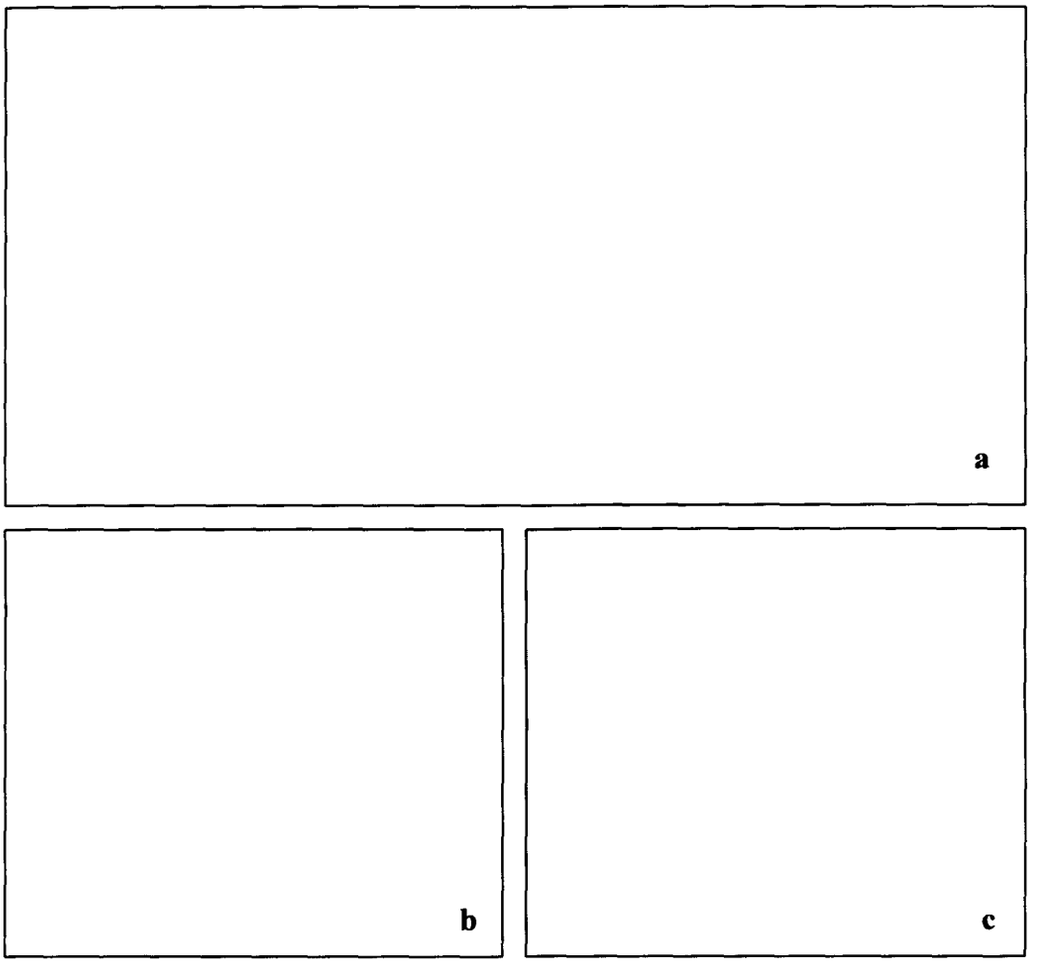

seed progeny
c

Fig. 38 Variations in the somaclone seed progeny of Round Ornamental.

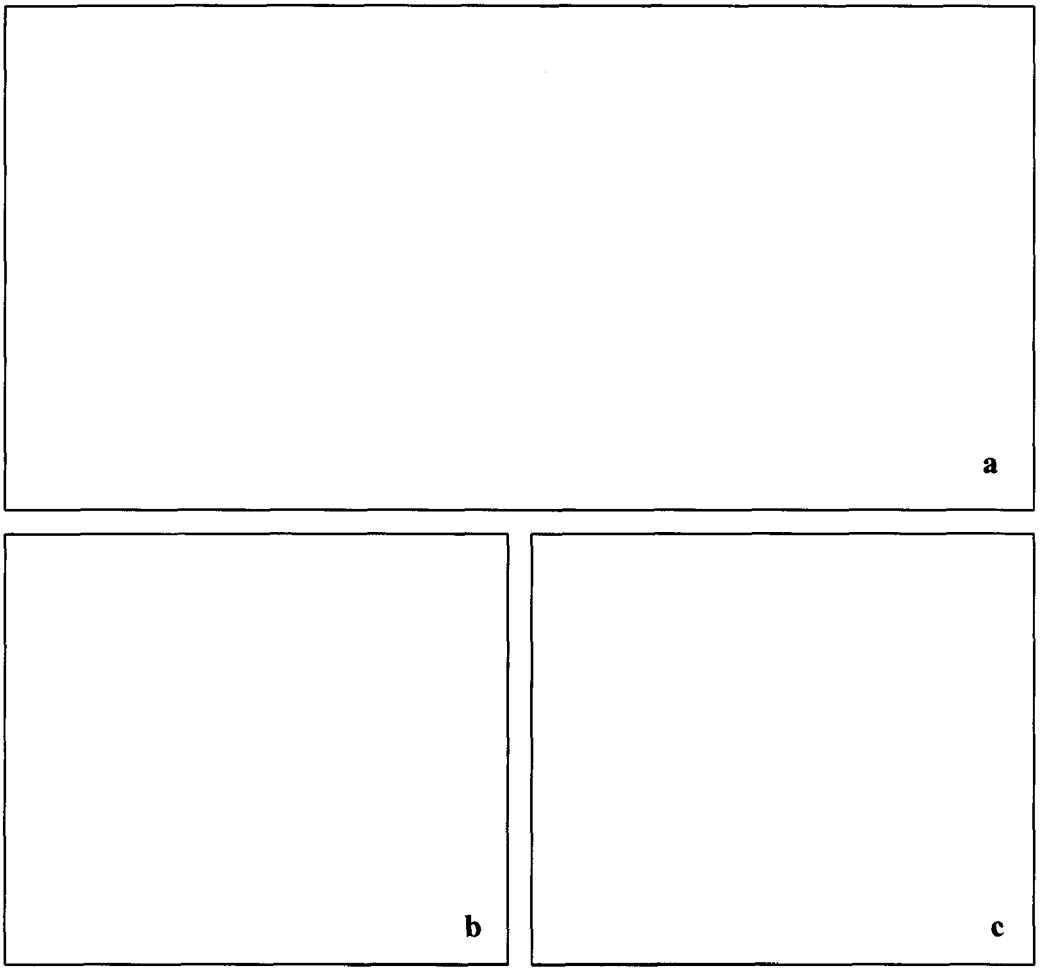


a Variation in fruit size in the seed progeny of somaclones of Round Ornamental.

b Somaclone seed progeny of Round Ornamental showing elongate pendent fruits.

c Somaclone seed progeny of Round Ornamental showing blocky fruits.

Fig. 39 Variations in the somaclone seed progeny of Round Ornamental.



a Round Ornamental parent plant with cherry like fruits.

b Somaclone seed progeny of Round Ornamental showing elongate pendent fruits.

c Somaclone seed progeny of Round Ornamental showing pendent triangular fruits.

Table 80 Evaluation of seedling progeny of somaclones of Round Ornamental for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
R.orn 8 - 1	42	42	53
R.orn 8 – 2	56	44	57
R.orn 8 – 3	40	41	53
R.orn 8 – 4	49	45	57
R.orn 8 – 5	50	42	54
R.orn 8 – 6	53	40	51
R.orn 8 – 7	45	38	52
R.orn 8 – 8	46	39	51
R.orn 8 – 9	32	40	50
R.orn 8 – 10	52	42	52
R.orn 8 – 11	36	43	55
R.orn 8 – 12	40	45	57
R.orn 8 – 13	30	41	53
R.orn 8 – 14	60	40	51
R.orn 8 – 15	50	42	55
R.orn 8 – 16	55	41	53
R.orn 8 – 17	70	43	56
R.orn 8 – 18	45	42	55
R.orn 8 – 19	47	41	53
R.orn 8 – 20	45	40	52
R.orn 8 – 21	38	44	56
R.orn 8 – 22	40	46	58
R.orn 8 – 23	64	41	53
R.orn 8 – 24	30	40	52
R.orn 8 – 25	30	42	55
	SD	Mean	CV%
Plant height	13.3	44.3	30.0
Days to flower	2.00	41.75	4.8
Days to fruit	2.16	53.62	4.0

Table 81 Evaluation of seedling progeny of somaclones of Round Ornamental for plant height, days to flower and days to fruit

Plant no.	Plant height (cm)	Days to flower	Days to fruit
R.orn 4 – 1	58	40	52
R.orn 4 – 2	35	41	53
R.orn 4 – 3	30	42	54
R.orn 4 – 4	30	40	52
R.orn 4 – 5	45	39	51
R.orn 4 – 6	34	42	53
R.orn 4 – 7	40	40	52
R.orn 4 – 8	46	43	55
R.orn 4 – 9	52	37	50
R.orn 4 – 10	30	38	51
R.orn 4 – 11	40	34	46
R.orn 4 – 12	30	32	45
R.orn 4 – 13	40	40	52
R.orn 4 – 14	30	41	53
R.orn 4 – 15	46	42	54
R.orn 4 – 16	43	40	52
R.orn 4 – 17	34	42	53
R.orn 4 – 18	30	40	53
R.orn 4 – 19	38	41	54
R.orn 4 – 20	28	40	51
R.orn 4 – 21	43	42	53
R.orn 4 – 22	36	40	54
R.orn 4 – 23	39	39	51
R.orn 4 – 24	41	38	50
R.orn 4 – 25	35	35	46
	SD	Mean	CV%
Plant height	7.48	37.6	19.8
Days to flower	2.65	39.6	6.7
Days to fruit	2.49	51.66	4.8

Fruit length (cm)

Fruit length ranged from 4.3 (R.orn 8-23) to 12.2cm (R.orn 8-5) among the seedling progeny of somaclone Round Ornamental 8 (Table 82, Fig.39) and ranged from 4.21 (R.orn 4-21) to 11.9cm (R.orn 4-13) among the seedling progeny of somaclone Round Ornamental 4 (Table 83).

Fruit width (cm)

Fruit width ranged from 1.1 (R.orn 8-23) to 2.1cm (R.orn 8-16) among the seedling progeny of somaclone Round Ornamental 8 (Table 82) and ranged from 1.30cm (R.orn 4-3) to 3.23cm (R.orn 4-24) among the seedling progeny of somaclone Round Ornamental 4 (Table 83).

Fruit weight (g)

Fruit weight ranged from 2.20 (R.orn 8-18) to 5.8g(R.orn 8-8) among the seedling progeny of somaclone Round Ornamental 8 (Table 82) and ranged from 1.42g (R.orn 4-2) to 5.73g (R.orn 4-11) among the seedling progeny of somaclone Round Ornamental 4 (Table 83).

Table 82 Evaluation of seedling progeny of somaclones of Round Ornamental for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
R.orn 8 – 1	8.2	1.2	3.10
R.orn 8 – 2	10.4	1.7	3.10
R.orn 8 – 3	9.5	1.4	3.00
R.orn 8 – 4	9.1	1.2	5.10
R.orn 8 – 5	12.2	1.4	4.20
R.orn 8 – 6	9.9	1.4	5.40
R.orn 8 – 7	10.0	1.5	2.89
R.orn 8 – 8	10.0	1.3	5.80
R.orn 8 – 9	10.5	1.4	5.50
R.orn 8 – 10	8.1	1.8	2.56
R.orn 8 – 11	8.1	1.2	5.10
R.orn 8 – 12	11.8	1.6	4.60
R.orn 8 – 13	11.4	1.6	3.57
R.orn 8 – 14	8.0	1.4	2.86
R.orn 8 – 15	7.2	1.8	3.64
R.orn 8 – 16	5.5	2.1	5.87
R.orn 8 – 17	10.0	1.3	4.21
R.orn 8 – 18	9.5	1.3	2.20
R.orn 8 – 19	9.2	1.6	3.58
R.orn 8 – 20	8.4	1.3	4.43
R.orn 8 – 21	6.5	1.4	3.38
R.orn 8 – 22	5.3	1.2	2.56
R.orn 8 – 23	4.3	1.1	3.12
R.orn 8 – 24	6.2	1.6	4.10
R.orn 8 – 25	7.1	1.4	5.12
	SD	Mean	CV%
Fruit length	2.09	8.67	24.1
Fruit width	0.227	1.448	15.7
Fruit weight	1.073	3.95	27

Table 83 Evaluation of seedling progeny of somaclones of Round Ornamental for fruit length, fruit width and fruit weight

Plant no.	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
R.orn 4 - 1	9.80	2.0	3.10
R.orn 4 – 2	9.20	1.40	1.42
R.orn 4 – 3	8.20	1.30	3.57
R.orn 4 – 4	10.50	2.00	2.98
R.orn 4 – 5	9.70	1.50	3.67
R.orn 4 – 6	8.10	1.80	3.12
R.orn 4 – 7	8.20	1.90	3.54
R.orn 4 – 8	10.30	4.00	4.68
R.orn 4 – 9	6.20	1.40	3.33
R.orn 4 – 10	8.80	1.80	3.46
R.orn 4 – 11	9.30	1.60	5.73
R.orn 4 – 12	10.0	2.00	3.24
R.orn 4 – 13	11.9	2.16	3.48
R.orn 4 – 14	8.50	1.30	3.14
R.orn 4 – 15	9.80	1.50	3.22
R.orn 4 – 16	7.30	1.40	3.19
R.orn 4 – 17	9.50	1.70	3.45
R.orn 4 – 18	8.00	1.35	4.12
R.orn 4 – 19	11.13	2.45	5.12
R.orn 4 – 20	6.23	3.12	3.12
R.orn 4 – 21	4.21	4.12	2.56
R.orn 4 – 22	7.26	1.43	2.45
R.orn 4 – 23	8.14	1.34	4.54
R.orn 4 – 24	6.73	3.23	2.56
R.orn 4 – 25	5.36	2.53	3.12
	SD	Mean	CV%
Fruit length	1.77	8.52	20.8
Fruit width	0.812	2.01	40.3
Fruit weight	0.89	3.49	25.6

Yield /plant (g)

Yield/plant ranged from 82.13 (R.orn 8-16) to 132g (R.orn 8-11) among the seedling progeny of somaclone Round Ornamental 8 (Table 84) and ranged from 83.2 (R.orn 4-9) to 121g (R.orn 4-15) among the seedling progeny of somaclone Round Ornamental 4 (Table 85).

Seed size (cm)

Seed size ranged from 0.28 (R.orn 8-15) to 0.46cm (R.orn 8-11) among the seedling progeny of somaclone Round Ornamental 8 (Table 84) and ranged from 0.30cm (R.orn 4-3) to 0.41(R.orn 4-11) among the seedling progeny of somaclone Round Ornamental 4 (Table 85).

Seed number

Seed number ranged from 70 (R.orn 8-1) to 120 (R.orn 8-18) among the seedling progeny of somaclone Round Ornamental 8 (Table 84) and ranged from 63 (R.orn 4-3) to 120 (R.orn 4-7) (Table 85).

Colour value (ASTA)

Colour value ranged from 93 (R.orn 8-15) to 194 ASTA (R.orn 8 –14) among the seedling progeny of somaclone Round Ornamental 8 (Table 86) and ranged from 64.70 (R.orn 4-7) to 132.13 ASTA (R.orn 4-17) among the seedling progeny of somaclone Round Ornamental 4 (Table 86).

Table 84 Performance of seedling progeny of somaclones of Round Ornamental

Plant no.	Yield /plant (g)	Seed size (cm)	Seed no.
R.orn 8 - 1	109	0.30	70
R.orn 8 – 2	112.45	0.35	107
R.orn 8 – 3	106.78	0.30	100
R.orn 8 – 4	99.78	0.35	110
R.orn 8 – 5	123.45	0.30	72
R.orn 8 – 6	110.38	0.42	112
R.orn 8 – 7	122.29	0.45	113
R.orn 8 – 8	95.65	0.40	88
R.orn 8 – 9	100.08	0.30	80
R.orn 8 – 10	121.13	0.40	113
R.orn 8 – 11	132.10	0.46	80
R.orn 8 – 12	86.45	0.37	83
R.orn 8 – 13	82.43	0.40	109
R.orn 8 – 14	97.14	0.38	114
R.orn 8 – 15	103.29	0.28	123
R.orn 8 – 16	82.13	0.31	72
R.orn 8 – 17	114.63	0.33	86
R.orn 8 – 18	106.15	0.31	120
R.orn 8 – 19	112.08	0.34	114
R.orn 8 – 20	103.20	0.30	105
R.orn 8 – 21	111.34	0.34	107
R.orn 8 – 22	118.21	0.36	98
R.orn 8 – 23	101.13	0.33	113
R.orn 8 – 24	92.31	0.35	105
R.orn 8 – 25	103.23	0.31	114

	S.D	Mean	CV%
Yield/plant	12.82	105.4	12.16
Seed size	0.049	0.349	14.1
Seed number	16.2	101.0	16.0

Table 85 Performance of seedling progeny of somaclones of Round Ornamental.

Plant no.	Yield / plant (g)	Seed size (cm)	Seed no.
R.orn 4 – 1	102.39	0.33	112
R.orn 4 – 2	110.47	0.31	114
R.orn 4 – 3	99.54	0.30	63
R.orn 4 – 4	113.45	0.35	69
R.orn 4 – 5	114.58	0.30	111
R.orn 4 – 6	123.56	0.31	115
R.orn 4 – 7	117.85	0.31	120
R.orn 4 – 8	130.40	0.36	110
R.orn 4 – 9	83.22	0.32	80
R.orn 4 – 10	97.21	0.40	85
R.orn 4 – 11	100.00	0.41	110
R.orn 4 – 12	104.56	0.40	100
R.orn 4 – 13	114.21	0.32	100
R.orn 4 – 14	116.13	0.31	65
R.orn 4 – 15	121.13	0.30	73
R.orn 4 – 16	105.63	0.32	75
R.orn 4 – 17	114.45	0.38	89
R.orn 4 – 18	118.21	0.31	105
R.orn 4 – 19	105.23	0.32	104
R.orn 4 – 20	111.21	0.31	98
R.orn 4 – 21	92.13	0.31	91
R.orn 4 – 22	94.54	0.31	111
R.orn 4 – 23	84.21	0.34	113
R.orn 4 – 24	112.36	0.35	93
R.orn 4 – 25	103.12	0.36	96
	SD	Mean	CV%
Yield /plant	11.75	107.5	10.9
Seed size	0.033	0.33	10.1
Seed number	17.124	96.08	17.8

Table 86 Evaluation of seedling progeny of somaclones of Round Ornamental for colour value.

Plant no.	Colour value (ASTA)	Plant no.	Colour (ASTA)	value
R.orn 8 - 1	133.13	R.orn 4 – 1	100.90	
R.orn 8 – 2	123.15	R.orn 4 – 2	105.4	
R.orn 8 – 3	131.18	R.orn 4 – 3	114.56	
R.orn 8 – 4	145.28	R.orn 4 – 4	89.24	
R.orn 8 – 5	121.19	R.orn 4 – 5	124.09	
R.orn 8 – 6	134.52	R.orn 4 – 6	98.28	
R.orn 8 – 7	154.13	R.orn 4 – 7	64.70	
R.orn 8 – 8	110.12	R.orn 4 – 8	92.12	
R.orn 8 – 9	113.25	R.orn 4 – 9	106.12	
R.orn 8 – 10	135.20	R.orn 4 – 10	103.21	
R.orn 8 – 11	114.20	R.orn 4 – 11	96.12	
R.orn 8 – 12	103.21	R.orn 4 – 12	65.34	
R.orn 8 – 13	176.53	R.orn 4 – 13	93.12	
R.orn 8 – 14	194.2	R.orn 4 – 14	113.12	
R.orn 8 – 15	93.00	R.orn 4 – 15	98.13	
R.orn 8 – 16	115.05	R.orn 4 – 16	93.14	
R.orn 8 – 17	112.13	R.orn 4 – 17	132.13	
R.orn 8 – 18	132.13	R.orn 4 – 18	115.12	
R.orn 8 – 19	147.8	R.orn 4 – 19	120.15	
R.orn 8 – 20	112.16	R.orn 4 – 20	115.26	
R.orn 8 – 21	103.12	R.orn 4 – 21	102.13	
R.orn 8 – 22	116.13	R.orn 4 – 22	96.90	
R.orn 8 – 23	142.13	R.orn 4 – 23	114.12	
R.orn 8 – 24	129.34	R.orn 4 – 24	103.42	
R.orn 8 – 25	136.27	R.orn 4 – 25	116.21	
	SD	Mean	CV%	
Seedling progeny R.orn 8	22.8	129.1	17.7	
Seedling progeny R.orn 4	23.2	99.5	23.3	

DISCUSSION

Anu Augustine “Selection of promising lines, production of somaclones and their utilization in paprika (Capsicum annuum L.) ” Thesis. Indian Institute of Spices Research Calicut, University of Calicut, 2001

Discussion

The Portuguese introduced chilli to India in the 17th century. Chilli is now the indispensable part of every Indian cuisine. It is cultivated in all states and union territories of the country. The important states growing chilli are Andhra Pradesh, Orissa, Maharashtra, West Bengal, Rajasthan and Tamil Nadu. Andhra Pradesh alone commands 46 percentage of chilli production in India. No country in the world has so much area and production of chilli as in India.

Chilli is nature's wonder; it appears in different sizes, shapes and colours. It has two commercial qualities, a few varieties are famous for red colour, others are known for biting pungency. India is the only country rich in many varieties with different quality factors.

Paprika is sweet red capsicum powder rich in vitamin C. The colour in paprika is the principle criterion for assessing the quality value. The pigment content of paprika powder ranges from 0.1- 0.8%. The colour values preferred in the industry are 85, 100, 120 and 150 ASTA (Tainter and Grenis, 1993). Paprika is distinguished by virtually nil/trace pungency; as a group, it entertains only less than 0.1% capsaicinoids (Verghese, 1995).

Today, there is considerable demand for paprika powder and its oleoresin in the western world. It is desirable to extend the cultivation of paprika in India for export oriented production for which there is immense scope. Although the trials taken up by IARI, New Delhi and CFTRI, Mysore had showed the scope for its successful cultivation, efforts are yet to begin for extensive cultivation which would facilitate to add one more

spice to the exportable range of spices in the country's spice basket. At the time when there is increase in domestic demand coupled with sizeable international demand, the potential that exists in the country for paprika production is required to be exploited (John, 1989). Paprika colours are not metabolized in human body and hence are an ideal natural colour additive for food articles. India has the potential to produce high quality paprika and there is tremendous potential for export.

The increasing commercial importance world wide of paprika both as paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Breeding programmes were initially started at IARI sub station Katrain, Himachal Pradesh. Joshi *et al.*, (1988) evaluated paprika genotypes and identified three high yielding types Kt-pl-8, Kt-pl-19 and Kt-pl-18.

Spice paprika is entirely a new crop to Kerala. Twenty paprika genotypes were evaluated by Indira (1994) at Kerala Agricultural University, Trichur and lines, CA 575 and CA 517 were found high yielding and CA582 (132.1ASTA) and CA 612 (135.7 ASTA) had high colour.

In the present study, forty paprika genotypes collected from AVRDC, Taiwan; IIHR, Bangalore; KAU, Kerala and Institute of Crop Genetics, Gaterslaben, Germany were evaluated for three seasons. They were evaluated for their morphological, yield and biochemical characters. The scope of somaclonal variation for improvement of paprika was also studied. The results obtained from the studies are discussed under different heads as follows.

Evaluation

The paprika types were evaluated for their morphological, yield and quality characters. Evaluation of morphological characters showed that there was significant difference among the lines in several characters (Table 7). There is significant difference among the lines in plant growth habit. The growth habit ranged from erect, intermediate to compact. The genotypes varied in stem pubescence also. Most of the lines had no pubescence at all. CAP 1086/35 had dense stem pubescence. Significant difference was also found in other morphological characters like leaf colour (varying from light green to dark green), leaf shape, number of flowers/axil, flower position, corolla colour, anther colour, stigma exsertion, fruit colour at mature and intermediate stage, fruit shape, fruit shape at blossom end and fruit surface (Figs. 7, 8, 9 and 10). Variation in growth habit, stem pubescence, stem color, leaf pubescence, stem colour, leaf pubescence, flower position, fruit shape and fruit length were reported by Mohammed (1994) and variation in morphological characters like plant height, number of branches and number of leaves among sweet pepper varieties was reported by Aliyu and Olerawaju (1994).

Variation in quantitative characters was also found among the genotypes (Tables 8 - 12). There was significant variation among the lines for characters like plant height, days to flower and days to fruit. Lines Kt-19 and Dokomlasi 640 were the latest to flower. They were also late to fruit.

Significant difference was found in fruit length among the lines (Fig 11). A few lines had fruits ten times as long as some other lines. Round ornamental, had small cherry like fruit, PBC 1369 and PBC 436 had round blocky fruits. PBC 743 and PBC 717 had

narrow small fruits. Paprika king had the longest fruit. There was considerable variation in fruit width also among the lines. PBC 743 and PBC 717 had narrow fruit width whereas; PBC 1369 and PBC 436 had broad fruits.

Fresh fruit weight is an important character in determining the amount of paprika powder obtained because paprika powder is made from dried powdered fruit wall. Fruit weight was highest in CAP 1088/35 (18.2g). Low yield being the limiting factor in paprika production (Bosland *et al.*, 1991), yield /plant is also a crucial character in paprika breeding. Among the forty lines evaluated, Paprika King had the highest yield (255.6g), followed by PBC 066 (227.3g) and Kt-pl-8 (190.3g). Seed size and seed number also varied among the lines. Paprika types with fleshy fruits generally had large seeds and highly pungent types had small seeds.

Paprika is valued most for its colour and mildness of flavour. Hence biochemical analysis for colour and pungency were done for all the lines. Genotypes with ASTA colour values in the range of 101-150 are classified under high colour group, those with 70-100 ASTA units under medium colour group and those below 70 ASTA units under low colour group. Among the forty genotypes, Paprika King had the highest colour value (268 ASTA), followed by PBC 828 (258 ASTA) and Kt-pl-19 (225 ASTA). There were quite a few genotypes under the high colour group. Paprika as a group entertains a pungency value less than 0.1%. Among the lines studied, PBC 436 had the lowest capsaicin percentage (0.05) and the highest was in 517-1 (0.63%).

From the evaluation of the lines, it was found that Paprika King had high fresh fruit weight (16.9g), high yield (225g), high colour value (268 ASTA) and low capsaicin

percentage (0.34). PBC 066 also had high fruit weight (11.4g), yield (227g), high colour value (128.6ASTA) and low capsaicin (0.23%). PBC 1347 gave good yield (173.3g) and high colour value (120 ASTA), but had high percentage of capsaicin (0.42). Round Ornamental also gave high yield (174.3g) and high colour value (105 ASTA), but the percentage of capsaicin was high. With the technology to separate colour and pungency compounds already available using super critical CO_2 as solvent (Skerget, 1998), the high capsaicin lines can also be used to prepare paprika oleoresin with low pungency. Byadagi, a well-known paprika type from Dharward, Karnataka was low yielding (115 g) under Calicut (North Kerala) conditions. Kt-pl-19 was low yielding (120.3g), but Kt-pl-8 was high yielding (190.3g) and had high colour value (102 ASTA) and capsaicin (0.28%). Kt-pl-20 was moderate in yield (155g), but had high colour value (137 ASTA) and capsaicin content of 0.38%. Seasonal variation in the expression of both quantitative and qualitative characters was also found in the present study. It could be due to the difference in adaptability and response to changes in the environment. From the study, it was revealed that the suitable time for cultivation of paprika in Kerala is from September to March (Winter months). Disease incidence (fruit rot) was more during the rainy season. It was found to be better to transplant after the rains and harvest before the summer months. Future line of work includes the evaluation of the promising lines like Paprika King, PBC 066, KT-pl-8 and Kt-pl-20 for several seasons at several locations, to release a paprika line suitable for Kerala.

Morphometric and seed protein analysis are used to reveal differences among species. Analysis of proteins is an additional tool for supplementing the evidence obtained by

comparative morphology, breeding experiments and cytological analysis. Seed protein analysis of twenty-nine genotypes were done using SDS PAGE electrophoresis (Fig. 12). It was found that the average similarity was highest between PBC 436 (originated in Portugal) and Round Ornamental (collected from KAU), suggesting that Round Ornamental could have originated in Portugal (Table 14). Most of the paprika lines had high seed protein content and they also clustered together (Table 13). Fruit length, fruit colour or percentage of capsaicin did not show correlation with the clustering of the genotypes; but in general, lines with common places of origin clustered together, low pungency high colour lines (paprika) also showed clustering together. The average similarity suggested that there was considerable genetic variability among the accessions though all of them fall under the species *C.annuum*.

***In Vitro* Studies**

Plant cell and tissue culture are utilized in horticultural crops for rapid propagation, first in orchids by G.M.Morel in 1960 and then for a number of ornamental plants. Extensive investigations continue to explore the potential of cell and tissue culture as an adjunct to crop improvement. Techniques include embryo rescue, freeing plants from virus and other pathogens, haploid induction, cryogenic storage of cells and meristems for germplasm preservation, creation of new nuclear and cytoplasmic hybrids via protoplast fusion, and the exploitation of changes, dubbed somaclonal variation, induced by cell and tissue culture (Janick, 1988).

The family Solanaceae is one of the most responsive and diverse groups among the dicotyledons in the context of the application of tissue culture techniques. It has long

been recognized that cells, tissues and organs from members of this family (tobacco, potato, tomato, petunia) undergo morphogenesis and *in vitro* plant regeneration easily. However, tissue culture of Capsicum has lagged behind, most likely due to lack of success in early attempts to regenerate plants from cultured tissues. Unlike other solanaceous species, chilli has been a recalcitrant species with regard to the capacity for *in vitro* plant regeneration. Most of the work on *in vitro* techniques in chilli was concerned with direct organogenesis in exotic cultivars. However, they did not succeed in regenerating plants from established callus cultures. Efficient culture systems need to be developed to get maintainable callus cultures of high morphogenic potential and to regenerate plants from such cultures. In the present study, an effort has been made to study the *in vitro* responses of five paprika genotypes.

Callus induction

Establishment of maintainable callus of high morphogenic potential is a preliminary step in tissue culture of any species. The nature of callus depends upon the complex relationship between the explants used to initiate the callus, genotypes, nutrient media and growth regulators. Accordingly, the effects of these factors on callus induction response have been discussed.

Effect of explants on callus induction

Virtually any part of the plant can be used to induce callus. In chilli, several explants like cotyledon, hypocotyls, anther, petiole, stem, leaf, fruit and root segments were used by earlier workers to initiate callus cultures. Among these, hypocotyls, stems, cotyledons and petioles are widely used explants (Ge *et al.*, 1991; Gatz *et al.*, 1994; Gatz

and Rogozinska, 1994). In the present study, the explants tried for callus induction were leaf and stem. Both the explants produced almost similar responses as far as callus induction was concerned, but the amount of callus produced was more in case of stem explants (Tables 16, 18 and 20). The nature of callus produced was friable in leaf and more watery, loose and friable in stem.

Effect of growth regulators on callus induction

Plant growth regulators are the most important factors regulating growth and morphogenesis in plant tissue culture. These chemicals occur endogenously (within the plant tissue) and in tissue cultures applied from out side. More over, synthetic chemicals have been discovered with similar biological activity and are used in tissue culture. There are several groups of plant growth regulators. Most important of these for tissue culture work are auxins and cytokinins.

Auxins

Most commonly used auxins in tissue culture are IAA, IBA and NAA. Of these, IAA is a naturally occurring auxin and others are synthetic. IBA, NAA and 2,4-D were used in the present investigation. Different auxins produced different results in the explants (Tables 16, 19 and 20). 2,4-D produced loose friable callus. NAA produced hard callus with thick roots. IBA produced compact callus with roots. 2,4-D produced direct regeneration at lower concentrations and callus at higher concentrations. As the concentration increased above 2mg/l, the callus turned brown soon. NAA induced roots and direct plant regeneration at lower concentration and hard compact callus with thick

swollen roots as the concentration increased. IBA produced roots and direct regeneration (Fig. 17, d) at lower concentrations and compact callus with roots at higher concentrations. Similar results of obtaining friable callus with 2,4-D and NAA producing compact callus with roots were reported by Pundeva and Simeonova (1992a,b); Sripichitt *et al.*, 1987).

Cytokinins

Cytokinins, the most commonly used in tissue culture are Kinetin (6-Furfurylaminopurine) and BAP (6-Benzyl amino purine). In the present study, cytokinins BAP and Kinetin were used to study its effect on stem, leaf and shoot tip explants. BAP and Kinetin at all concentrations induced only callus in leaf and stem explants. BAP and Kinetin induced multiple shoots at lower concentrations and callus regeneration at higher concentrations (Table 22). The percentage of response of explants was more in BAP than in Kinetin. BAP at $2mgl^{-1}$ was the best for inducing multiple shoots in *C.annuum* among the different treatments tried (Fig. 18, a).

Callus Regeneration

Plant regeneration from callus cultures of plant species can be achieved either through organogenesis or through somatic embryogenesis. In chilli, like in most members of family Solanaceae, organogenesis is the main mode of regeneration.

The basic principle that bud organogenesis can be induced with high ratio of exogenous cytokinin to auxin has already been established in different set of plant species and demonstrated in solanaceous crops like tomato (Bejhki and Lesly, 1976; Reina and Luque, 1988; Le *et al.*, 1991 and Ali and Li, 1994) and potato (Kollist and Tikk, 1994).

Callus regeneration from friable callus in Capsicum was found difficult (Agrawal *et al.*, 1989), but Ge *et al.*, (1989, 1991), Pundeva and Simeonova, (1992, b) and Gatz (1994) reported induction of callus and organogenesis in Capsicum.

Effect of growth regulators

In the present study, low concentrations of auxins (NAA and IBA) with higher concentrations of cytokinins were supplemented to MS medium to find the best combination suitable for callus regeneration (Table 24). BAP and Kinetin in combination with IBA induced callus regeneration. NAA was not suitable for callus regeneration. NAA induced shoot elongation and tuberous roots in shoot tip and nodal explants. Among the combinations tried, it was found that BAP $3mgl^{-1}$+IBA $1mgl^{-1}$ was the best combination to induce callus regeneration in Capsicum (Table 26). Higher concentrations of BAP with IBA and IAA were also tried and it was found that BAP$3mgl^{-1}$+ IBA$1mgl^{-1}$ was the optimum concentration for obtaining callus regeneration (Fig.18, b). Similar conclusions that BAP along with low concentrations (0.1- 1 mgl^{-1}) of other auxins promoting organogenesis, have been drawn by others (Liu *et al.*, 1990; Ochoa and Ireta, 1990; Arroyo and Revilla, 1991; Christopher *et al.*, 1991 and Huolin, 1994). The role of BAP as a necessary growth regulator and as a better cytokinin than others has been well established in different studies (Sripichitt *et al.*, 1987; Agrawal *et al.*, 1989 and Mirza and Narkhede, 1996). The results obtained in the present study are also in accordance with these observations. In earlier studies, IAA was the most predominantly used for shoot induction (Fari and Czako, 1981; Sripichitt *et al.*, 1987; Subhash and Sumalini, 1990; Pundeva and Simeonova, 1992a,b and Bahetee *et*

al., 1994). In the present studies, we found that the results obtained using IAA were not repeatable.

Effect of explants

It is important to select an explant that gives more shoots and calli per plant from maximum number of cultures to develop a viable protocol. Different explants like hypocotyls, cotyledons, shoot tip, roots, rooted hypocotyls and decapitated seedlings were used to induce vegetative buds. Among these, hypocotyls and cotyledons had significant regeneration potential (Gunay and Rao, 1978 and Fari and Czako, 1981). In earlier studies, it was found that callus regeneration could be induced only from young seedling explants like cotyledons and hypocotyls (Ge *et al.*, 1991, Gatz *et al.*, 1994 and Gatz and Rogozinska, 1994). But, in the present study, different explants like leaf, stem, shoot tip and nodal segments were used to induce callus regeneration. Stem explant was not suitable for regeneration (Table 24). Leaf explants at higher concentrations of BAP and Kinetin did induce callus regeneration, but to a lesser extent. Shoot tip explants and nodal segments were the best in inducing callus regeneration. Of these, nodal segments were found to be more suitable for callus regeneration (Table 24).

Effect of genotypes

According to Bebeli *et al.* (1988), the genotype of the parent material can influence somaclonal variation irrespective of the regeneration mode. Cultivar differences on the *in vitro* responses of *C.annuum* were reported by Ochoa and Ireta, 1990; Bahetee *et al.*, 1994 and Steinitz *et al.*, 1999. Although the five genotypes used in the study belong to same species (*C.annuum*), considerable differences with regard to their shoot bud

induction response were observed. The percentage of response of the genotypes varied but the number of shoots regenerated did not show much variation. PBC 375 was the most responsive, followed by PBC 385. Round Ornamental was the least responsive among the genotypes.

Elongation of regenerated shoots

Shoot/stem elongation has repeatedly been found as a major obstacle in obtaining normal pepper plants. Shoot elongation took place after transfer of shoot or shoot bud clusters to shoot elongation medium *in vitro*. Majority of these buds developed either leafy structures or stunted otherwise aberrant shoots (Stenitz *et al.*, 1999). Using the best genotypes and the choice protocols, only about five fully functional plants/explant were obtained by Wolf *et al.* (1998). GA-3 was usually added to elongation medium (Stenitz *et al.*, 1999). 24-epibrassinolide was also used for stem elongation in *C.annuum* (Duchenne *et al.*, 1998). The presence of coconut milk or casein hydrolysate in the medium also promoted shoot elongation (Cao and Jia, 1993). In the present study, hormone free MS medium, half strength MS medium, MS medium with activated charcoal and MS + GA-3 $1mgl^{-1}$ were tried. Covering the sides of the culture vessel with black paper in order to make the shoot bud clusters elongate was also tried (Table 28). Among the treatments, it was found that MS+IBA $1mgl^{-1}$ was the best for shoot elongation in *C.annuum*. Agrawal *et al.* (1989) also reported elongation of shoot buds on medium with IBA.

Rooting

For rooting of regenerated shoots either hormone free medium or a medium supplemented with low concentration of auxin was usually used. In the present study, it was found that hormone free MS medium with activated charcoal was the best for rooting of shoots (Table 29). It induced 5-6 roots without callus formation (Fig 19, a).

Transfer of *in vitro* plantlets to soil

Plants developed *in vitro* are adapted to the environmental conditions prevailing *in vitro*. They have to be re adapted to *ex vitro* conditions before they can be successfully established outside. *In vitro* plants are generally developed in high humidity and low light intensity. As a result, they have less epicuticular wax and lose water rapidly when transferred to external condition. Plants developed *in vitro* are only partially autotrophic because they are supplied with carbohydrate (sucrose) and low light intensity. Hence, when they are transferred outside they take a while before becoming fully autotrophic. This investigation showed that survival of transferred plants improved significantly when high humidity was provided by covering the plant with polythene bag (Table 30). Requirement for green house or humid chamber was avoided by practicing this method. The method of using polythene bag for covering to keep humidity is simple and cost effective (Fig. 19 b and c).

Somaclonal Variation

Genetic variation found in plants regenerated from any type of *in vitro* culture is termed somaclonal variation (Larkin and Scowcroft, 1981). In most cases, *in vitro* differentiation is a major cause of genetic variation (Swartz, 1991) and plants

regenerated from such de-differentiated tissue are called somaclones (Larkin and Scowcroft 1981). But according to De Klerk (1990), only random variations found in regenerated plants that are transmitted to the progeny through meiosis and are not reversible can be called as somaclonal variation. Variation in callus regenerated plants has been documented in many plant species for a wide array of characters (Larkin and Scowcroft, 1981; Reisch, 1983; Vasil, 1986 and Bajaj, 1990). Moreover somaclonal variation has been successful in yielding new varieties in sugar cane, sorghum, tomato, wheat, celery, flax and Pelargonium (Skirwin and Janick, 1976, a; Sears *et al.*, 1992; Duncan *et al.*, 1995 and Karp, 1995). Variation in morphological characters among callus regenerated plants are observed in other plant species also. In rice, phenotypic variation occur in grain size, tiller number, leaf number, maturity (Sun and Zhen, 1990), panicle number, seed weight, mature plant height and culm height (Lal and Lal, 1990). In potato, some somaclones varied in maturation time, shape, size, number and colour of tubers, leaf shape and size and in yield (Karp, 1990; Lal and Lal, 1990).

Basis of somaclonal variation

Somaclonal variation is a useful tool for crop improvement as well as a source of new varieties of plants (Evans *et al.*, 1984). Mechanisms involved in the origin of somaclonal variation are not fully understood. It may be that different processes are in operation in different species or that a number of processes are operating simultaneously in one culture (Larkin and Scow croft, 1981). Various factors contribute to the extent of variation observed among regenerated plants. These are genotype of the parent,

physiological state of the parental material, type of explants used, pre existing variation in the explant tissue, tissue culture pathway (micropropagation, direct or indirect organogenesis or embryogenesis, anther culture and protoplast culture), time in culture, kind of medium and growth regulators used and culture conditions (Gould 1986, George 1993 a, Meins 1983, Ogura 1990 and Siby 1990). Chromosomal structural changes and gene mutations, as well as other genetic alterations in regenerated plants have been postulated as responsible for the variations. (Ahloowalia, 1982 a, Karp and Maddock , 1984, Larkin *et al.*, 1984, Cooper *et al.*, 1986, Davies *et al.*, 1986 and Maddock, 1986). Changes in the organelle DNA and proteins including enzymes can be correlated to the occurrence of variation. In potato, changes in organelle DNA were observed in protoplast derived plants (Kemble and Shepard, 1984). Culhis (1983) working on flax cell cultures, observed about 15% decrease in total DNA quantity and reported a dramatic effect for a satellite DNA sequence in two fold range that led to sequence deamplification. Unstable expression is also a hall mark of transposon induced changes and has been reported in a number of cases such as wheat (Ahloowalia and Sherington, 1985), tobacco (Lorz and Scowcroft 1983) and alfa alfa (Groose and Bingham 1984). Genetic variability in tissue culture may partly originate from cellular changes in the mother plant and partly from changes that are induced during culture. Major factors that influence variations are

1. Genotype of the starting materials
2. Source of explant tissues
3. *In vitro* culture condition

According to Bebli *et al.* (1988), the genotype of the parent material can influence somaclonal variation irrespective of regeneration mode. Ploidy of the starting material is one factor that influences somaclonal variation. Genotype differences in somaclonal variation were also evident within ploidy level (Karp, 1995). Genotype dependent somaclonal variation was observed in sugarcane (Liu and Chen, 1976), pelargonium (Skirvin and Janick, 1976 b) and wheat (Winfield *et al.*, 1993). Genome with large proportion of heterochromatin and genome carrying transposable element would give more somaclonal variation.

Under identical conditions, the explant used can affect the quantity and nature of variation produced (Reisch, 1983; George, 1993 b and Karp, 1995). Generally old and specialized tissues give more variation while meristematic tissue and tissues of very young organs give less variation. This is because endopolyploidy, amplification or diminution of DNA sequences and poly somatism are more in older tissues compared to younger ones (D'Amato, 1985, 1989; George, 1993 b and Karp, 1995). Difference in somaclonal variation depending on the explant used for culture was evident in pineapple (Wakasa, 1979), potato (Van Harten *et al.*, 1981), chrysanthumum (Bush *et al.*, 1976), and pelargonium (Skirvin and Janick, 1976 b). In the present study, nodal and shoot tip explants were used, since they gave the maximum percentage of response. Leaf explants also produced callus regeneration, but to a lesser extend. Standardizing callus regeneration using different explants and studying the effect of explant on callus regeneration can be a future line of work.

In vitro culture conditions that can induce variation include physical factors in culture (temperature, light intensity and osmolarity of medium), chemical factors in culture (inorganic, organic and gaseous constituents of culture environment), degree of departure from organized growth and time in culture. In the present study, the temperature of the culture room was always maintained at 22 ± 2^0C, photoperiod of 12 hours and light intensity was $30E\mu m^{-2}s^{-1}$. Time in culture was one year. Effect of different temperatures, photoperiods, light intensities and different periods in culture may be a future line of work.

Chemical factors that influence variation in tissue culture include growth regulators, nutrition and carbon source (Gould, 1986). There is considerable evidence to indicate that somaclonal variation is influenced by the kind and concentration of growth regulators used in the medium (Karp, 1995). How they affect changes are not fully understood. They can either induce mutation or induce high rate of cell division, which in turn, cause mutation (George, 1993 b), or they alter the state of DNA methylation which results in mutation (Phillips *et al.*, 1990) or they may preferentially increase the rate of division of already mutated cells (Bayliss, 1980). 2,4-D is associated with genetic abnormalities like aneuploidy, polyploidy and endo reduplication, more than any other growth regulator (Swartz, 1991). Excessive use of cytokinin also resulted in variation as in oil palm and African plantains (Karp 1995). Generally, high concentration of cytokinin induced variation (George 1993 b). Gould (1986) suggested that in addition to the role in cell division, cytokinins could act as base analogs there by inducing genetic change.

Departure from organized growth is a key element in somaclonal variation, suggesting that in unorganized growth, the constraints that act to eliminate genetic variation in normal meristems are suppressed, or that mechanisms of genetic instability are induced. The greater the departure from organized growth and longer the time spent in this state, the greater the chances of generating somaclonal variation (Karp, 1995). Further, degree of genetic variation in regenerated plants depends on the method by which they have been produced from callus. Plants obtained by indirect shoot organogenesis are liable to be most variable, while those derived through indirect somatic embryogenesis are more stable (George, 1993 b). In the present study, it was found that purely unorganized callus could not be regenerated through organogenesis. Friable callus as that obtained by using 2,4-D may be regenerated through somatic embryogenesis. This can also be a future line of work.

From the present investigation, it is clear that callus regenerated plants exhibited more variation as compared to the conventionally propagated plants. Variability among conventionally propagated plants of Capsicum suggests that some of these variations could have been pre-existed. Some have argued that somaclonal variation in tissue culture has its equivalent in nature. Every dividing cell has an intrinsic error rate, which is the central source of natural selection. *In vitro* conditions are not that stringent and genetic variations are more frequent (Edwards *et al.*, 1990 and Anon, 1993). Somatic mutation with in the meristem can have tremendous consequences in subsequent branches that will be formed and in sexual and asexual progeny. Resistance to the insect *Anoplognathus montanus* in some branches of the same *Eucalyptus* tree has been

identified (Edwards *et al.*, 1990). According to Gould (1986) rate of cell division is very important in accumulation of mutations. Higher the rate of cell division (per unit time), higher the rate of mutation. Cells under *in vivo* condition divide much slower than those under *in vitro* conditions. Hence expected mutation rate is lower in *in vivo* than in *in vitro* condition. Extrapolating this with earlier point that *in vivo* condition is more stringent than *in vitro* condition; it follows that expected genetic variation is more in *in vitro* than *in vivo* condition. This explains the higher amount of variation found in callus regenerated plants compared to conventionally propagated plants in *Capsicum*.

In the present study, callus regenerated plants (50 plants each) of five genotypes were field transferred and variations in morphological and biochemical characters were recorded. Among the five genotypes, Round Ornamental, PBC 535, PBC 375, PBC 066 and PBC 385, Round Ornamental showed maximum variation in morphological characters. It showed variation in plant growth habit (erect and compact), flower position (pendent and erect), anther colour (blue and purple), stigma exsertion (exserted and inserted), fruit shape (elongate and triangular) and fruit shape at blossom end (Table 31). Among the quantitative characters there was maximum variation in fruit weight, fruit width and fruit length (Table 33). Colour value also varied among the somaclones, from 46 ASTA to 123 ASTA (Table 35). Somaclones of PBC 535 showed variation in morphological characters like plant growth habit (erect and compact) and leaf shape (ovate and lanceolate) only (Table 36). Among the quantitative characters, maximum variation was found in fruit weight and yield/plant (Tables 38 and 39). Colour value

also varied significantly among the somaclones of PBC 535, from 52.3 ASTA to 123.5 ASTA (Table 40). Callus regenerated plants of PBC 375 showed variation in morphological characters like plant growth habit (erect and compact) and leaf shape (ovate and lanceolate), Table 41. Among the quantitative characters, maximum variation was found in fruit weight, fruit width and fruit length (Table 43). Colour value ranged from 74 ASTA to 156.5 ASTA (Table 45). PBC 385 somaclones showed variation in morphological characters like stem pubescence (intermediate and nil) and anther colour (blue and purple) Table 46. Among quantitative characters, maximum variation was observed in fruit width, fruit weight and days to flower (Tables 47 and 48). Colour value also showed significant variation. Colour ranged from 70.2 ASTA to 205 ASTA (Table 50). Somaclones of PBC 066 varied in morphological characters like stem pubescence and plant growth habit (Table 51). Quantitative characters like fruit length and fruit width also varied significantly (Table 53). Colour value ranged from 152.2 ASTA to 242.16 ASTA (Table 55). From the above observations, it was found that maximum variation was found in fruit morphology and colour value. This points out that it may be possible to get a plant with high colour value by producing somaclones in large numbers and screening them. Since plants with high and low values are recovered, it may be possible that the changes occurring in tissue culture are at random as far as the traits are concerned.

Cytological studies of somaclones

Anthers collected from somaclones of the five genotypes were used for cytological studies. Abnormalities like lagging chromosomes, bridge formation, and hexavalent

formation were found during pollen formation of the somaclones (Fig. 20). The predominant feature observed among all the genotypes was stickiness of the chromosomes. The phenotypic manifestation of stickiness may be highly variable, ranging from a mild phenomenon involving only a few chromosomes in the genome, to a wide phenomenon involving the whole chromosome complement. Although many studies have reported occurrence of chromosome stickiness, the primary cause and biochemical phenomenon are still unknown. Stickiness and chromosome bridges cause the most varied types of abnormal microspores ranging from binucleate to multinucleate ones in Maize (Aparcida *et al.*, 1996). Karyotypic variations in callus cultures have been reported in *Crepis capillares*. L (Sacristan, 1971) and *Allium fistulosum* (Su Lee and Ono, 1999). Ploidy changes among the regenerated plants in *Allium cepa*.L was reported by Raju and Ashalatha (1998). Chromosomal variations like micronuclei, binuclei, bridges and laggards were reported in callus cultures of *Allium senescens* L.var. Minor (Ashalatha *et al.*, 1993). High frequency of univalents and multivalents at diakinensis and metaphase - 1 and abnormalities such as unequal chromosome distribution, laggards, chromatid bridges, micro nuclei at anaphase and the quartet stage were reported in somaclones of *Elymus canadensis* (Park and Walton, 1990)

Evaluation of seedling progeny of somaclones

To find whether the variations found in somaclones of *C.annuum* are continued in the next generation, seedling progeny of the somaclones were also evaluated for their morphological and quality characters. Among the seedling progeny of PBC 385-8, significant variation was found in morphological characters. Variation in morphological

characters like stem pubescence (dense, intermediate and nil), plant growth habit (erect and intermediate), leaf colour (green and dark green), flower position (pendent and erect), fruit colour at intermediate stage (green, dark green) and fruit shape (elongate and triangular) and fruit position (pendent, erect), Table 56, (Figs. 27, 28 29,b). Clustering of fruits were also observed. Among the quantitative characters, significant variation was found in fruit width and fruit weight (Table 60). Colour value ranged from 84.2 ASTA to 170.3 ASTA among 385-8 and from 91.4 ASTA to 168.3 ASTA among 385-7 seedling progeny (Table 63). Seedling progeny of PBC 375 (PBC 375-3) showed variation in stem pubescence (dense and nil), plant growth habit (erect and intermediate), branching habit (high, intermediate and sparse), leaf colour (light green and green), flower position (pendent and intermediate), fruit colour at intermediate stage (green and yellowish green) and fruit shape at blossom end (pointed and blunt) Table 64. Clustering of fruits was also observed (Fig. 31, b). Significant variation was found in days to flower, fruit width and fruit weight (Tables 65 and 66). Colour value ranged from 78 ASTA to 242 ASTA among the seedling progeny (Table 68). PBC 066 –1 seedling progeny also showed variation in plant growth habit, branching habit, leaf colour, stigma exsertion, fruit colour at intermediate stage and fruit shape at blossom end (Table 69). Significant variation was found in characters like days to flower, fruit width, fruit weight and seed size (Tables 70, 71 and 72). Colour value also showed variation, ranging from 123.5 ASTA to 224.6 ASTA (Table 73). Variation was found in morphological characters of seedling progeny of somaclone PBC 535-6. Variation was found in morphological characters like branching habit, leaf colour and fruit colour at

intermediate stage (Table 74). Significant variation was found in plant height (Fig 35,b), fruit width, fruit weight and yield /plant (Tables 75, 76, 77). Variation was also found in fruit position (Fig. 35,c). Colour value ranged from 91.3 ASTA to 176.3ASTA (Table 78). Morphological variation was the maximum among the seedling progeny of Round Ornamental somaclones. There was variation in stem pubescence, branching habit, plant growth habit, leaf shape, leaf colour, flower position, fruit colour at intermediate stage, fruit shape and fruit shape at blossom end (Table 79, Figs. 38 and 39). Significant variation was also found in plant height, fruit length and fruit weight of Round Ornamental 8 (Tables 80 and 82). Colour value ranged from 93 ASTA to 194 ASTA (Table 86). Significant variation was found among the seedling progeny of Round Ornamental – 4 in fruit length, fruit width and fruit weight (Table 83). Colour value in Round Ornamental-4 ranged from 64.7 ASTA to 132.13 ASTA (Table 86). It was found that somaclonal variation was genotype dependent. Round Ornamental showed the maximum variation among the genotypes studied and PBC 066 showed the minimum. From this study, it was found that variation among the seedling progeny was more than that found in the somaclones. The abnormalities found in the pollen meiosis of somaclones also point to the occurrence of abnormal gametes. Recessive characters such as clusterness of fruit and erect fruit habit were also expressed in the seedling progeny of somaclones of PBC 385. The recessive variation being heterozygous might not have been expressed in the somaclones, but it expressed in the next generation due to the homozygosity caused by selfing of the somaclones. Expression of primitive characters like dense stem pubescence and recessive characters mentioned above point

that it may be possible to produce primitive characters such as disease resistance through somaclonal variation. Estimation of colour values also showed promising results, indicating that it may be possible to obtain a high colour line by somaclonal variation. Major criticisms against somaclonal variation are that, not all of the variation is useful; it is unstable and unpredictable. Accepting that not all of the variation is useful, or stable, the fact remains that some changes are useful. Somaclonal variation may not be the complete answer to the Capsicum breeder's problems. Realistic objectives, with careful choice of starting material and experimental procedure are required. There are numerous problems associated with the application of variation and extensive screening will be needed, particularly in the early stages, to remove unwanted variants such as aneuploids. However, judging from 'successes' in other Solanaceous crops like potato and tomato, a somaclonal programme is a procedure worth under taking.

SUMMARY AND CONCLUSIONS

Anu Augustine “Selection of promising lines, production of somaclones and their utilization in paprika (Capsicum annuum L.) ” Thesis. Indian Institute of Spices Research Calicut, University of Calicut, 2001

Summary and Conclusions

Paprika is the Hungarian word for plants in the genus *Capsicum*. International spice traders use the term 'paprika' for non-pungent red capsicum powder. This mild powder can be made from any type of *Capsicum annuum* that is non-pungent and has brilliant red colour.

Paprika is valued most for its colour and mildness of flavour. The market value of paprika depends largely on its red colour, both surface hue and extractable colour. Its flavour quality is of secondary importance only. Oleoresin of paprika, extracted from the ground pods, is used to impart bright red color to meat, sausage products, sauces and to other processed foods thus making the product more acceptable and pleasing to the eye.

The pigment content of paprika varies from 0.1 – 0.8%. The pigments comprise a mixture of closely related carotenoids such as capsorubin, capsanthin, β - carotene, zeaxanthin, violaxanthin and lutene. The most important pigments responsible for red colour are capsanthin and capsorubin. The paprika colours are not metabolised in human body and hence are an ideal natural colour additive for food items. The colour of paprika is expressed in ASTA units (American Spice Trade Association). This is the extractable colour present in paprika. Common paprika ASTA colours present in the industry are 85, 100, 120 & 150 (Tainter and Grenis, 1993). According to Govindarajan (1985), the group paprika contains less than 0.1% of capsaicinoids, the best grade of Spanish paprika having 0 – 0.0003% and for the pungent grade a maximum of 0.5%.

The increasing commercial importance world over for paprika as sources of paprika powder and oleoresin has resulted in establishing breeding programmes on its improvement to develop varieties/hybrids to meet international demand. Today there is considerable demand for paprika powder and its oleoresin in the western world. It is desirable to extend the cultivation of paprika in India for export production for which there is immense scope. Although the trials taken up by IARI, New Delhi and CFTRI, Mysore had showed the scope for its successful cultivation, efforts are yet to begin for extensive cultivation which would facilitate to add one more spice to the exportable range of spices in the country's spice basket. At the time when there is increase in domestic demand coupled with sizeable international demand, the potential that exists in the country for paprika production is required to be exploited (John, 1989). Paprika colours are not metabolized in human body and hence are an ideal natural colour additive for food articles. India has the potential to produce high quality paprika and there is tremendous potential for export.

Forty paprika genotypes were evaluated for their morphological and biochemical characters for three seasons at the Indian Institute of Spices Research, Calicut, Kerala. Among the forty genotypes, Paprika King had the highest colour value (268 ASTA), followed by PBC 828 (258 ASTA) and Kt-pl-19 (225 ASTA). There were quite a few genotypes under the high colour group. Among the lines studied, PBC 436 had the lowest capsaicin percentage (0.05) and the highest was 517-1 (0.63%).

It was found that Paprika King had high fresh fruit weight (16.9g), high yield (225g), high colour value (268 ASTA) and low capsaicin percentage (0.34). PBC 066 also had high fruit weight (11.4g), yield (227g), high colour value (128.6ASTA) and low capsaicin (0.23%). PBC 1347 gave good yield (173.3g) and high colour value (120 ASTA), but had high percentage of capsaicin (0.42). Round Ornamental also gave high yield (174.3g) and high colour value (105 ASTA), but the percentage of capsaicin was high. With the technology to separate colour and pungency compounds already available using super critical CO_2 as solvent (Skerget, 1998), the high capsaicin lines can also be used to prepare paprika oleoresin with low pungency. Byadagi, a well-known paprika type from Dharward was low yielding (115 g) under Calicut conditions. Kt-pl-19 was low yielding (120.3g), but Kt-pl-8 was high yielding (190.3g) and had high colour value (102 ASTA) and capsaicin (0.28%). Kt-pl-20 was moderate in yield (155g), but had high colour value (137 ASTA) and capsaicin content of 0.38%.

Seed protein analysis of the different lines of Capsicum was performed by SDS-PAGE electrophoresis. It was found that the average similarity was highest between PBC 436 (originated in Portugal) and Round ornamental (collected from KAU), suggesting that Round ornamental could have originated in Portugal. Most of the paprika lines had high seed protein content and they also clustered together. Fruit length, fruit colour or percentage of capsaicin did not show correlation with the clustering of the genotypes;

but in general, lines with common places of origin clustered together, low pungency high colour lines (paprika) also showed clustering together.

With the objective of studying the effect of somaclonal variations in the improvement of paprika lines, callus regeneration was attempted. For callus regeneration, different explants like, leaf, stem, shoot tip and nodal explants were used. Auxins like 2,4-D, NAA, IBA and IAA and cytokinins like BAP and Kinetin were used. The combination BAP3 mg/lit + IBA 1mg/lit was found to be the best combination and nodal explant was found to be the most responsive. Elongation of the regenerated plants was achieved using MS medium containing 1mg/lit IBA. Rooting occurred in MS medium containing activated charcoal. Hardening was done in plastic cups containing sand and potting mixture in 3:1 ratio and covered with polythene bag to preserve humidity. The somaclones were transferred to field after hardening and their morphological and biochemical characters were recorded. From the observations, it was found that maximum variation was found in fruit morphology and colour value. This points that it may be possible to get a plant with high colour value by producing somaclones in large numbers and screening them.

Anthers collected from somaclones of the five genotypes were used for cytological studies. Abnormalities like quadrivalent formation, lagging chromosomes, bridge formation and hexavalent formation indicated that there are abnormalities in pollen formation of the somaclones.

To find whether the variations found in somaclones of *C.annuum* are continued in the next generation, seedling progeny of the somaclones were also evaluated for their

morphological and quality characters. It was found that there was significant variation in the morphological and biochemical characters of all the five lines evaluated. Variations were found in characters like stem pubescence, plant growth habit, leaf colour, flower position, fruit colour and fruit shape. Colour value also varied among the somaclone seed progeny. The seedling progeny of Round Ornamental exhibited maximum variation. Recessive characters such as erect fruit position and clustering of fruits were obtained among the somaclone progeny. Expression of primitive characters like dense stem pubescence and recessive characters mentioned above point that it may be possible to produce primitive characters such as disease resistance through somaclonal variation. Estimation of colour values also showed promising results, indicating that it may be possible to obtain a high colour line by somaclonal variation. Though somaclonal variation may not be the complete answer to the Capsicum breeder's problems. Realistic objectives, with careful choice of starting material and experimental procedure are required. There are numerous problems associated with the application of variation and extensive screening will be needed, particularly in the early stages, to remove unwanted variants such as aneuploids. However, judging from the results of this study and 'successes' in other Solanaceous crops like Potato and Tomato, a somaclonal programme is a chance worth taking.

Thus by this study, paprika genotypes Paprika King, PBC 066, Kt-pl-8, PBC 1347 and Kt-pl-20 were identified as suitable for cultivation in Kerala. Simple and efficient protocols for callus regeneration, elongation of regenerated shoots and hardening of paprika types were standardized. This protocol was useful for inducing somaclonal

variation in capsicum. The utility of somaclonal variation as a tool for the improvement of paprika was also established by this study.

"It doesn't matter who you are, or what you have done, or think you can do, some where in your life, there is a confrontation with destiny awaiting you. Some where, there is a chilli you cannot eat" .

(Daniel Pink Water, "A hot time in Nairobi").

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