

STUDY OF GENETIC VARIABILITY IN BETELVINE

(*Piper betle* L.)

A Thesis

Submitted to the

Bidhan Chandra Krishi Viswavidyalaya

for the award of the Degree of Doctor of Philosophy

in

GENETICS AND PLANT BREEDING

By

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DEPARTMENT OF GENETICS AND PLANT BREEDING

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JUNE-1994

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CERTIFICATE

This is to certify that the thesis entitled "Study of genetic variability in betelvine (*Piper betle* L.)" submitted for the award of the degree of DOCTOR OF PHILOSOPHY in Genetics and Plant Breeding of Bidhan Chandra Krishi Viswavidyalaya is a record of bona fide research work carried out by Md. Mosiur Rahaman under our joint supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been duly acknowledged.

(N.D. Das)

(S.C. Jana)

ACKNOWLEDGEMENT

I wish to record my deep sense of gratitude and indebtedness to Dr. N.D.Das, Reader (Res.), Department of Genetics and Plant Breeding and to Dr.S.C.Jana, Sr.Lecturer(Res.), Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya for their keen interest, ever willing help, constant guidance and critical suggestions throughout the course of present investigation and preparation of this manuscript.

I express my feeling of indebtedness to Prof. T.K.Chattopadhyay, Department of Horticulture for his spontaneous help, instinctive co-operation and valuable advice.

I am also grateful to Dr.M.Hossain, Reader, Department of Genetics and Plant Breeding for his valuable advice, helpful suggestions and constructive comments during the entire course of the study.

I also record my indebtedness to Dr.K.K.Ghosal, former Head, Dr.K.Roy, Head, Department of Genetics and Plant Breeding and Prof.G.C.Banerjee, Dean , Post Graduate Studies, B.C.K.V. for their kind support during the tenure of my investigation.

I am equally indebted to Dr.K.Sengupta, Sr.Lecturer, Department of Agronomy for providing me with the necessary materials for study and Dr.T.Dasgupta,Sr.Lecturer, Department of Genetics and Plant Breeding for his help during the statistical

analysis of the data.

Sincere thanks are also due to Mr.Dipak Kumar Sarangi, Research Fellow, Department of Horticulture for his constant co-operation, encouragement and valuable advice.

I can not but express my thankfulness to my friends, Dr.Kanchan Banerjee, Dr.P.K.Mani, Mr.Dulal Saha, Mr.Gunadhar De, Mr.Subhasis Mondal, Mr.Zahiruddin Khan, Mr.Sailendranath Sarker, Mr.Sandip Bera, Dr.Gopal Chandra Bera, Mr.Suvashis Saha, Mr. Debmalaya Choudhury and Mr.Subhasis Paul who encouraged and helped me in every possible way to complete this thesis.

I am also thankful to Mr.Sisir Bose, Farm Manager, other farm employee of "Kalayani C Block Farm" B.C.K.V. , Mr. Rosoranjana Roy and Mr.Arjun Rajak for their sincere help and co-operation.

Lastly , sincere thanks are due to the members of the Institute of Applied Computer Service, B-1/143, Kalyani, Nadia for typing and printing within a very short period.

Mosir Rahman

Date. 28th June, 1994.

(MOSIUR RAHAMAN)

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CHAPTER - I

INTRODUCTION

INTRODUCTION

Betelvine (*Piper betle* L., Family Piperaceae) is a perennial, dioecious climber. It ranks second amongst the most economically important plant species of this family, the first one being black pepper (*Piper nigrum* L.).

The native country of betelvine is probably Malaysia, particularly the Islands of Java and the crop has come to Eastern India from Malaya and Java through Burma and to South India via Andaman Islands and Sri Lanka (Mudgal *et al*, 1982).

In India there are about one hundred varieties or types of betelvine having variation in shape, size, colour, taste, aroma and chemical contents of leaves. The somatic (2n) chromosome number also varies from 42 to 195 (Jose and Sharma, 1985).

The crop is strictly propagated by vegetative means and cutting of the length of 15 cm is suitable for its propagation (Chattopadhyay, 1982). The leaves are traditionally used for chewing which are fairly rich in Vitamin B, Vitamin C and several essential amino acids. The different drugs used for brain, liver and heart are prepared from the extract of leaves. The leaf extract is aromatic, carminative and astringent and possess properties against several gram-positive and gram-negative bacteria. It has also significant fungicidal and nematicidal properties.

Betel leaf occupies a significant place in the everyday life of the Indian people. In our country the crop is cultivated as a commercial crop in about 40,000 hectares of land (Raghavendra Rao, 1993). The leaves exported in 1991-92 were 1051 metric tonnes, amounting to Rs.208.54 lakhs (Directorate of Cocoa, Arecanut and spices Development, Ministry of Agriculture, Govt.of India,1993). It's trade provides livelihood to over 1.5 million families in the country (Rawat *et al*., 1988). Unlike other crops, betelvine conservatory, once established, is a source of employment and cash for meeting day-to-day requirements of the growers. A family of 4-5 members, including children, may get a living from a betelvine conservatory of 0.05 to 0.06 ha. In India if any cooperative farming has succeeded, it is the betelvine, where usually 8-10 farmers join and organize a single conservatory of about 0.5 ha. (Khoshoo, 1982).

In spite of these, the crop has received very little scientific attention. It has not attracted the attention of agricultural scientists and botanists in a measure commensurate with its importance in our daily life, its countrywide consumption and export potential. There has been virtually no attempt ever made to improve its productivity.

The lack of attention towards betelvine may be due to the fact that the vine seldom flowers and bears fruit when cultivated. New types, with desirable characters could not be evolved following systematic breeding (Khoshoo,1982). But recently the occurrence of flowering, fruiting and proper

identification of male and female vine in Bangalore conditions, has opened an avenue for the improvement of betelvine through hybridization (Raghavendra Rao and Maiti, 1989; Maiti and Biswas, 1991 and Maiti *et al*, 1992). Accordingly, successful hybridization have been made to combine desirable characters (Raghavendra Rao, 1993). But this crop suffers much due to the scarcity of the informations on the variability estimated systematically for different quantitative characters. Till to-day there is no report which has discussed the extent of genetic variability, relationship among the characters, path analysis and grouping of the existing genotypes. The adaptability of the genotypes and the improvement of the most economic characters like leaf and its shelf - life through the conventional breeding methods are the most important aspects of breeding for this crop. The variability created artificially through the process of physical and chemical metagenesis may be the source of selection for desirable types.

Keeping the above view in mind, the present programme has been undertaken to study the variability, relationship amongst the characters and their relative contribution to yield (leaf yield) and to study the diversion amongst the genotypes as well as grouping of them under different clusters. It is also envisaged to investigate the pattern of adaptability of genotypes to various climatic stressess and to induce variation artificially through the application of ethyl methane sulphonate and gamma-rays.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Attention on the improvement of betelvine (*Piper betel* L.) is being emphasised recently. A few works have been reported on genetical aspects. The nature of investigations available are limited to qualitative characters and morphological variation of the varieties along with the chemical constituents of betel leaves. But genetical information on quantitative characters is still lacking. Grouping of the varieties using D^2 statistics in the species and some cytological works are also available. The variation on morphological, biochemical, chromosomal and flowering characters along with the very recent report on hybridization are reviewed below.

Morphological Variation:

The morphological variation in some quantitative traits of betelvine varieties of West Bengal including Sanchi or Khas, Meetha (sweet or Karpurkath) and Bangla or country types grown in Midnapore district were studied in detail by Ganguly and Gupta (1973). The workers reported that the above three varieties were morphologically different and their anatomical characteristics also varied. The types under Bangla and Sanchi cultivars also differed among themselves in gross morphology as well as some anatomical aspects (Ganguly and Gupta, 1974a and 1974b). A new Bangla type, popularly known as "Dudhae Bhabna" was identified by Barui and Ganguly (1982) in the district of Hooghly

of West Bengal which was proposed by them to be more or less related to Bhabna Amtala type grown in another place of West Bengal. The study of growth parameters like increase in vine, petiole and internodal length, stem diameter, number of leaf production, laminar area, laminar thickness and laminar length: breadth ratio showed a remarkable variation among Bangla types (Das and Chattopadhyay, 1982a). The Bangla types, as a whole, showed better growth than Mitha and Sanchi types, and among the Bangla types Borghai and Bhabna proved to be the best in the group (Das and Chattopadhyay, 1982a and Rawat and Balasubrahmanyam, 1988). The presence of such variations in the quantitative characters of betelvine varieties was explained by Das and Chattopadhyay (1982b). The workers proposed that the varieties under investigation possessed higher chromosome number at polyploid level. The proposal seems sound as the progenies of the polyploid ancestor may have emerged without anomalies in chromosome number due to the nature of vegetative reproduction in *Piper betle*. The low percentage of pollen viability (40-50% only) as noted by Raghavendro Rao and Maiti (1989) may also be indicative of the irregular chromosomal separation in this higher polyploid species.

Attempts were also made to classify the betelvine varieties into different groups on the basis of morphological, anatomical, physiological as well as bio-chemical components (Das and Chattopadhyay, 1982b; Rawat and Balasubrahmanyam, 1988 and Balasubrahmanyam and Rawat, 1990). Seventeen varieties grown in

Midnapore district were classified into short, medium short, medium-long and tall groups on the basis of internodal length. The varieties were also classified into slightly lanceolate, cordate lanceolate and typical cordate group on the basis of leaf shape (Das and Chattopadhyay, 1982b). The workers classified the varieties into four broad groups and each group into various sub-groups on the basis of leaf phenolics. In this classification Sanchi, Bangla and Kapoori were placed in the same group, though Ganguly and Dutta (1973) and Rawat and Balasubrahmanyam (1988) identified Sanchi and Bangla as totally different group. However, Das and Chattopadhyay (1982b) pointed out that classification of all the betelvine varieties into different groups and sub-groups on the basis of any parameter was not perfect as one group overlapped the other group i.e., no two groups showed perfect similarity in respect of two or more characters. The intraspecific divergence among the clones of betelvine also showed highly significant variation in the D^2 values based on internodal length, petiole length, leaf length, leaf breadth, leaf area, fresh weight and leaf index (Maiti *et al*, 1992). The D^2 values between the male and female clusters were much higher than those within the male or within the female clusters indicating sexual dimorphism in the materials.

However, this classification on the basis of some morphological characters is meaningful and statistically more sound.

The interspecific variation in the quantitative traits revealed in the D^2 statistics was found significant in the genus *Piper* (Rahiman and Bhagavan, 1985). The workers estimated the inter and intra-cluster distances using male and female plants of eight species of *Piper*, occurring in the Western Ghat regions of South India. There was also a great diversity in the somatic chromosome number in the different species of the genus *Piper* (Dasgupta and Dutta, 1976; Bai and Subramanian, 1985; Rahiman and Nair, 1986).

Biochemical Variation:

Different cultivars of betelvine showed a significant variation among themselves in the content and composition of essential oil (Rawat *et al* 1989a; 1989b). The phenolic compounds in the essential oil of betelvine varied from 13.90 percent in Sanchi to 69.83 percent in Bangla cultivars (Balasubrahmanyam and Rawat, 1990). The cultivars also showed significantly differential response to the same strain of fungal pathogens due to the presence of different amount of biochemical substances having resistance properties (Tripathi *et al*, 1985).

Chromosomal Variation:

The chromosomes are extremely small in size but high in number having a great diversity in somatic chromosome number, size and shape and even in basic set among the different cultivars of *Piper betle* L. (Dasgupta and Dutta, 1976; Samuel and

Bavappa, 1981; Jose and Sharma, 1983, 1985). While Samuel and Bavappa (1981) reported $2n=26$ and $2n=52$ chromosomes in two separate accessions of *Piper betle*, Jose and Sharma (1983) observed $2n=42$, $2n=58$, $2n=78$ and $2n=195$ chromosomes in different varieties of this species. In those varieties the number of chromosomes with secondary constriction varied from two to four and total chromatin length ranged from $24.81\ \mu$ to $86.94\ \mu$. Jose and Sharma (1985) also reported $2n=52$ chromosomes in another variety and a range of $46.30\ \mu$ to $173.88\ \mu$ in total chromatin length in a collection of 33 varieties of *Piper betle*. A polyploid series in the varieties of betelvine having a basic set of 13 chromosomes in contrast to basic set of 12 chromosomes (Dasgupta and Dutta, 1976; Sharma and Bhattacharyya, 1956, 1959) were also reported by Jose and Sharma 1985. Dasgupta and Dutta (1976) reported that in both the cases of Jhal Pan and Mitha Pan $2n=64$ but in the former the total chromosome length was $30\ \mu$ in comparison to $39\ \mu$ in the latter.

Formation of multivalents, quadrivalents along with bivalents were also an indication of polyploid nature of this species (Bai and Subramanian, 1985). But the basic chromosome number in this species was contradictory. Aneuploid series of this species was also identified (Dasgupta and Dutta, 1976; Jose and Sharma, 1985).

The pollen fertility between the range of 40-50% was reported in the varieties of betelvine by Raghavendra Rao and Maiti (1989). The low percentage of fertility was an indirect

evidence of polyploid nature of the species.

With regard to the chromosomal variation in *Piper betle*, a list of somatic chromosome number indicating the basic set as advocated by different workers is given below.

Cultivars/ types	Somatic chromosome number (2n)	Basic ch. number (x)	Workers
<i>Piper betle</i> L.	32		Johnson, 1910a;1910b
<i>P. betle</i> L.	32		Janaki Ammal, 1945
<i>P. betle</i> L.	26		Samuel and Bavappa, 1981
<i>P. betle</i> L.	52		-do-
<i>P. betle</i> L.	64	12	Sharma and Bhattacharyya 1956, 1959
<i>P. betle</i> L.	64	12	Dasgupta and Dutta, 1976
<i>P. betle</i> L.	78		Mathew, 1958
<i>P. betle</i> L.	64		Bai and Subramanian, 1985
<i>P. betle</i> L. var karpurkanthi	42		Jose and Sharma, 1985
<i>P. betle</i> L. var Ranipan	58		-do-
<i>P. betle</i> L. var Chava-wild	195		-do-
<i>P. betle</i> L. var Ramtek-kapoori	52	13	-do-
<i>P. betle</i> L.	78		-do-

Flowering and Breeding:

Till the discovery of male and female flowering in betelvine, it was believed that only male plants were being grown in India (Aiyer, 1947). This belief was due to the absence of flowering. Later on flowering and fruiting were observed for the first time in a collection of 45 indigenous types, maintained at Indian Institute of Horticultural Research at Bangalore (Raghavendra Rao and Maiti, 1989). Male and female flowers were described and identified by some workers in detail (Raghavendra Rao and Maiti, 1989; Balasubrahmanyam and Rawat, 1990). Attempt was also made to predict sex of non-flowering cultivars on the basis of sexual dimorphism in leaf shape (Maiti and Biswas, 1991). The extent of divergence existing between the male and female clones in a collection of 30 cultivars was estimated which could help in crop improvement through heterosis breeding. (Maiti *et al*, 1992). Successful hybridization was also made to incorporate powdery mildew resistant genes of Desawari type to Kapoori type. Hybrid seedlings are in the process of evaluation (Raghavendra Rao, 1993).

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

The location of study, the materials used and methods followed in the present work are described below.

3.1 LOCATION OF THE STUDY:

The experiment was conducted at 'C' Block Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal. The place is situated at 23.5°N latitude, 89°E longitude and at an altitude of 9.75 m above the mean sea level. It is a sub-tropical humid climate and situated just to the south of the tropic of cancer.

The soil is alluvial (Entisol), sandy loam, leached and neutral in reaction with good drainage facilities.

The average annual rainfall is 1457 mm, mostly precipitated during June to September and the mean temperature ranges from 10 to 37°C. The winter and summer seasons are not severe at this place. The meteorological data pertaining to the period of experimentation (July, 1991 to December, 1993) are presented in Table 1.

3.2 EXPERIMENTAL MATERIALS:

3.2.1 Cultivers used for study of natural variability:

Twenty seven cultivars/types of betelvine were collected from different parts of West Bengal as well as from

Table 1: Meteorological data pertaining to the years of experimentation

Month	Temperature(°c)			Rainfall(mm)			Relative humidity(%)					
	Maximum			Minimum			Maximum			Minimum		
	1991	1992	1993	1991	1992	1993	1991	1992	1993	1991	1992	1993
JANUARY	24.6	24.4	24.4	11.3	11.7	8.4	0.0	86	89	45	41	
FEBRUARY	27.1	28.9		14.4	16.3	103.2	0.0	87	86	48	50	
MARCH	34.5	31.0		20.9	18.6	0.0	76.6	86	81	32	37	
APRIL	38.2	34.4		23.6	23.1	7.8	47.4	83	84	32	51	
MAY	35.1	33.3		24.7	24.6	141.2	148.5	77	84	56	60	
JUN	33.1	32.2		24.8	25.4	174.7	341.0	84	89	66	72	
JULY	33.2	32.1	31.4	26.1	25.1	25.8	506.6	89	92	74	76	
AUGUST	33.0	33.0	31.9	25.2	26.1	25.7	369.6	92	93	72	79	
SEPTEMBER	33.1	30.5	31.8	25.5	25.5	25.5	177.0	91	91	78	75	
OCTOBER	30.9	32.1	31.5	22.1	23.1	22.6	100.0	90	89	62	64	
NOVEMBER	29.0	29.4	29.2	19.8	19.0	19.4	0.0	86	86	58	53	
DECEMBER	27.3	26.0	26.6	12.7	11.7	12.2	28.2	87	88	41	48	

Source: Meteorological Station, Haringhata Farm, Mohanpur, Nadia, W.B.

outside of West Bengal for the present work. These cultivars/types alongwith their source of collection are given in table 2.

Table 2: Cultivars alongwith their source of collection

Access- ion No.	Cultivars/types	Source of collection
1.	Mitha Pan	Tomluk, Midnapur, West Bengal
2.	Kali Bangla	Bagnan, Howrah, West Bengal
3.	Ghanagete Bangla	Bagnan, Howrah, West Bengal
4.	Simurali Bangla	Simurali, Nadia, West Bengal
5.	Sanchi (Tomluk)	Tomluk, Midnapur, West Bengal
6.	Sanchi (Halisahar)	Halisahar, 24-Parganas(N), West Bengal
7.	Godi Bangla	Orissa
8.	Halisahar Jhal(Bangla)	Halisahar, 24 Parganas(N), West Bengal
9.	Kapoori (Ramtek)	Maharashtra
10.	Karapaka Bangla	Andhra Pradesh
11.	Noua Bangla	Orissa
12.	Kapoori (Palghat)	Kerala
13.	Kapoori (T.N.)	Tamil Nadu
14.	Kapoori (Sangli)	Maharashtra
15.	Haldi Pan (Bangla)	Ramnagar, Midnapur, West Bengal
16.	Birkuli (Bangla)	Orissa
17.	Simurali Deshi (Bangla)	Simurali, Nadia, West Bengal
18.	Simurali Bhabna (Bangla)	Simurali, Nadia, West Bengal
19.	Kare Bangla	Tomluk, Midnapur, West Bengal

Table.2 contd.

Access- ion No.	Cultivars/types	Source of collection
20.	Ayamal Bangla	Tomluk, Midnapur, West Bengal
21.	Borghai (Bangla)	Tomluk, Midnapur, West Bengal
22.	Dhal Bangla	Bagnan, Howrah, West Bengal
23.	Adi Bangla	Tomluk, Midnapur, West Bengal
24.	Tilak Bangla	Bagnan, Howrah, West Bengal
25.	Chandrokona (Bangla)	Ramnagar, Midnapur, West Bengal
26.	Ramnagar Deshi (Bangla)	Ramnagar, Midnapur, West Bengal
27.	Kalidhal Bangla	Bagnan, Howrah, West Bengal

3.2.2 Materials used for study of artificial variability induced by chemical mutagen.

- i) Ethylmethane sulphonate (EMS): $\text{CH}_3\text{SO}_3\text{C}_2\text{H}_5$
- ii) Phosphate buffer pH 7.0
- iii) Cultivars: Simurali Bangla, Sanchi (Tamluk)
and Halisahar Jhal.

3.2.3 Materials used for study of artificial variability induced by physical mutagen.

- i) Gamma-rays (Source: Cobalt-60)
- ii) Cultivar: Simurali Bangla

3.2.4 Materials used for estimation of chlorophyll a and b:

- i) Acetone (80%)
- ii) Whatman Filter Paper No.42

3.3 EXPERIMENTAL METHODS;

3.3.1 Growing of the vines: The vines were raised in different ways depending upon purpose as described below.

i) Growing of the vines for study of natural variability: Juvenile cuttings of 15 cm length were first kept in mud water for two days for sprouting of roots and subsequently transferred to the betelvine conservatory (Chattopadhyay, 1982) at Kalyani, West Bengal. Planting was in the month of July (Sarkar *et al*, 1982), 1991 in completely randomized block design (CRBD) with three replications. The spacing was 20 cm between plants and 75 cm between the rows (20 cm x 75 cm). The decomposed mustard oil cake at one month intervals @ 100 kg/ha and tank silts once in a year were applied to the vines. Bucket irrigations with pond water were given as and when needed. For proper support to the vines, bamboo sticks were used. At the end of October, 1991, the vines were lowered for rejuvenation as advocated by Nath (1984) and the practice (lowering) was continued upto October, 1993 at an interval of four months.

(ii) Growing of the vines for study of artificial variability induced by EMS: Three cultivars viz., Simurali Bangla, Sanchi (Tomluk) and Halisahar Jhal were selected for the purpose on the basis of availability of sufficient number of clones. Cuttings of each cultivar were transplanted separately in large earthen pots in July, 1991. The pots were kept within the conservatory. When the new auxillary shoot appeared at two node

stage, the EMS solution with different concentrations were applied on the tip by cotton-plugs. The concentrations of EMS were made by diluting it with phosphate buffer. At first the growing tip of the new shoot was opened by forceps which normally remained overarched by young leaves. The apical tip was covered by cotton-plugs and soaked in EMS solution of 0.025%, 0.05%, 0.10%, 0.20%, 0.35% and 0.50% concentrations. Each concentration of EMS was applied for 4 and 8 hours duration. The solution was given in drops to moist the cotton-plugs throughout the period of treatment. The cotton-plugs after the specified period were removed and the stem tips were washed with distilled water. The control vines were also treated similarly with distilled water. A few days later (1-3) the treated tips started growth. Data were recorded when the tips started development. The surviving vines were handled as follows.

The mutagen treated vines (M_1V_1) including the controls were pruned (Diagram 1) to eliminate chimera by encouraging the mutant cells to develop into a entire shoot following Bauer (1957) and Lu *et al* (1988). The pruning resulted in the formation of (M_1V_2) generation which was allowed to develop for a period of 10 months (Nov., 1991 to Aug., 1992). At this stage when the vines (M_1V_2) became 10-12 node stage, the entire stem was cut down into several pieces, each having 15 cm length and planted in large earthen pots to raise the next generation (M_1V_3). The newly developed vines (M_1V_3) were allowed to grow for a period of 10 months (Aug., 1992 to June, 1993) and finally

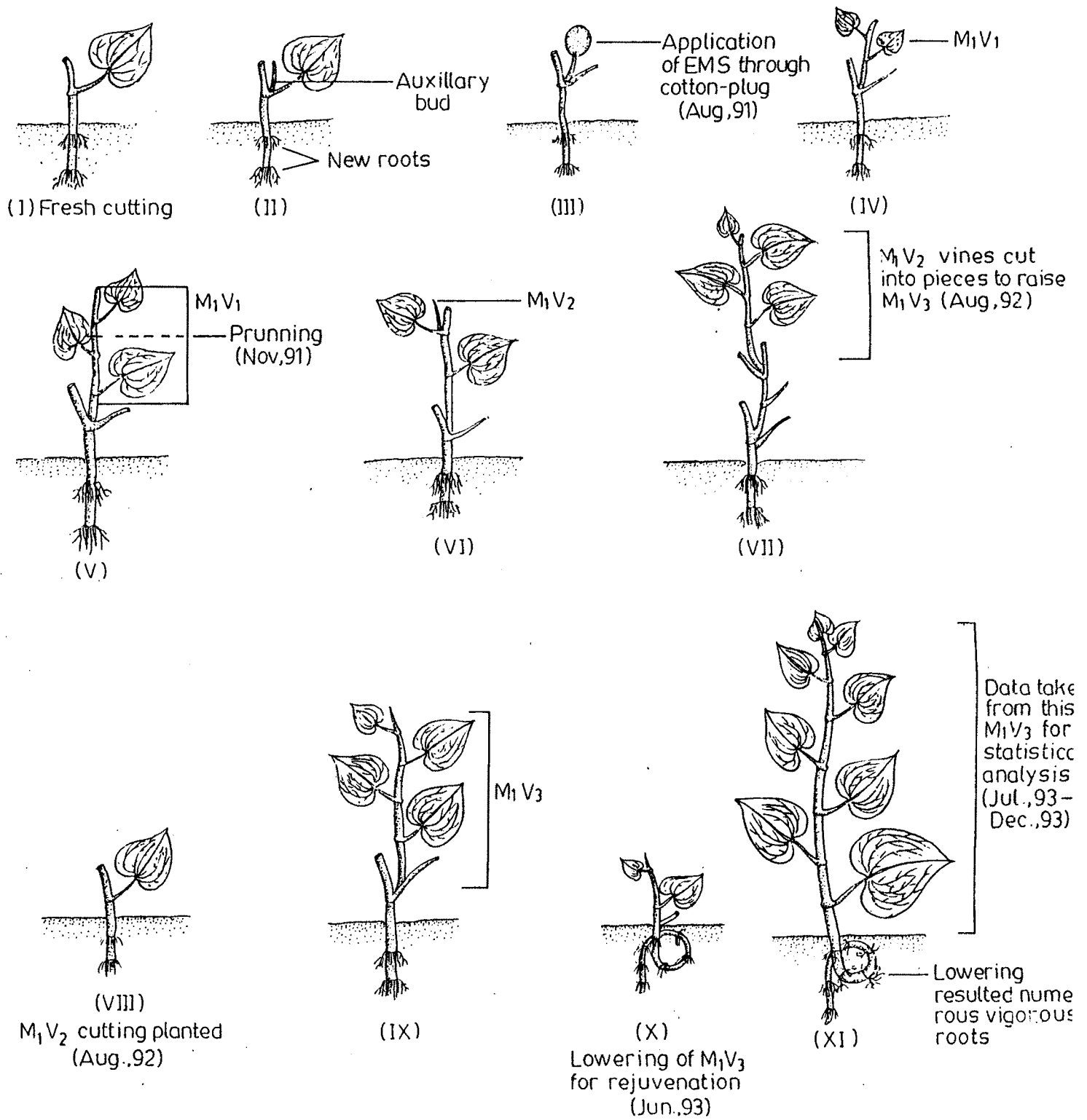


Diagram 1: Handling of mutagenized population induced by EMS (Fig.1-XI) and γ -rays (Fig. IV-XI)

lowering was done to have more vigorous vines. Data were collected from those vines (M_1V_3) during July, 1993 to December, 1993 for statistical analysis.

(iii) Growing of the vines for study of artificial variability induced by gamma-rays: The cultivar Simurali Bangla was selected for this study. Cuttings comprising of two nodes and one internode (small size was taken for practical expediency) were subjected to 2 KR, 5 KR and 10 KR radiation at Jute Agricultural Research Institute, ICAR, Barrackpore, West Bengal. A set of control cuttings of similar size were also taken to JARI. These untreated cuttings were handled similarly as those of the treated cuttings to observe any physical or physiological injuries caused by the transportation to the Institute. All the cuttings (both irradiated and control) were then planted in large earthen pots in Aug. 1991. Each pots, having four cuttings, were kept within the well maintained conservatory and nourished properly. After 12-17 days the auxillary buds (M_1V_1) started growth and development. The record on survivality was noted after 30 days of irradiation. Both the irradiated and control vines were handled in the same way as done in case of vines treated by EMS to raise the M_1V_3 generation (Diagram 1). This M_1V_3 generation was considered for collection of various quantitative data during July, 1993 to December, 1993 for statistical analysis.

3.3.2 Data Recording: For collection of data from the natural entries (27 types), the entire year was demarkated into three seasons viz., winter season (comprising the months of November, December, January and February), Summer season (comprising the months of March, April, May and June) and Rainy season (comprising the months of July, August, September and October). At the end of each season data were collected and subsequently the vines were lowered for rejuvenation. The process was continued from October, 1991 to October, 1993 (7 times). During collection of data on the following 15 metric characters (except internodal length) the 6th, 7th and 8th leaves from the apex (6-9 weeks old) were considered after Singh *et al* (1998).

Internodal length (cm): In each replication 10 vines were randomly chosen, labelled and three measurements in each vine were noted.

Petiole length (cm): 10 vines in each replication were randomly chosen, and 3 mature leaves (6th, 7th and 8th) of each vine were taken for measuring this trait.

Leaf length and breadth (cm): Measurements of leaf length and breadth were taken from the above leaves (6th, 7th and 8th) of the labelled vines.

Leaf number/vine: Fifteen vines were chosen randomly and tagged in each replication and all the leaves in each vine were counted.

Average leaf area (sq cm): Three mature leaves (6th, 7th and 8th) of each randomly selected 10 vines were plucked and measured by leaf area meter. Then the total leaf area was divided by the number of leaves taken ($3 \times 10 = 30$).

Total leaf area/vine (sq cm): At first a correction factor was obtained in each cultivar by dividing the actual leaf area by the product of leaf length and breadth. Then this factor was multiplied by the product of leaf length and breadth to obtain estimated leaf area of another leaf. In this way all the leaves (mature and immature at a certain stage) of randomly selected 10 vines were estimated.

Leaf thickness (mm): Ten mature leaves were chosen in each replication and thickness of lamina were made through basal, middle and upper portion under a low power lens (10 x).

Shelf-life (no of days): The 6th, 7th and 8th leaves from the apex of randomly selected 10 vines were plucked and depetiolated. Only the laminar portion was kept in polythene packet under room condition. Water in the form of moisture was applied at 12 hours interval. The practice was recommended by Singh and his co-workers (1988).

Stomatal frequency (no/sq mm), Length (μ) and Breadth (μ): The stomal frequency length and breadth were measured under a compound microscope from the basal, middle and upper peels of lower epidermis of each leaf. High power lens (40X) was used for this purpose.

Stomatal index: The index was calculated as follows:

$$\text{Stomatal index (S.I.)} = \frac{\text{frequency of stomata}}{\text{frequency of stomata} + \text{frequency of epidermal cells}} \times 100$$

Chlorophyll a and b (mg/g of leaf): Spectrophotometric determination of chlorophyll a and b was carried out following Ranganna (1977).

For study of variation, induced by chemical and physical mutagens, data were collected during the period of July, 1993 to December, 1993 (the main betel leaf growing season). For statistical analysis all the vines in each treatment were considered for measuring the plant height. In case of all other characters the same procedure was followed, as stated earlier, in each treatment (not in replication).

Before estimation of different genetic parameters on the various characters, data were collected in different seasons of different years. For practical expediency the averaged data of the same season in different years were considered. It was observed that there were no significant difference in the data

collected during different years of the same season. A test of significance was carried out for the purpose as follows.

The larger variance ratio of the genotypes of one season was divided by the smaller variance ratio of the same genotype of another season. Then the resultant was compared to the table value of F at error degrees of freedom. In case of all the characters the resultant was lower than the table value which indicated the insignificant difference in the data of the same season collected in different years (Chandel, 1978).

3.3.3. Statistical Analysis :

3.3.3.1 Determination of Anova: Analysis of variance and covariance for each character and each pair of characters respectively were computed for genotypes grown in a replicated trial according to a Randomised Complete Block Design. The expectation of mean squares and mean cross products are given below:

Source	Analysis of variance		Analysis of covariance	
	M.S.	Expectation of M.S.	M.S.	Expectation of M.S.
Replications	Mr_{11}	$\sigma^2_{e_{11}} + g\sigma^2_{r_{11}}$	Mr_{12}	$\sigma^2_{e_{12}} + g\sigma^2_{r_{12}}$
Genotypes	Mg_{11}	$\sigma^2_{e_{11}} + r\sigma^2_{g_{11}}$	Mg_{12}	$\sigma^2_{e_{12}} + r\sigma^2_{g_{12}}$
Error	Me_{11}	$\sigma^2_{e_{11}}$	Me_{12}	$\sigma^2_{e_{12}}$

where $\sigma^2_{e_{11}}$, $\sigma^2_{g_{11}}$ and $\sigma^2_{r_{11}}$ are variances due to environments, genotypes and replications respectively of character X_1 . Similarly $\sigma^2_{e_{12}}$, $\sigma^2_{g_{12}}$ and $\sigma^2_{r_{12}}$ are covariances due to environments, genotypes and replications respectively of characters X_1 and X_2 and r is the number of replication.

3.3.3.2 Estimation of variances, heritability and genetic advance:

The genotypic and phenotypic variances ($\sigma^2_{g_{11}}$ and $\sigma^2_{p_{11}}$) and covariances ($\sigma^2_{g_{12}}$ and $\sigma^2_{p_{12}}$) were estimated following Panse and Sukhatme (1978) as follows:

$$\begin{aligned}\sigma^2_{g_{11}} &= (Mg_{11} - Me_{11})/r; & \sigma^2_{p_{11}} &= \sigma^2_{g_{11}} + \sigma^2_{e_{11}} \\ \sigma^2_{g_{12}} &= (Mg_{12} - Me_{12})/r; & \sigma^2_{p_{12}} &= \sigma^2_{g_{12}} + \sigma^2_{e_{12}}\end{aligned}$$

The genotypic coefficients of variation (GCV) and phenotypic coefficient of variation were computed following Burton (1952): where

$$\text{G.C.V.} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \times 100$$

$$\text{P.C.V.} = \frac{\sqrt{\sigma_p^2}}{\bar{x}} \times 100 \quad \text{in which } \bar{x} \text{ is the experimental mean for a particular character.}$$

The heritability (in broad sense) was estimated according to Hanson *et al.* (1956).

$$\text{where, } H(\%) = (\sigma_g^2 / \sigma_p^2) \times 100$$

The genetic advance (G.A.) was calculated following Johnson *et al.* (1955)

$$\text{where G.A.} = (\sigma_g^2 / \sigma_p^2) \times K \times \sigma_p$$

in which σ_p = phenotypic standard deviation

K = selection differential, a constant 2.06 for 5% select.

And genetic advance as percentage of mean was calculated by:-

$$\text{GA as \% of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

3.3.3.3. Estimation of correlation coefficients :

The phenotypic and genotypic correlation coefficients for all possible combinations were computed from the phenotypic and genotypic variances and covariances following Johnson *et al.* (1955): where

$$\text{Phenotypic correlation coefficient, } r_p(x_1 x_2) = \frac{\text{COV}_p(x_1 x_2)}{\sqrt{V_p(x_1) \times V_p(x_2)}}$$

$$\text{Genotypic correlation coefficient, } r_g(x_1 x_2) = \frac{\text{COVg}(x_1 x_2)}{\sqrt{Vg(x_1) \times Vg(x_2)}}$$

in which $\text{COVp}(x_1 x_2)$ and $\text{COVg}(x_1 x_2)$ are phenotypic and genotypic covariance respectively between character x_1 and x_2

$Vp(x_1)$ and $Vg(x_1)$ are phenotypic and genotypic variances respectively of character x_1 : and

$Vp(x_2)$ and $vg(x_2)$ are phenotypic and genotypic variances respectively of character x_2 .

3.3.3.4. Path - coefficients analysis :

It was conducted as described by Dewey and Lu (1959) at the phenotypic and genotypic levels by solving a set of simultaneous equations which express the basic relationship between correlation and path coefficients.

The direct and indirect path coefficient:

$$\begin{Bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{Bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdot & \cdot & \cdot & r_{1n} \\ r_{21} & r_{22} & \cdot & \cdot & \cdot & r_{2n} \\ \vdots & \vdots & \ddots & \ddots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdot & \cdot & \cdot & r_{nn} \end{bmatrix} \begin{Bmatrix} ry_1 \\ ry_2 \\ \vdots \\ ry_n \end{Bmatrix}$$

where, $r_{11}, \dots, r_{nn}$ represent the phenotypic or genotypic correlations among independent variables. $ry_1, \dots, ry_n$ represent phenotypic or genotypic correlations between dependent and independent variables,

$P_1, \dots, P_n$ are direct paths.

Indirect effects for the first variable are-

$$r_{11} \times P_1, r_{12} \times P_2, \dots, r_{1n} \times P_n$$

$$(\text{Residual effect})^2 = 1 - P_1 \times ry_1 - P_2 \times ry_2 \dots - P_n \times ry_n$$

3.3.3.5. Genetic Divergence

a) Test of significance (Wilk's criterion):

After testing for the differences between populations (genotypes) for each character a simultaneous test of significance for differences in the mean values of a number of correlated variable of 15 characters (variables) was carried out by using a 'V' statistic which in turn utilizes "Wilk's criterion" (Rao,1952). The sum of squares and sum of products of error and error + variety were used for this purpose. The estimation of "Wilk's criterion" was done using the following relationship.

$$\Lambda = \frac{|E|}{|E + V|}$$

where, $|E|$ was the determinant of error sum of squares and sum of products matrix and $|E + V|$ was the determinant of the error + varieties sum of squares and sum of products matrix.

The significance of ' Λ ' was tested by χ^2 as $\chi^2_{pq} = V = -m \log \hat{e}$, where $m = n - (p+q+1)/2$ with pq degrees of freedom; in which, n = total number of observations - 1

$q = K-1$ and

K = number of populations

b) D^2 -Statistic (Mahalanobis, 1936):

D^2 statistic was used for assessing the genetic divergence between populations. The generalised distance between any two population/genotypes is defined as:

$$D^2 = (\lambda_{ij}) \delta_i \delta_j$$

where, (λ_{ij}) is the reciprocal matrix to the common dispersion matrix, δ_i is the difference between the mean values of the two populations for the i -th character and δ_j is the difference between the mean values of the two populations for the j -th character. These quantities were estimated by the D^2 - statistic (Majumder and Rao, 1958) as

$$D^2 = (S^{ij}) d_i d_j$$

where, (S^{ij}) is the sample estimate of (λ_{ij}) and d_i of δ_i . Since the formula for computation requires the inversion of the matrix of eleventh order, transformation of the original correlated unstandardised character means to standardised uncorrelated variables was done to simplify the computational procedure. This transformation was effected by pivotal condensation method (Rao, 1952). The significance of D^2 values was tested by treating them as χ^2 values and $(V-1)P$ degrees of freedom at the $p=0.05$ level of significance, where V is the number of population and P the number of variables.

c) Determination of group constellations:

The grouping of the genotypes was done by using Tocher's method as described by Rao (1952). The criterion used in clustering by this method is that any two populations/genotypes belonging to the same cluster should on the average, show a smaller D^2 than those belonging to two different clusters. To start with two closely associated population and finding a third

population which had the smallest average D^2 from the first two. Similarly the fourth was chosen to have the smallest average from the first three, and so on. At certain stage when it was felt that after adding a particular population there was abrupt increase in the average D^2 that population was not considered for including in that cluster. The groups of the first cluster was then omitted and the rest were treated similarly. This process was continued till all the populations were included into one or other clusters.

d) Average intra and inter-cluster distance and cluster diagram:

For the measure of intra-cluster distances the formula $\Sigma D_i^2/n$ was used, where ΣD_i^2 is the sum of distances between all possible combinations (n) of populations (genotypes included in a cluster).

For calculating inter-cluster distances the formula $\Sigma D_{ij}^2/n_i n_j$ were used; where, ΣD_{ij}^2 is the sum of all possible D^2 values between all the members of two clusters, n_i is the number of population in cluster i and n_j is the number of population in cluster j.

The square root of the average D^2 values of intra and inter-cluster distances were utilized to draw the cluster diagram.

3.3.6 Phenotypic stability analysis:

For stability analysis the data recorded in different seasons (Winter , Summar and Rainy) were first subjected to environment wise (season) analysis of variance followed by pooled analysis of the data. After testing the significant interaction

between genotypes and environments, stability analysis was carried out using the model of Eberhart and Russell (1966) as follows:

$$Y_{ij} = m + B_i I_j + \delta_{ij} \quad (i=1.2\dots t \text{ and } j= 1.2\dots 5)$$

where, Y_{ij} = mean of i th variety in j th environment,

m = mean of all the varieties over all the environments

B_i = the regression coefficient of the i th variety on the environmental index which measures the response of the variety to varying environments,

I_j = the environmental index (i.e. deviation of the mean of all the varieties at a given location (here season) from the overall mean

$$= \frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts} \quad \text{with } \sum_j I_j = 0 \text{ and}$$

δ_{ij} = the deviation from regression of the i th variety at j th environment.

According to the model of Eberhart and Russell (1966), the total variance was divided into two components i.e. (1) genotypes and (2) environment + interaction ($G \times E$). The second component ($E + G \times E$) was further subdivided into three components viz. (a) environment linear, (b) genotype $\times$ environment (linear) and (c) pooled deviations. The S.S. due to pooled deviations were further divided into S.S. due to individual genotype. The detailed analysis of variance for the estimation of stability parameter is presented in the following page.

ANOVA for estimation of stability parameters

Source	df	s.s.	M.S.
Total	(ng-1)	$\sum_{i=1}^g \sum_{j=1}^n Y_{ij}^2 - C.F. = T.S.S$	
Genotype (g)	(g-1)	$\frac{1}{n} \sum_{i=1}^g Y_i^2 - C.F. = G.S.S.$	MS_1
Environment (E)	(n-1)	$\frac{1}{g} \sum_{j=1}^n Y_j^2 - C.F. = E.S.S.$	
G x E	(n-1)(g-1)	$T.S.S. - G.S.S. - E.S.S.$	MS_2
E + G x E	g(n-1)	$\sum_{i=1}^g \sum_{j=1}^n Y_{ij}^2 - \sum_{i=1}^g Y_i^2 / n$	
E (linear)	1	$\frac{1}{g} - \left(\sum_{j=1}^n Y_j I_j \right)^2 / \sum_{j=1}^n I_j^2 = E(L)S.S.$	
G x E (L)	(g-1)	$\sum_{i=1}^g \left(\sum_{j=1}^n Y_{ij} I_j \right)^2 / \sum_{j=1}^n I_j^2 - E(L)S.S$	MS_3
Pooled deviation	g(n-2)	$\sum_{i=1}^n \sum_{j=1}^n \delta_{ij}^2$	MS_4
Genotype-1	(n-2)	$\sum_{j=1}^n Y_{ij}^2 - \left(\frac{Y_i}{n} \right)^2 - \left(\sum_{j=1}^n Y_{ij} I_j \right)^2 / \sum_{j=1}^n I_j^2 = \sum_{j=1}^n \delta_{ij}^2$	
Genotype-g	g(n-2)	$\sum_{i=1}^n Y_{gi}^2 - \left(\frac{Y_g}{n} \right)^2 - \left(\sum_{j=1}^n Y_{gi} I_j \right)^2 / \sum_{j=1}^n I_j^2 = \sum_{j=1}^n \delta_{gi}^2$	
Pooled error	n(g-1)(n-2)	$\sum_{j=1}^n \delta_{ej}^2 / n$	MS_5

where g = number of genotypes; n = number of environments and
 S_e^2 = estimate of error mean square at each environment.

Two parameters of stability were calculated viz. (a) the regression coefficient (b_i) and (b) mean square deviation ($\bar{S}_d^2$) from linear regression, where

$$(a) \text{ Regression coefficient } (b_i) = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

in which $\sum_j Y_{ij} I_j$ is the sum of products and $\sum_j I_j^2$ is the sum of squares.

(b) Mean square deviation from linear regression

$$(\bar{S}_d^2) = \frac{\sum_j \Delta_{ij}^2}{s-2} - \frac{S_e^2}{r}$$

in which

$$\sum_j S_{ij}^2 = \left[\sum_j Y_{ij}^2 - \frac{Y_i^2}{t} \right] - \frac{(\sum_j Y_{ij} I_j)^2}{\sum_j I_j^2}$$

and S_e^2 = the estimate of pooled error

The following test of significance were made:

(i) The deviation of b_i values from the unit was tested using 't' test. For null hypothesis.

$$H_0: B_i = 1$$

$$(b-1)$$

$$t = \frac{(b-1)}{SE(b)} \quad \text{on } g(n-2) \text{ d.f. at 5\% and 1\% level}$$

$$\text{where } SE(b) = \frac{\sqrt{\text{Pooled deviation MS}}}{\sum_{j=1}^n \Delta I_j^2}$$

(ii) Deviation from regression for each genotype was tested using the 'F' test,

where

$$F = \left(\sum_{j=1}^n s_{ij}^2 / n-2 \right) / MS_5 \quad \text{on } n-2 \text{ and pooled error d.f. at 5\%}$$

and 1% level of significance.

3.3.3.7 Statistical analysis of mutant population:

To estimate the mean difference between controls and mutant populations (induced by chemical and physical mutagens) the 't' test was applied following Singh and Choudhary (1985) as follows:

$$t = \bar{x}_1 - \bar{x}_2 / \sqrt{s_1^2/n_1 + s_2^2/n_2}$$

where, $\bar{x}_1$ and $\bar{x}_2$ are two sample means

s_1 and s_2 are corresponding variances of the two samples and

n_1 and n_2 are number of observation of the samples.

CHAPTER - IV

RESULTS

4.1 ASSESSMENT OF VARIABILITY

All the 15 characters studied in 27 genotypes showed highly significant variance ratio (F value) in all the seasons (Table 3). The results indicated thereby, the existence of genetic variability among the genotypes taken in this study.

The different parameters of variability for each character in different seasons are presented in Table 4. The results of each character are described below.

Internodal length: In winter, summer and rainy, the mean values of this character were 6.24, 5.85 and 6.45 cm respectively. The magnitude of phenotypic variances were 1.73, 1.67 and 2.14 respectively in winter, summer and rainy season and those of genotypic variances for the seasons were 1.53, 1.44 and 1.96 respectively. The differences between the estimates of phenotypic and genotypic variances for all the seasons were considerably narrow. The coefficients of variation for phenotype (21.08, 22.09 and 22.68 for winter, summer and rainy respectively) and for genotype (19.82, 20.51 and 21.72 in winter, summer and rainy respectively) were more or less similar in magnitude. The heritability estimates in broad sense were as high as 88.44%, 86.23% and 91.59% respectively in winter, summer and rainy. Genetic advances were fairly higher in magnitude for winter (2.38), summer (2.29) and rainy (2.76).

Petiole length: The means of this character were 5.29,

Table 3 : Analysis of variance for 15 characters in 27 genotypes in different seasons

Characters	Season	Mean sum of squares		F - values	
		Replications (df=2)	Treatments (df=26)	Replications	Treatments
1 Internodal length (cm)	Winter	0.27	4.80	1.36	24.15**
	Summer	0.33	4.55	1.41	19.61**
	Rainy	0.08	6.07	0.44	34.64**
2 Petiole length (cm)	Winter	0.09	2.88	0.53	15.83**
	Summer	0.15	2.36	0.96	15.22**
	Rainy	0.06	7.52	0.30	36.18**
3 Leaves/vine (no)	Winter	3.32	29.94	3.01	27.19**
	Summer	0.86	28.61	0.82	27.09**
	Rainy	0.73	39.99	0.36	19.77**
4 Leaf length (cm)	Winter	0.43	9.31	0.41	8.84**
	Summer	2.17	11.03	1.51	7.66**
	Rainy	0.43	15.74	0.50	18.43**
5 Leaf breadth (sq cm)	Winter	0.08	9.64	0.32	39.34**
	Summer	0.33	8.95	1.00	26.84**
	Rainy	0.89	15.36	2.28	39.53**
6 Avg.leaf area (sq cm)	Winter	55.75	1934.28	1.61	55.96**
	Summer	2.12	3093.30	0.06	91.03**
	Rainy	27.84	5340.07	0.31	59.56**
7 Leaf thickness (mm)	Winter	0.0001	0.0023	0.63	11.33**
	Summer	0.0004	0.0024	1.29	8.13**
	Rainy	0.0001	0.0024	0.42	10.50**
8 Stomatal freq. (no /sq mm)	Winter	114.25	5286.83	0.63	29.28**
	Summer	149.06	4076.60	0.66	18.10**
	Rainy	362.00	3762.35	1.61	16.78**

Table 3 continued

Characters	Season	Mean sum of squares		F - values	
		Replications (df=2)	Treatments (df=26)	Replications	Treatments
9 Stomatal index	Winter	0.22	15.18	0.23	15.26**
	Summer	0.15	13.18	0.11	9.77**
	Rainy	0.99	13.22	0.97	12.91**
10 Stomatal length (μ)	Winter	2.38	12.05	1.90	9.66**
	Summer	2.31	17.82	0.89	6.84**
	Rainy	1.73	17.68	0.77	7.82**
11 Stomatal breadth (μ)	Winter	0.04	9.43	0.06	15.12**
	Summer	0.59	10.13	0.53	9.05**
	Rainy	1.59	13.24	1.64	13.67**
12 Chlorophyll a (mg/g)	Winter	0.0050	0.1600	0.92	26.98**
	Summer	0.0009	0.1675	0.07	13.09**
	Rainy	0.0030	0.1981	0.20	12.62**
13 Chlorophyll b (mg/g)	Winter	0.0010	0.0740	0.68	32.11**
	Summer	0.0009	0.0950	1.31	13.66**
	Rainy	0.0020	0.1510	3.48*	26.34**
14 Shelf - life (days)	Winter	7.81	49.07	3.79*	23.84**
	Summer	0.42	37.71	0.19	16.50**
	Rainy	1.73	31.53	0.78	14.28**
15 Total leaf area/vine (sq cm)	Winter	15803.00	357416.08	1.91	43.21**
	Summer	3092.00	706282.23	0.22	50.52**
	Rainy	6568.00	1782983.40	0.11	29.18**

* Significant at 0.05 level

** Significant at 0.01 level

Table 4 : Mean, variability, heritability (broad sense) and genetic advance for 15 characters in different seasons

Characters	Season	Mean	Coefficient of variation				Heritability (broad sense) (%)	Genetic advance (GA)	GA as % of mean
			Variance		variation				
			Phenoty -pic	Genoty -pic	Phenoty -pic	Genoty -pic			
1 Internodal length (cm)	Winter	6.24 ± 0.36	1.73	1.53	21.08	19.82	88.44	2.38	38.14
	Summer	5.05 ± 0.39	1.69	1.44	22.09	20.51	86.23	2.29	39.14
	Rainy	6.45 ± 0.34	2.14	1.96	22.68	21.72	91.59	2.76	42.79
2 Petiole length (cm)	Winter	5.29 ± 0.35	1.09	0.90	19.74	17.93	82.57	1.78	33.65
	Summer	5.41 ± 0.32	0.89	0.73	17.44	15.79	82.02	1.59	29.39
	Rainy	6.16 ± 0.37	2.65	2.44	26.43	25.36	92.08	3.09	50.16
3 Leaves/vine (no)	Winter	8.69 ± 0.86	10.72	6.61	37.68	29.58	61.66	4.16	47.87
	Summer	10.43 ± 0.84	10.24	6.18	30.68	23.83	60.35	3.98	38.16
	Rainy	12.56 ± 1.16	14.68	9.66	30.51	24.75	65.80	5.19	41.32
4 Leaf length (cm)	Winter	11.32 ± 0.84	3.81	2.76	17.24	14.68	72.44	2.91	25.71
	Summer	12.41 ± 0.98	4.84	3.40	17.72	14.86	70.25	3.18	25.62
	Rainy	13.83 ± 0.75	5.81	4.96	17.43	16.10	85.37	4.24	30.65
5 Leaf breadth (cm)	Winter	8.34 ± 0.40	3.38	3.13	22.04	21.21	92.60	3.51	42.09
	Summer	9.24 ± 0.47	3.21	2.87	19.39	18.33	89.41	3.28	35.50
	Rainy	10.44 ± 0.51	5.38	4.99	22.22	21.40	92.75	4.43	42.43
6 Avg.leaf area (sq cm)	Winter	67.40 ± 4.80	87.52	52.96	13.88	10.80	60.51	11.66	17.30
	Summer	82.47 ± 4.76	125.76	91.98	13.60	11.63	73.14	16.86	20.44
	Rainy	101.63 ± 7.73	237.77	148.12	15.17	11.98	62.30	19.79	19.47
7 Leaf thickness (mm)	Winter	0.27 ± 0.01	0.0009	0.0007	11.11	9.80	77.78	0.048	17.78
	Summer	0.27 ± 0.01	0.0010	0.0007	11.71	9.80	70.00	0.046	17.04
	Rainy	0.27 ± 0.01	0.0009	0.0007	11.11	9.80	77.78	0.048	17.78
8 Stomatal freq.(no /sq mm)	Winter	148.42 ± 10.97	1882.66	1702.09	29.23	27.80	90.41	80.80	54.44
	Summer	148.87 ± 12.25	1509.00	1283.80	26.09	24.07	85.08	68.10	45.74
	Rainy	144.68 ± 12.22	1404.22	1180.07	25.90	23.73	84.04	64.87	44.84

Contd. next page

Table 4 continued

Characters	Season	Mean	Coefficient of variation				Heritability (broad sense) (%)	Genetic advance (GA)	GA as % of mean
			Variance		variation				
			Phenoty -pic	Genoty -pic	Phenoty -pic	Genoty -pic			
9 Stomatal index	Winter	26.98 ± 0.81	5.73	4.73	8.87	8.06	82.55	4.07	15.08
	Summer	28.23 ± 0.95	5.29	3.94	8.15	7.03	74.48	3.53	12.50
	Rainy	29.41 ± 0.83	5.09	4.06	7.67	6.85	79.76	3.71	12.61
10 Stomatal length (μ)	Winter	29.71 ± 0.91	3.75	3.60	6.52	6.39	69.33	2.77	9.32
	Summer	31.02 ± 1.32	7.67	5.07	8.93	7.26	66.10	3.77	12.15
	Rainy	31.05 ± 1.23	7.40	5.04	8.76	6.47	68.11	3.82	12.30
11 Stomatal breadth (μ)	Winter	18.48 ± 0.64	3.55	2.93	10.19	9.26	82.53	3.20	17.32
	Summer	19.23 ± 0.86	4.12	3.00	10.56	9.01	72.82	3.04	15.81
	Rainy	19.26 ± 0.80	5.06	4.09	11.68	10.50	80.83	3.75	19.47
12 Chlorophyll a (mg/g)	Winter	0.79 ± 0.06	0.06	0.05	31.01	28.30	83.33	0.42	53.16
	Summer	1.24 ± 0.09	0.16	0.15	32.26	31.23	93.75	0.77	62.07
	Rainy	1.35 ± 0.10	0.08	0.06	20.95	18.14	75.00	0.44	32.59
13 Chlorophyll b (mg/g)	Winter	0.44 ± 0.01	0.022	0.029	33.71	32.14	90.91	0.28	63.64
	Summer	0.72 ± 0.07	0.036	0.029	26.35	23.65	80.56	0.31	43.05
	Rainy	0.80 ± 0.06	0.054	0.048	29.05	27.39	88.89	0.43	53.75
14 Shelf - life (days)	Winter	20.22 ± 1.17	17.73	15.67	20.82	19.58	88.38	7.67	37.93
	Summer	16.99 ± 1.23	15.00	11.81	22.79	20.23	78.73	6.28	36.91
	Rainy	18.61 ± 1.21	11.98	9.77	18.60	16.80	81.55	5.81	31.22
15 Total leaf area/vine (sq cm)	Winter	607.22 ± 74.17	427.91	9157.18	21.74	15.56	52.54	142.88	23.53
	Summer	884.64 ± 96.32	863.32	18882.52	20.49	15.53	57.45	214.88	24.25
	Rainy	1344.66 ± 20.61	308.31	39065.81	18.41	14.70	63.72	325.01	24.17

5.41 and 6.16 cm respectively in winter, summer and rainy. The phenotypic variances like 1.09, 0.89 and 2.65 respectively for three consecutive seasons and those of genotypic variances as 0.90, 0.73, and 2.44 respectively showed considerably minimum difference between the two parameters within a season. It was noted that the magnitudes of phenotypic and genotypic variances in rainy season were comparatively larger than the other two seasons. The estimates of phenotypic coefficients of variation (PCV) were 19.74, 17.44 and 26.43 respectively and those of genotypic coefficients of variation (GCV) were 17.93, 15.79 and 25.36 respectively in the three consecutive seasons. The estimates of heritability for winter, summer and rainy were as high as 82.57%, 82.02% and 92.08% respectively. The genetic advances were low in winter (1.78) and summer (1.59) seasons but it was very high in rainy season (3.09).

Number of leaves/vine: In winter, summer and rainy the means of this character were 8.69, 10.43 and 12.56 respectively. The phenotypic variances were found to be 10.72, 10.24 and 14.68 in winter, summer and rainy season respectively whereas the genotypic variances were 6.61, 6.18 and 9.66 in those consecutive seasons. There was considerable difference between these two parameters in each season. The estimate of PCVs were considerably higher in magnitude as compared to the estimate of GCVs in each of the three seasons. The PCV were 37.68, 30.68 and 30.51 and those of GCVs were 29.58, 23.83 and 24.75 respectively in the winter, summer and rainy season. The magnitude of heritabilities

were 61.66% in Winter, 60.35% in summer and 65.80% in rainy season. The genetic advances were as high as 4.16, 3.98 and 5.19 respectively in winter, summer and rainy season.

Leaf length: The mean performances of this character were 11.32, 12.41 and 13.83 cm respectively in winter, summer and rainy season. The estimates of phenotypic and genotypic variances were 3.81 and 2.76 respectively in winter, 4.84 and 3.40 respectively in summer and 5.81 and 4.96 respectively in rainy season. The estimates of PCV (17.24) and GCV (14.68) in winter, those of PCV (17.72) and GCV (14.86) in summer and those of PCV (17.43) and GCV (16.10) in rainy were more or less similar in magnitude. The estimates of heritability were 72.44%, 70.25% and 85.37% respectively in winter, summer and rainy season and those of genetic advances were 2.91, 3.18 and 4.24 respectively for the above seasons. All the estimates showed higher in magnitude in rainy season as compared to other seasons.

Leaf breadth: The mean values of this character were 8.34, 9.24 and 10.44 cm respectively in winter, summer and rainy season. The phenotypic and genotypic variances were 3.38 and 3.13 respectively in winter, 3.21 and 2.87 respectively in summer and 5.38 and 4.99 respectively in rainy season. The estimates of PCVs were 22.01, 19.39 and 22.22 respectively in winter, summer and rainy season and those of GCVs were 21.21, 18.33 and 21.40 respectively for the those consecutive seasons. The estimates of heritability were as high as 92.60%, 89.41% and 92.75% respectively in winter, summer and rainy season and the genetic

advances were also fairly higher in magnitude for winter (3.51), summer (3.28) and rainy season (4.43).

Average leaf area: In winter, summer and rainy season the means of this character were 67.40 , 82.47 and 101.63 sq cm respectively. The magnitude of phenotypic variances were as high as 87.52, 125.76 and 237.77 respectively in winter, summer and rainy season and those of genotypic variances were 52.96, 91.98 and 148.12 respectively for those seasons. The differences between the estimates of phenotypic and genotypic variances were considerably high within each season. The differences between PCVs (13.88, 13.60 and 15.17 respectively in winter, summer and rainy season) and GCVs (10.80, 11.63 and 11.98 respectively for those seasons) in the respective seasons were also considerably high to some extent. The estimates of heritability were 60.51%, 73.14% and 62.30% respectively in winter, summer and rainy season. The genetic advances were relatively lower in magnitude in rainy (19.79), summer (16.89) and winter (11.66) season.

Leaf thickness: The mean value of this character was 0.27 mm throughout the year i.e. there was no variation in mean in different seasons. The other parameters like phenotypic and genotypic variances, PCVs and GCVs etc. also showed more or less similar in magnitude in each season. The estimates of heritability were 77.78%, 70.00% and 77.78% respectively in winter, summer and rainy season. The genetic advances for winter, summer and rainy season were 0.048, 0.046 and 0.048

respectively.

Stomatal frequency: In winter, summer and rainy the means of this character were 148.42, 148.87 and 144.68 per sq mm respectively. There was no significant difference among the seasons for this character. The estimates of phenotypic and genotypic variances were 1882.66 and 1702.09 respectively in winter, 1509.00 and 1283.80 respectively in summer and 1404.22 and 1180.07 respectively in rainy season. The difference between the estimates of PCVs (29.23, 26.09 and 25.90 respectively in winter, summer and rainy season) and GCVs (27.80, 24.07 and 23.73 respectively in winter, summer and rainy season) were quite low. The heritabilities were as high as 90.41%, 85.08% and 84.04% respectively in winter, summer and rainy season and those of genetic advances for these consecutive seasons were as high as 80.80, 68.10 and 64.87 respectively.

Stomatal index : The mean values of this character were 26.98, 28.23 and 29.41 respectively in winter, summer and rainy season. The phenotypic and genotypic variances were 5.73 and 4.73 respectively in winter, 5.29 and 3.94 respectively in summer and 5.09 and 4.06 respectively in rainy season. The estimates of PCVs and GCVs were 8.87 and 8.06 respectively in winter, 8.15 and 7.03 respectively in summer and 7.67 and 6.85 respectively in rainy. The estimated heritabilities were as high as 82.55%, 74.48% and 79.76% respectively in winter, summer and rainy. The genetic advances were considerably lower in magnitude for all the three seasons. The magnitudes were 4.07, 3.53 and 3.71 respectively in

winter, summer and rainy.

Stomatal length : The mean values of this character were estimated as 29.71, 31.02 and 31.05 μ respectively in winter, summer and rainy. The magnitude of phenotypic variances were 3.75, 7.67 and 7.40 respectively in winter, summer and rainy season and those of genotypic variances for the respective seasons were 3.60, 5.07 and 5.04. The coefficients of variation for phenotype and genotype were 6.52 and 6.39 respectively in winter, 8.93 and 7.26 respectively in summer and 8.76 and 6.47 respectively in rainy. The estimate of heritabilities were 69.33%, 66.10% and 68.11% respectively in winter, summer and rainy and those of genetic advances were as low as 2.77, 3.77 and 3.82 respectively for the respective seasons.

Stomatal breadth : The mean values of this character were 18.48, 19.23 and 19.26 μ respectively in winter, summer and rainy. The magnitude of phenotypic and genotypic variances were 3.55 and 2.93 respectively in winter, 4.12 and 3.00 respectively in summer and 5.06 and 4.09 respectively in rainy season. The coefficients of variation for phenotype were 10.19, 10.56 and 11.68 respectively in winter, summer and rainy season and for genotypes were 9.26, 9.01 and 10.50 respectively for those seasons. The estimates of heritability were as high as 82.53%, 72.82% and 80.83% respectively for winter, summer and rainy. In winter, summer and rainy the genetic advances were 3.20, 3.04 and 3.73 respectively.

Chlorophyll a: The mean values for chlorophyll a content showed a increasing trend from winter to rainy. In winter, summer and rainy, the said contents were 0.79, 1.24 and 1.35 mg/g respectively. The variances for phenotype and genotype were 0.06 and 0.05 respectively in winter, 0.16 and 0.15 respectively in summer and 0.08 and 0.06 respectively in rainy. The differences between the phenotypic and genotypic variances in winter and summer seasons were considerably low as compared to rainy season. The estimates of PCV and GCV were 31.01 and 28.30 respectively in winter, 32.26 and 31.23 respectively in summer and 20.95 and 18.14 respectively in rainy. The heritabilities were as high as 83.33%, 93.75% and 75.00% respectively in winter summer and rainy and the genetic advances were very low in winter (0.42) and rainy (0.44) as compared to summer (0.77).

Chlorophyll b: The means of this character were 0.44, 0.72 and 0.80 mg/g respectively in winter, summer and rainy. The values showed a increasing trend from winter to rainy. The difference between the estimates of phenotypic and genotypic variances were considerably lower in magnitude in each season. The estimates of PCV and GCV were 33.71 and 32.14 respectively in winter, 26.33 and 23.65 respectively in summer and 29.05 and 27.39 respectively in rainy. The estimate of heritabilities were as high as 90.91%, 80.56% and 88.89% respectively in winter, summer and rainy and the genetic advances were also very high over the seasons. The estimates of GA were 0.28, 0.31 and 0.43 respectively in winter, summer and rainy.

Shelf-life : In winter, summer and rainy season, the mean values were 20.22 , 16.99 and 18.61 days respectively. The variances for phenotype and genotype were 17.73 and 15.67 respectively in winter, 15.00 and 11.81 respectively in summer and 11.98 and 9.77 respectively in rainy. The differences between the estimates of PCVs and GCVs within each season were considerably low. The PCV and GCV were 20.82 and 19.58 respectively in winter, 22.79 and 20.23 respectively in summer and 18.60 and 16.80 respectively in rainy. The estimate of heritabilities were 88.38%, 78.38% and 81.55% respectively in winter, summer and rainy and the genetic advances were 7.67 , 6.28 and 5.81 respectively in the above sequence of the seasons.

Total leaf area/vine: The values indicated as the means of this character were 607.22, 884.64 and 1344.66 sq cm respectively in winter, summer and rainy. The mean performance showed a increasing trend from winter to rainy. The estimate of phenotypic variances were considerably higher in magnitude in each season and the differences between the phenotypic and genotypic variances were considerably higher in winter and summer season as compared to rainy season. The estimates of PCV and GCV were 21.74 and 15.56 respectively in winter , 20.49 and 15.53 respectively in summer and 18.41 and 14.70 respectively in rainy. The estimate of heritabilities were 52.54%, 57.45% and 63.72% respectively in winter, summer and rainy. The genetic advances were 142.88 and 214.54 and 325.01 respectively in winter, summer and rainy.

4.2 CORRELATION COEFFICIENTS

The phenotypic and genotypic correlation coefficients among 15 quantitative characters for winter, summer and rainy are presented in Table 5 and 6 respectively.

Phenotypic correlation coefficients (rph)

The association between internodal length and other characters did not come to the level of significance except petiole length and stomatal frequency. Internodal length registered significant positive correlation with petiole length in summer (0.511) and rainy (0.430) but with stomatal frequency in winter (0.410) only.

Petiole length was significantly positively correlated with leaves/vine (0.388), leaf length (0.576), stomatal length (0.425) and total leaf area per vine (0.707) in only rainy. It also showed significantly negative correlation with stomatal frequency (-0.492) in the same season. The character also registered significant positive association with leaf breadth in winter (0.385) and rainy (0.673) but with average leaf area in all the seasons (0.474, 0.405 and 0.730 respectively in winter, summer and rainy). Only in winter the significant correlations of petiole length with chlorophyll a (0.582) and chlorophyll b (0.403) were noted. Associations between petiole length and other remaining traits were not of comparable magnitude in any season.

Leaves/vine showed significant positive correlations

Table 5 : Phenotypic correlation coefficients (rph) in different seasons

Petiole length	Leaves/vine	Leaf length	Leaf breadth	Avg. leaf area	Leaf thickness	Stomatal freq.	Stomatal index	Stomatal length	Stomatal breadth	Chloro-phyll a	Chloro-phyll b	Shelf-life	Total leaf area/vine
0.135	0.077	-0.122	-0.072	-0.079	-0.059	0.410*	0.359	-0.250	-0.111	0.002	0.125	-0.175	0.053
0.511**	0.123	0.282	0.321	0.345	-0.122	0.008	0.043	0.143	-0.021	0.011	0.032	0.054	0.341
0.430*	-0.079	0.297	0.313	0.334	-0.078	-0.054	0.057	0.209	-0.143	-0.075	-0.042	0.001	0.201
	-0.095	0.326	0.385*	0.474*	-0.003	-0.289	-0.140	0.275	-0.070	0.582**	0.403*	0.099	0.244
	-0.195	0.244	0.361	0.405*	-0.050	-0.190	0.161	0.326	0.169	-0.047	0.001	0.530	0.164
	0.388*	0.576**	0.673**	0.730**	0.097	-0.492**	0.172	0.425*	0.133	0.017	-0.186	-0.222	0.707**
		0.163	0.316	0.277	0.203	-0.228	-0.097	0.219	0.432*	-0.012	-0.006	0.241	0.797**
		0.260	0.221	0.252	0.077	0.009	0.245	0.248	0.396*	0.268	0.201	-0.073	0.734**
		0.370	0.446*	0.420*	0.071	-0.297	0.342	0.404*	0.169	0.093	0.082	-0.014	0.751**
			0.839**	0.793**	0.554**	-0.372	-0.069	0.466*	0.225	0.228	0.182	0.151	0.549**
			0.766**	0.753**	0.024	-0.274	0.381*	0.326	0.396*	0.013	-0.091	0.111	0.621**
			0.849**	0.700**	-0.026	-0.287	0.106	0.374	0.193	-0.057	-0.051	0.046	0.628**
				0.847**	0.562**	-0.447*	-0.070	0.477*	0.382*	0.364	0.274	0.123	0.695**
				0.856**	0.074	-0.288	0.449*	0.395*	0.482*	0.003	-0.149	-0.080	0.674**
				0.861**	0.080	-0.363	0.240	0.436*	0.164	-0.067	-0.094	-0.069	0.797**
					0.510**	-0.416*	-0.125	0.390*	0.176	0.491**	0.220	0.129	0.774**
					0.153	-0.336	0.467*	0.393*	0.388*	0.006	-0.226	-0.093	0.820**
					0.179	-0.439*	0.392*	0.469*	0.195	0.001	-0.236	-0.191	0.891**
						0.044	0.151	0.109	0.357	-0.011	0.098	0.104	0.387*
						0.120	0.039	-0.017	-0.146	0.197	-0.057	0.073	0.125
						0.001	0.081	0.008	-0.166	0.060	-0.020	0.007	0.123
								0.520**	-0.637**	-0.252	-0.273	-0.023	-0.483*
								0.034	-0.313	-0.204	0.224	0.271	-0.050
								0.055	-0.355	-0.218	0.217	0.274	0.067
													-0.442*
													-0.157
													0.469*
													0.417*
													0.338
													0.383*
													0.497**
													0.363
													0.462*
													0.156
													0.298
													0.181
													0.059
													0.117
													-0.055
													-0.123
													0.203
													-0.147
													-0.158

** Significant at 1% level

with leaf breadth (0.446), average leaf area (0.420) and stomatal length (0.404) only in rainy but with stomatal breadth in winter (0.432) and summer (0.396). This character was found to be highly positively correlated at phenotypic level with total leaf area/vine in all the seasons (0.797, 0.734 and 0.751 respectively in winter, summer and rainy).

In all the seasons, leaf length exhibited considerably high positive correlations with leaf breadth (0.839, 0.766 and 0.849 respectively in winter, summer and rainy), average leaf area (0.793, 0.753 and 0.700 respectively in winter, summer and rainy) and with total leaf area/vine (0.549, 0.621 and 0.628 in aforesaid seasons) at phenotypic level. This character recorded positive and significant correlations but comparatively lower in magnitude with leaf thickness (0.554) and stomatal length (0.466) in winter only and with stomatal index (0.381) and stomatal breadth (0.396) in summer only. The character, leaf length also showed negative correlation with stomatal frequency in all the three seasons but the magnitudes did not come to the level of significance.

The associations of leaf breadth with average leaf area (0.847, 0.856, 0.861 respectively in winter summer and rainy) and total leaf area/vine (0.695, 0.674 and 0.797 respectively in winter, summer and rainy) were significantly very high in magnitude and positive in all the three seasons. The character, leaf breadth showed significant positive correlations in lower

magnitude with stomatal length in all the three seasons and with stomatal breadth in winter and summer only. The trait also registered significant positive correlations with leaf thickness (0.562) in winter and with stomatal index (0.449) in summer only. It showed negative correlation coefficient with stomatal frequency in all the three seasons but only the magnitude recorded in winter came to the level of significance.

The magnitudes of association of average leaf area with total leaf area/vine in winter, summer and rainy were 0.774, 0.820 and 0.891 respectively. The correlation between average leaf area and stomatal length was also positive and significant but lower in magnitude for all the three seasons. The average leaf area registered positive and significant correlation coefficients with leaf thickness (0.510) and chlorophyll a (0.491) in winter only. This character also showed significantly positive correlations with stomatal index in summer and rainy and with stomatal breadth in only summer. The correlation coefficient between average leaf area and stomatal frequency was negative in all the three seasons but only in winter (-0.416) and rainy (-0.439) seasons the magnitudes came to the level of significance.

The association between leaf thickness and total leaf area/vine (0.387) was considerably lower in magnitude and significant only in winter.

Stomatal frequency showed negative correlation

coefficients with maximum of the characters under study. The correlation coefficient with stomatal index was positive and highly significant (0.520) in only winter but with stomatal length and shelf-life the relationships were significant but negative in nature in the same season. The association between stomatal frequency and total leaf area /vine in rainy season only was significantly negative (-0.442).

Stomatal index showed significant positive association with total leaf area/vine in both summer (0.469) and rainy (0.417).

Stomatal length was found to be significantly positively correlated with stomatal breadth and total leaf area/vine in both summer and winter season and with shelf-life in winter only.

The association between stomatal breadth and total leaf area/vine was found to be positive and significant (0.462) only in summer.

Chlorophyll a showed significantly positive correlation with chlorophyll b in winter, summer and rainy which were respectively 0.554, 0.590 and 0.472 in magnitude.

The correlation coefficients of chlorophyll b with maximum of the characters did not exhibit significance at any level except stomatal frequency and stomatal breadth as stated earlier.

Similarly shelf-life registered insignificant associations with all the characters under study except stomatal frequency (in negative direction) and stomatal length (in positive direction) as described earlier.

Genotypic correlation coefficients (r_g)

The genotypic correlation coefficients among the studied quantitative traits in winter, summer and rainy (Table 6) are described below.

In maximum of the cases, the associations between internodal length and other characters did not come to the level of significance. The correlation coefficient at genotypic level between internodal length and petiole length was positive and significant in summer (0.646) and rainy (0.482). The correlation between internodal length and average leaf area was positive and significant (0.385) in summer season. The character also showed significant and positive correlations with stomatal frequency (0.465) and stomatal index (0.438) in only winter. Significant relationship at any level was not observed with other characters.

Petiole length was found to be positively and significantly correlated with leaf breadth (0.445, 0.425 and 0.734 in winter, summer and rainy respectively) and average leaf area (0.541, 0.460 and 0.781 respectively in the above consecutive seasons). It also exhibited significantly positive correlations with leaves/vine in rainy (0.436); with leaf length in winter (0.443) and rainy (0.660) and with chlorophyll a

Table 6 : Genotypic correlation coefficients (rg) in different seasons

Petiole length	Leaves/vine	Leaf length	Leaf breadth	Avg. leaf area	Leaf thickness	Stomatal freq.	Stomatal index	Stomatal length	Stomatal breadth	Chloro-phyll a	Chloro-phyll b	Shelf-life	Total leaf area/vine
0.125	0.074	-0.164	-0.096	-0.071	-0.063	0.465*	0.438*	-0.328	-0.152	0.005	0.125	-0.225	0.067
0.646**	0.112	0.326	0.355	0.385*	-0.119	0.005	0.019	0.229	0.004	-0.019	0.028	0.343	0.370
0.482*	-0.075	0.345	0.335	0.368	-0.099	-0.051	0.063	0.263	-0.176	-0.085	-0.050	-0.005	0.234
	-0.097	0.443*	0.445*	0.541**	-0.009	-0.306	-0.143	0.312	-0.110	0.652**	0.453*	0.097	0.292
	-0.207	0.323	0.425*	0.460*	-0.098	-0.233	0.238	0.303	0.124	-0.049	0.005	0.097	0.203
	0.436*	0.660**	0.734**	0.781**	0.129	-0.558**	0.198	0.499**	0.138	0.023	-0.197	-0.248	0.778**
		0.235	0.341	0.301	0.215	-0.255	-0.158	0.280	0.457*	-0.008	0.010	0.276	0.802**
		0.313	0.252	0.266	0.127	0.010	0.273	0.375	0.504**	0.357	0.246	-0.061	0.734**
		0.425*	0.465*	0.434*	0.091	-0.321	0.412*	0.538**	0.228	0.110	0.101	0.009	0.749**
			0.900**	0.984**	0.693**	-0.429*	-0.058	0.570**	0.320	0.301	0.243	0.212	0.707**
			0.932**	0.927**	0.068	-0.276	0.483*	0.552**	0.553**	-0.015	-0.097	0.082	0.765**
			0.930**	0.782**	-0.031	-0.374	0.160	0.497**	0.240	-0.113	-0.076	0.050	0.716**
				0.905**	0.654**	-0.478*	-0.069	0.554**	0.443*	0.403*	0.317	0.146	0.743**
				0.940**	0.095	-0.363	0.556**	0.526**	0.554**	0.011	-0.167	-0.060	0.752**
				0.916**	0.095	-0.406*	0.287	0.552**	0.181	-0.070	-0.088	-0.063	0.848**
					0.589**	-0.443*	-0.136	0.489**	0.179	0.528**	0.248	0.162	0.787**
					0.177	-0.364	0.577**	0.489**	0.491**	-0.002	-0.238	-0.116	0.831**
					0.210	-0.493**	0.468*	0.546*	0.232	-0.013	-0.251	-0.236	0.904**
						0.077	0.205	0.201	0.432*	-0.011	0.137	0.063	0.441*
						0.137	0.101	0.017	-0.194	0.211	-0.129	0.049	0.158
						0.001	0.143	-0.006	-0.215	0.065	-0.082	0.096	0.160
							0.601	-0.818*	-0.299	-0.307	-0.057	-0.510**	-0.401*
							0.036	-0.473*	-0.267	0.291	0.310	-0.004	-0.195
							0.116	-0.452*	-0.295	0.231	0.326	0.055	-0.497**
								-0.190	0.070	-0.220	0.088	-0.362	-0.206
								0.407*	0.395*	0.309	-0.166	-0.276	0.568**
								0.409*	0.368	0.328	0.020	-0.191	0.523**
									0.422*	0.172	0.107	0.528*	0.430*
									0.549**	-0.007	0.132	0.240	0.509**
									0.518**	0.086	0.182	0.070	0.558**
										-0.200	-0.003	0.037	0.371
										0.192	0.327	-0.162	0.587**
										0.449*	0.231	-0.037	0.203
											0.583**	0.096	0.325
											0.654**	-0.121	0.225
											0.518**	-0.075	0.058
												0.029	0.149
												0.101	-0.041
												0.385*	-0.132
													0.247
													-0.167
													-0.189

** Significant at 1% level

(0.652) and chlorophyll b (0.453) in winter only. The petiole length showed negative nature of relationship with stomatal frequency in all the seasons but the value was significant (-0.558) in rainy only. The association between petiole length and stomatal length was significant with positive direction. The character also registered comparatively higher and positive (0.778) association with total leaf area/vine in winter only.

Leaves/vine was positively and highly correlated with total leaf area/vine in all the three seasons (0.802 in winter, 0.734 in summer and 0.749 in rainy). It also showed significantly positive correlations with leaf length (0.425), leaf breadth (0.465), average leaf area (0.434), stomatal index (0.412) and stomatal length (0.538) in only rainy season and with stomatal breadth in both winter (0.457) and summer (0.504). Leaf length revealed a strong positive correlations over all the seasons with leaf breadth (0.900, 0.932 and 0.930), average leaf area (0.984, 0.927 and 0.782), total leaf area/vine (0.707, 0.765 and 0.716) and stomatal length (0.570, 0.552 and 0.497). The character also showed significantly positive correlations with leaf thickness (0.693) in winter season only and with stomatal index (0.483) and stomatal breadth (0.553) in summer season only. The association between leaf length and stomatal frequency was negative in nature in all the seasons but only the magnitude recorded in winter (-0.429) was significant at 5 per cent level.

Like leaf length, leaf breadth also showed positive and

very high correlation coefficients in all the three seasons with average leaf area (0.905, 0.940 and 0.916), total leaf area/vine (0.743, 0.752 and 0.484) and stomatal length (0.554, 0.526 and 0.552). This character also showed significantly positive correlations with leaf thickness (0.654) and chlorophyll a (0.403) in rainy season and with stomatal breadth in both the winter and summer season but not in rainy season. Like leaf length, leaf breadth also recorded significantly negative correlation with stomatal frequency except in summer season.

The average leaf area exhibited high positive correlations with stomatal length and total leaf area/vine in all the seasons under study. The correlation coefficient between average leaf area and total leaf area/vine was 0.787 in winter, 0.831 in summer and 0.904 in rainy. The character showed significant and positive correlations with leaf thickness (0.589), and chlorophyll a (0.528) in only winter and with stomatal index in summer and rainy. With stomatal frequency average leaf area showed negative correlation in all the seasons but the values indicated statistically significant in summer (-0.443) and rainy (-0.493).

Leaf thickness was found to be significantly positively correlated with stomatal breadth (0.432) and total leaf area/vine (0.441) in only winter.

Stomatal frequency showed significantly negative correlations with stomatal length (-0.818, -0.473 and -0.452 in

winter, summer and rainy respectively), total leaf area/vine (-0.401 and -0.497 in winter and rainy respectively) and with shelf-life (-0.510) in winter only.

The stomatal index recorded significant and positive correlation coefficients with stomatal length and total leaf area/vine in both summer and rainy season and with stomatal breadth (0.395) in only summer season.

Stomatal length showed significantly positive correlations with stomatal breadth and total leaf/vine over the seasons but the magnitudes were higher in summer and rainy season as compared to winter season.

The stomatal breadth registered significant and high positive correlation coefficients with chlorophyll a (0.499) in rainy and with total leaf area/vine (0.587) in summer only.

The association between chlorophyll a and chlorophyll b in all the seasons under study was positive and statistically significant even at 1 per cent (0.583 in winter, 0.654 in summer and 0.518 in rainy).

The relationship between chlorophyll b and shelf-life was significantly positive (0.385) in rainy only.

It was also observed that the relationship between shelf-life and total leaf area/vine was insignificant even at 5 per cent level in any season under study.

4.3 PATH-COEFFICIENTS

The magnitude of phenotypic and genotypic path-coefficients of total leaf area/vine through different quantitative characters for winter, summer and rainy seasons are presented in Table 7 and Table 8 respectively.

Phenotypic path-coefficients:

The result indicated that out of 14 characters only two i.e. leaves/vine and average leaf area had remarkable positive direct effect on total leaf area/vine over all the seasons under study. The magnitude of direct path values (phenotypic) of leaves/vine on total leaf area/vine were 0.613 in winter, 0.545 in summer and 0.451 in rainy whereas the corresponding total correlations between leaves/vine and total leaf area/vine were 0.797 in winter, 0.734 in summer and 0.751 in rainy. Similarly, the magnitude of direct path values of average leaf area were 0.679 0.796 and 0.758 respectively in winter, summer and rainy against the corresponding total correlation coefficient with total leaf area/vine of 0.774 in winter, 0.820 in summer and 0.891 in rainy. The direct path effects (phenotypic) of other remaining 12 characters were not remarkable in magnitude.

Through average leaf area the indirect effects of petiole length in rainy (0.553) that of leaf length in winter (0.538), in summer (0.599) and in rainy (0.530) and that of leaf

Table 7: Phenotypic path-coefficients showing direct (diagonal & bold) and indirect effects

Charac- ters	Season	Internod- al length	Petiole length	Leaves/ vine	Leaf length	Leaf breadth	Avg.leaf area	Leaf thickness	Stomatal freq.	Stomatal index	Stomatal length	Stomatal breadth	Chloro- phyll a	Chloro- phyll b	Shelf- life	Correlation with total leaf area/ vine
Internodal length	W	0.052	0.000	0.047	0.007	-0.003	-0.054	0.004	0.018	-0.018	0.004	-0.003	0.000	-0.002	0.000	0.053
	S	0.057	-0.013	0.067	-0.013	-0.035	0.275	0.005	0.000	0.000	0.001	-0.001	0.001	-0.002	-0.001	0.341
	R	-0.037	0.022	-0.036	-0.027	0.007	0.253	0.006	0.000	-0.001	0.003	0.014	-0.004	-0.001	0.000	0.201
Petiole length	W	0.007	0.002	-0.058	-0.018	0.015	0.322	0.000	-0.013	0.007	-0.005	-0.002	-0.007	-0.006	0.000	0.244
	S	0.029	-0.025	-0.106	-0.012	-0.039	0.323	0.002	-0.008	-0.001	0.002	0.004	-0.003	0.000	-0.001	0.164
	R	-0.016	0.032	0.175	-0.052	0.015	0.553	-0.007	0.001	-0.003	0.005	-0.013	0.001	-0.003	0.000	0.707
Leaves/vine	W	0.004	0.000	0.613	-0.009	0.012	0.188	-0.015	-0.010	0.005	-0.004	0.012	0.000	0.000	0.000	0.797
	S	0.007	0.005	0.545	-0.012	-0.024	0.201	-0.003	0.000	-0.001	0.001	0.010	0.017	-0.013	0.002	0.734
	R	0.003	0.020	0.451	-0.033	0.010	0.318	-0.005	0.000	-0.007	0.005	-0.017	0.004	0.001	0.000	0.751
Leaf length	W	-0.006	0.001	0.100	-0.054	0.033	0.538	-0.041	-0.017	0.003	-0.008	0.006	-0.003	-0.003	0.000	0.549
	S	0.016	-0.006	0.142	-0.048	-0.083	0.599	-0.001	-0.012	-0.002	0.002	0.010	0.001	0.006	-0.003	0.621
	R	-0.011	0.030	0.167	-0.089	0.019	0.530	0.002	0.000	-0.002	0.005	-0.020	-0.003	-0.001	0.000	0.628
Leaf breadth	W	-0.004	0.001	0.194	-0.045	0.039	0.575	-0.042	-0.020	0.003	-0.008	0.010	-0.005	-0.004	0.000	0.695
	S	0.018	-0.009	0.120	-0.036	-0.109	0.682	-0.003	-0.013	-0.002	0.002	0.012	0.000	0.009	0.002	0.674
	R	-0.012	0.035	0.201	-0.076	0.023	0.652	-0.006	0.000	-0.005	0.005	-0.017	-0.003	-0.002	0.000	0.797
Average leaf area	W	-0.004	0.001	0.170	-0.043	0.033	0.679	-0.038	-0.018	0.006	-0.007	0.005	-0.006	-0.003	0.000	0.774
	S	0.020	-0.010	0.137	-0.036	-0.093	0.796	-0.006	-0.015	-0.002	0.002	0.010	0.000	0.014	0.002	0.820
	R	-0.012	0.038	0.189	-0.063	0.020	0.758	-0.013	0.000	-0.007	0.006	-0.020	0.000	-0.004	0.000	0.891
Leaf thickness	W	-0.003	0.000	0.125	-0.030	0.022	0.346	-0.074	0.002	-0.008	-0.002	0.010	0.000	-0.002	0.000	0.387
	S	-0.007	0.001	0.042	-0.001	-0.008	0.122	-0.039	0.005	0.000	0.000	-0.004	0.012	0.004	-0.002	0.125
	R	0.003	0.005	0.032	0.002	0.002	0.136	-0.074	0.000	-0.002	0.000	0.017	0.003	0.000	0.000	0.123

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(Table 7 continued)

Charac- ters	Season	Internod- al length	Petiole length	Leaves/ vine	Leaf length	Leaf breadth	Avg. leaf area	Leaf thickness	Stomatal freq.	Stomatal index	Stomatal length	Stomatal breadth	Chloro- phyll a	Chloro- phyll b	Shelf- life	Correlation with total leaf area/ vine
Stomatal frequency	W	0.021	-0.001	-0.140	0.020	-0.017	-0.282	-0.003	0.044	-0.026	0.011	-0.007	0.003	0.000	-0.001	-0.376
	S	0.000	0.005	0.005	0.013	0.031	-0.267	-0.005	0.044	0.000	-0.002	-0.005	0.014	-0.017	0.001	-0.183
	R	0.002	-0.026	-0.134	0.026	-0.008	-0.332	0.000	-0.001	-0.001	-0.004	0.022	0.010	0.005	0.000	-0.442
Stomatal index	W	0.019	0.000	-0.060	0.004	-0.003	-0.085	-0.011	0.023	-0.050	0.003	0.002	0.002	-0.001	0.000	-0.157
	S	0.002	-0.004	0.133	-0.018	-0.049	0.372	-0.002	0.001	-0.005	0.002	0.007	0.018	0.005	0.006	0.469
	R	-0.002	0.009	0.154	-0.009	0.005	0.297	-0.006	0.000	-0.019	0.003	-0.028	0.013	0.000	0.000	0.417
Stomatal length	W	-0.013	0.001	0.134	-0.025	0.019	0.264	-0.008	-0.028	0.007	-0.017	0.008	-0.002	-0.002	0.001	0.338
	S	0.008	-0.008	0.135	-0.016	-0.043	0.313	0.001	-0.014	-0.001	0.005	0.010	0.003	-0.006	-0.004	0.383
	R	-0.008	0.022	0.182	-0.033	0.010	0.355	-0.001	0.000	-0.005	0.012	-0.046	0.006	0.003	0.000	0.497
Stomatal breadth	W	-0.006	0.000	0.265	-0.012	0.015	0.119	-0.026	-0.011	-0.004	-0.005	0.027	0.002	0.000	0.000	0.363
	S	-0.001	-0.004	0.216	-0.019	-0.052	0.309	0.006	-0.009	-0.001	0.002	0.025	0.006	-0.018	0.003	0.462
	R	0.005	0.007	0.076	-0.017	0.004	0.148	0.012	0.000	-0.005	0.006	-0.101	0.018	0.003	0.000	0.156
Chlorophyll a	W	0.000	0.001	-0.007	-0.012	0.014	0.333	0.001	-0.012	0.009	-0.003	-0.005	-0.013	-0.009	0.000	0.298
	S	0.001	0.001	0.146	-0.001	0.000	0.005	-0.008	0.010	-0.001	0.000	0.002	0.062	-0.038	0.001	0.181
	R	0.003	0.001	0.042	0.005	-0.002	0.001	-0.004	0.000	-0.005	0.001	-0.038	0.047	0.008	0.000	0.059
Chlorophyll b	W	0.007	0.001	-0.004	-0.010	0.011	0.149	-0.007	-0.001	-0.004	-0.002	0.000	-0.007	-0.016	0.000	0.117
	S	0.002	0.000	0.109	0.004	0.016	-0.180	0.002	0.012	0.000	0.000	0.007	0.037	-0.044	-0.002	-0.055
	R	0.002	-0.010	0.037	0.005	-0.002	-0.179	0.002	0.000	0.000	0.002	-0.019	0.022	0.017	0.001	-0.123
Shelf- life	W	-0.009	0.000	0.148	-0.008	0.005	0.088	-0.008	-0.021	0.016	-0.007	0.000	-0.001	0.000	0.001	0.203
	S	0.003	-0.001	-0.040	-0.005	0.009	-0.074	-0.003	-0.002	0.001	0.001	-0.004	-0.002	-0.006	-0.023	-0.147
	R	0.000	-0.012	-0.006	-0.004	-0.002	-0.145	-0.001	0.000	0.004	0.001	0.001	-0.003	0.005	0.002	-0.158
Residual effect		W=0.024														
		S=0.018														
		R=0.003														

W, S & R represent Winter, Summer and Rainy season respectively

breadth in winter (0.575), in summer (0.682) and in rainy (0.652) were considerably high in magnitude.

The indirect effects of leaves/vine via average leaf area in all the seasons were positive but lower in magnitude though the correlation coefficient between leaves/vine and total leaf area/vine showed considerably higher values (0.797 in winter, 0.734 in summer and 0.751 in rainy) suggesting thereby that maximum contribution was exerted through the direct effects of this character towards total leaf area/vine.

The indirect effects of other characters through average leaf area and leaves/vine in few cases were positive with some values which were not remarkable at all. Although the correlation coefficients were more or less considerable yet never high to a greater extent.

The indirect or direct effects of shelf-life were not acceptable by any means due to minimum values to a greater extent and even nil in most of the cases.

The residual effects were 0.024 in winter, 0.018 in summer and 0.003 in rainy. The result thus indicated that about 99.98% of the total variability in the leaf yield (total leaf area/vine) were accounted in the present study and no other important components which would contribute towards total leaves/vine were there for consideration.

Genotypic path-coefficients:

The path analysis (genotypic) indicated that leaves/vine, average leaf area and shelf-life had positive direct values on leaf yield (i.e. total leaf area/vine) over the seasons. The magnitudes of direct effect of leaves/vine on total leaf area/vine were 0.596 in winter, 0.456 in summer and 0.372 in rainy. Similarly, the direct path values of average leaf area were 0.407, 1.422 and 0.942 in winter, summer and rainy respectively against the total correlation of 0.787, 0.831 and 0.904 in the respective seasons. The direct effects of shelf-life in all the seasons were positive but considerably very low in magnitude. The direct effects of remaining characters were not remarkable in magnitude.

With regard to indirect genotypic effect petiole length, leaves /vine, leaf length and breadth, leaf thickness, stomatal index (except in winter) and stomatal length and breadth exerted considerable positive values through average leaf area over the seasons. The indirect effects of leaf length (1.318) and breadth (1.336) in summer via average leaf area towards total leaf area/vine were considerably high to a greater extent. On the other hand, the indirect effects of leaf length and breadth, stomatal length and breadth, average leaf area and leaf thickness through leaves/vine over the seasons (varying from 0.088 to 0.272) were also considerable to some extent as compared to other indirect effects. Thus, both leaves/vine and average leaf area were of great important, as efficient indirect vehicles to the

Table 8: Genotypic path-coefficients showing direct (diagonal and bold) and indirect effects

Charac- ters	Season	Internod- al length	Petiole length	Leaves/ vine	Leaf length	Leaf breadth	Avg. leaf area	Leaf thickness	Stomatal frequency	Stomatal index	Stomatal length	Stomatal breadth	Chloro- phyll a	Chloro- phyll b	Shelf- life	Correlation with total leaf area/ vine
Internodal length	W	0.079	-0.007	0.044	-0.036	-0.018	-0.029	0.015	0.160	-0.080	-0.042	-0.008	0.000	-0.007	-0.003	0.067
	S	0.490	-0.365	0.051	-0.236	-0.041	0.547	-0.013	-0.002	0.015	-0.122	0.000	0.011	0.022	0.013	0.370
	R	-0.136	0.060	-0.028	0.029	-0.100	0.347	0.013	0.002	0.004	0.012	0.042	-0.006	-0.003	0.000	0.234
Petiole length	W	0.010	-0.055	-0.058	0.098	0.085	0.220	0.002	-0.105	0.026	0.040	-0.006	0.059	-0.026	0.001	0.292
	S	0.316	-0.565	-0.095	-0.233	-0.049	0.655	-0.010	0.100	0.186	-0.161	-0.002	0.029	0.004	0.029	0.203
	R	-0.065	0.124	0.162	0.055	-0.219	0.736	-0.017	0.020	0.011	0.022	-0.033	0.002	-0.011	-0.009	0.778
Leaves/vine	W	0.006	0.005	0.596	0.052	0.065	0.123	-0.050	-0.088	0.029	0.036	0.025	-0.001	-0.001	0.003	0.802
	S	0.055	0.117	0.456	-0.226	-0.029	0.378	0.013	-0.004	0.214	-0.199	-0.008	-0.208	-0.193	-0.018	0.734
	R	0.010	0.054	0.372	0.035	-0.139	0.409	-0.012	0.011	0.024	0.024	-0.054	0.008	0.006	0.000	0.749
Leaf length	W	-0.013	-0.025	0.140	0.221	0.171	0.401	-0.160	-0.147	0.011	0.073	0.018	0.027	-0.014	0.003	0.707
	S	0.160	-0.182	0.143	-0.723	-0.107	1.318	0.007	0.118	0.378	-0.293	-0.009	0.009	-0.077	0.024	0.765
	R	-0.047	0.082	0.158	0.083	-0.278	0.737	0.004	0.013	0.009	0.022	-0.057	-0.009	-0.004	0.002	0.716
Leaf breadth	W	-0.008	-0.025	0.203	0.199	0.190	0.369	-0.151	-0.164	0.013	0.071	0.025	0.037	-0.018	0.002	0.743
	S	0.174	-0.240	0.115	-0.674	-0.115	1.336	0.010	0.155	0.434	-0.279	-0.009	-0.006	-0.131	-0.018	0.752
	R	-0.045	0.091	0.173	0.077	-0.299	0.863	-0.013	0.014	0.017	0.024	-0.043	-0.005	-0.005	-0.002	0.848
Average leaf area	W	-0.006	-0.030	0.180	0.218	0.172	0.407	-0.136	-0.152	0.025	0.063	0.010	-0.048	-0.014	0.002	0.787
	S	0.188	-0.260	0.121	-0.670	-0.108	1.422	0.019	0.156	0.451	-0.260	-0.008	0.001	-0.187	-0.034	0.831
	R	-0.050	0.097	0.161	0.065	-0.273	0.942	-0.028	0.018	0.027	0.024	-0.055	-0.001	-0.015	-0.008	0.904
Leaf thickness	W	-0.005	0.001	0.128	0.153	0.124	0.240	-0.231	0.027	-0.037	0.026	0.024	-0.001	-0.008	0.001	0.414
	S	-0.058	0.055	0.258	-0.049	-0.011	0.252	0.106	-0.058	0.079	-0.009	0.003	-0.123	-0.101	0.014	0.158
	R	0.013	0.016	0.034	-0.003	-0.028	0.197	-0.132	0.000	0.008	0.000	0.051	0.005	-0.005	0.003	0.160

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(Table 8 continued)

Charac- ters	Season	Internod- al length	Petiole length	Leaves/ vine	Leaf length	Leaf breadth	Avg. leaf area	Leaf thickness	Stomatal frequency	Stomatal index	Stomatal length	Stomatal breadth	Chloro- phyll a	Chloro- phyll b	Shelf- life	Correlation with total leaf area/ vine
Stomatal frequency	W	0.037	0.017	-0.152	-0.095	-0.091	-0.181	-0.018	0.363	-0.110	-0.105	-0.017	-0.028	0.003	-0.006	-0.403
	S	0.003	0.131	0.005	0.200	0.042	-0.518	0.015	-0.418	0.028	0.251	0.004	-0.169	0.244	-0.001	-0.193
	R	0.007	-0.069	-0.119	-0.031	0.121	0.464	0.000	-0.036	0.007	-0.050	0.070	0.018	0.019	0.002	-0.495
Stomatal index	W	0.035	0.008	-0.094	-0.013	-0.013	-0.055	-0.047	0.206	-0.182	-0.024	0.004	-0.020	-0.005	-0.005	-0.206
	S	0.009	-0.135	0.125	-0.350	-0.064	0.820	0.011	-0.015	0.782	-0.216	-0.007	-0.180	-0.130	-0.081	0.568
	R	-0.009	0.025	0.153	0.013	-0.086	0.441	-0.019	-0.004	0.058	0.018	-0.087	0.025	0.001	-0.007	0.523
Stomatal length	W	-0.026	-0.017	0.167	0.126	0.105	0.199	-0.046	-0.281	0.035	0.128	0.024	0.016	-0.006	0.007	0.430
	S	0.112	-0.171	0.171	-0.399	-0.061	0.696	0.002	0.203	0.318	-0.531	-0.009	0.004	0.104	0.071	0.509
	R	-0.036	0.062	0.200	0.041	-0.165	0.514	0.001	0.016	0.024	0.044	-0.123	0.007	0.011	0.002	0.598
Stomatal breadth	W	-0.012	0.006	0.272	0.071	0.084	0.073	-0.100	-0.103	-0.013	0.054	0.056	-0.018	0.000	0.000	0.371
	S	0.002	-0.070	0.230	-0.400	0.064	0.698	-0.021	0.114	-0.309	-0.291	-0.016	-0.112	0.257	-0.048	0.587
	R	0.024	0.017	0.085	0.020	-0.054	0.218	0.028	0.011	0.021	0.023	-0.237	0.034	0.013	-0.001	0.203
Chlorophyll a	W	0.000	-0.036	-0.005	0.067	0.077	0.215	0.003	-0.105	0.040	0.022	-0.011	0.091	-0.033	0.001	0.325
	S	-0.009	0.028	0.163	0.011	-0.001	-0.003	0.022	-0.124	0.242	0.004	-0.003	-0.583	0.515	-0.036	0.225
	R	0.012	0.003	0.041	-0.009	0.021	-0.012	-0.009	-0.008	0.019	0.004	-0.106	0.076	0.030	-0.003	0.058
Chlorophyll b	W	0.010	-0.025	0.006	0.054	0.080	0.101	-0.032	-0.019	-0.016	0.014	0.000	0.053	-0.057	0.000	0.149
	S	0.014	-0.003	0.112	0.070	0.019	-0.338	-0.014	-0.133	-0.129	-0.070	-0.005	-0.381	0.787	0.030	-0.410
	R	0.007	-0.024	0.038	-0.006	0.026	-0.237	0.011	-0.012	0.001	0.008	-0.055	0.039	0.058	0.013	-0.132
Shelf- life	W	-0.018	-0.005	0.165	0.047	0.028	0.066	-0.015	-0.175	0.066	0.068	0.002	0.009	-0.002	0.013	0.247
	S	0.021	-0.055	-0.028	-0.059	0.007	-0.165	0.005	0.002	-0.216	-0.127	0.003	0.071	0.080	0.295	-0.167
	R	0.001	-0.031	0.003	0.004	0.019	-0.222	-0.013	-0.002	-0.011	0.003	0.009	-0.006	0.022	0.034	-0.189
Residual effect		W=0.005														
		S=0.016														
		R=0.021														

W, S & R represent Winter, Summer and Rainy seasons respectively.

leaf yield (i.e. total leaf area/vine). The indirect effects of other characters were either negative or positive with a minimum value.

In the present study total effects for residual factors were 0.005, 0.016 and 0.021 in winter, summer and rainy respectively indicating thereby the presence of minimum role of other yield contributing characters which were not considered in this study.

4.4 GENETIC DIVERGENCE

Highly significant differences among 27 genotypes for all the 15 characters indicated the existence of sufficient genetic variability (Table 3). The significance of lamda statistic (which utilizes Wilk's criterion) showed that the differences between the mean values in respect of the pooled effect of all the characters between different populations were significant. Hence, further analysis to assess D^2 values with the present set of populations was done.

On the basis of relative magnitude of D^2 values (Appendix IV) all the 27 genotypes were grouped into 10 clusters (Table 9), assuming that the genotypes within a cluster have smaller D^2 values among themselves than those belonging to different clusters. Of the 10 clusters, four had single genotype while the remaining six had more than one. Six genotypes were accomodated in cluster I, five in cluster II, two each in cluster III and IV and four each in cluster V and VI. The six genotypes collected from Tomluk, were found to be distributed in four clusters; five from Bagnan got distributed in three clusters; and three from Simurali got distributed in two clusters. Thus, the distribution of genotypes from the same source into different clusters were found to be random. The grouping of the genotypes is presented Diagram2 .

The maximum intra-cluster distance (127.45) was scored by cluster V followed by cluster II, VI, I, IV and III in the

Table 9: Clustering pattern of 27 genotypes in different clusters and their place of acclimatization

Cluster No.	No. of genotypes	Constituent genotypes	Place of acclimatization
I	6	Kali Bangla, Ghanagete Bangla Mitha pan, Adi Bangla Simurali Bangla, Simurali Bhabna	Bagnan, Howrah, W.B. Tomluk, Midnapur, W.B. Simurali, Nadia, W.B.
II	5	Kare Bangla, Ayamal Bangla Chandrokona (Bangla), Haldi Pan Kalidhal Bangla	Tomluk, Midnapur, W.B. Ramnagar, Midnapur, W.B. Bagnan, Howrah, W.B.
III	2	Godi Bangla, Karapaku Bangla	Orissa Andhra Pradesh
IV	2	Haslisahar Jhal Kapoori (Palghat)	Halisahar, 24-Parganas (N), W.B. Kerala.
V	4	Kapoori (Sangli), Kapoori (Ramtek) Sanchi (Tomluk) Noua Bangla	Maharashtra. Tomluk, Midnapur, W.B. Orissa.
VI	4	Dhal Bangla, Tilak Bangla Simurali Deshi Ramnagar Deshi (Bangla)	Bagnan, Howrah, W.B. Simurali, Nadia, W.B. Ramnagar, Midnapur, W.B.
VII	1	Borghai (Bangla)	Tomluk, Midnapur, W.B.
VIII	1	Sanchi (Halisahar)	Halisahar, 24 Parganas (N), W.B.
IX	1	Birkuli (Bangla)	Orissa
X	1	Kapoori (T.N.)	Tamil Nadu

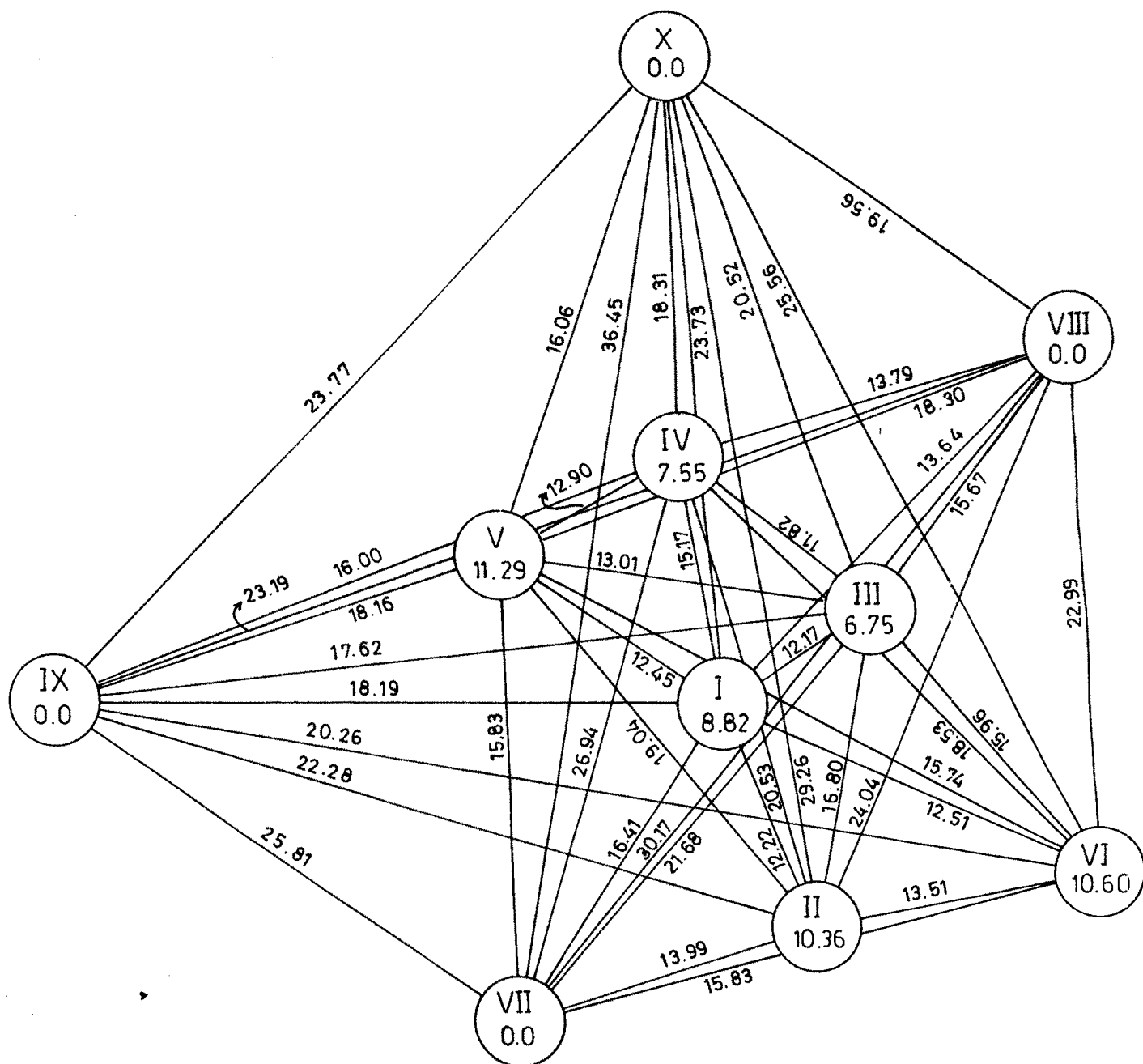


Diagram 2: Distribution of clusters based on inter-cluster distances.
Figures indicate square root of average D^2 values

descending order (Table 10). The intra-cluster D^2 estimates presented contradictory situations. Cluster I, a collection of six genotypes from different sources, revealed relatively smaller value (77.86) than the clusters II (120.18), V (127.45) and VI (112.34) comprising 5, 2 and 4 genotypes respectively. Minimum intra-cluster values were scored by cluster III (45.60) and IV (57.02) comprising only two genotypes each and indicating gross genetic similarity between the constituent genotypes. In the present study four clusters, viz., VII, VIII, IX and X were formed with single genotype in each. The average intra-cluster values of these four clusters may not be effective for any valid conclusion due to lack of basis of comparisons amongst all the clusters.

Maximum divergence at inter-cluster level (Table 10) was observed between cluster VII and X (1328.49). In general, the inter-cluster distances between cluster X and any one of the remaining clusters were found relatively higher indicating thereby cluster X as a quite distinct genetic group. The inter-cluster distances between cluster VII and VIII (910.39) and VII and IX (666.16) were also relatively higher as compared to other inter-cluster distances. Minimum divergence was noticed between cluster III and IV (139.63), followed by cluster I and III (148.06), cluster I and II (149.44), cluster I and V (154.99), cluster I and VI (156.50) and cluster IV and V (166.55) in ascending order.

Cluster mean values (Table 11) for all the 15

Table 10: Intra and intercluster D² values (average)

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X
I	77.86	149.44	148.06	230.02	154.99	156.50	269.38	186.21	330.75	563.28
II		120.18	282.34	421.40	362.73	182.45	195.74	578.07	496.21	856.29
III			45.60	139.63	169.33	254.76	470.26	246.11	310.65	421.06
IV				57.02	166.55	343.53	725.70	190.12	227.95	335.35
V					127.45	247.70	250.72	334.86	329.68	258.08
VI						112.34	250.72	528.60	410.67	653.42
VII							-	910.39	666.16	1328.49
VIII								-	537.89	382.63
IX									-	546.31
X										-

Diagonal values (bold) represent intra-cluster distances

characters under study highlighted wide range of variation except for leaf thickness, stomatal index, stomatal length and stomatal breadth. Cluster VII exhibited maximum leaf yield (2815.10 sq cm /vine) followed by clusters II (2096.65 sq cm/vine) and I (1806.86 sq cm/vine), while cluster X had the lowest leaf yield (328.85 sq cm/vine). High mean for leaves/vine was noted in clusters IV (16.38), followed by clusters I (15.41), VII (14.63) and VIII (14.36) and for average leaf area cluster VI registered high mean value (192.60 sq cm) which was followed by cluster II (151.42 sq cm) . Cluster VIII showed maximum value (22.81 days) for shelf-life whereas cluster X showed the lowest mean value (14.11 days) for this trait. Cluster IX exhibited maximum length of internode (11.06 cm) while cluster X showed minimum internodal length (3.78 cm). With regard to petiole length, cluster II showed the maximum value (7.17 cm) and the lowest value (3.85 cm) was recorded again in cluster X.

Table 11: Cluster means for 15 quantitative characters

Cluster No.	Internod- al length (cm)	Petiole length (cm)	Leaves/ vine (No.)	Leaf length (cm)	Leaf breadth (cm)	Avg.leaf area (Sq cm)	Leaf thickness (mm)	Stomatal freq. index (no./sq mm)	Stomatal length (μ)	Stomatal breadth (μ)	Chloro- phyll a (mg/g)	Chloro- phyll b (mg/g)	Shelf- life (days)	Total leaf area/vine (Sq.cm)
I	6.43	6.96	15.41	14.58	11.17	112.42	0.27	148.90	30.83	32.03	19.88	1.48	0.92	16.85 1806.86
II	6.93	7.17	13.79	15.58	12.73	151.42	0.30	132.87	30.88	32.21	18.66	1.23	0.69	20.51 2096.65
III	5.64	5.26	8.43	13.92	10.85	71.25	0.26	161.66	27.22	29.62	19.10	1.47	1.17	20.84 614.35
IV	5.12	4.40	16.38	13.34	9.39	56.26	0.27	152.26	27.00	31.61	18.95	1.28	0.97	22.14 937.40
V	5.83	4.81	9.46	12.71	8.27	63.82	0.27	142.23	27.38	28.24	17.83	1.20	0.66	19.38 604.16
VI	7.05	6.91	10.91	14.29	10.93	116.48	0.25	115.89	29.31	31.48	20.40	1.20	0.49	15.55 1276.71
VII	8.22	8.83	14.63	16.93	14.23	192.60	0.27	104.83	28.05	35.68	20.89	1.53	0.96	15.13 2815.10
VIII	4.84	3.60	14.36	12.11	7.60	61.05	0.23	187.75	34.09	33.02	25.08	1.81	1.17	22.81 875.37
IX	11.06	6.01	7.07	10.95	7.64	47.20	0.23	205.54	28.14	29.64	15.74	1.50	0.99	20.99 335.83
X	3.78	3.85	9.32	5.62	4.34	35.24	0.29	189.78	29.15	26.49	16.60	1.46	0.70	14.11 328.85

4.5 PHENOTYPIC STABILITY

In the present investigation 27 genotypes of betelvine were tested under three environments/seasons viz., winter, summer and rainy, with the objective of selecting stable genotypes across the environments. The traits which showed positive and significant correlation with leaf yield (i.e., total leaf area/vine) in any of the three environments or seasons, were taken for stability analysis . On the basis of this criterion 10 characters namely (i) petiole length (ii)leaves/vine , (iii) leaf length, (iv) leaf breadth, (v) average leaf area, (vi) leaf thickness, (vii) stomatal index, (viii) stomatal length, (ix) stomatal breadth and (x) total leaf area/vine were selected for this study. The results of the investigation are presented under the following sub-heads:

Pooled Analysis of Variance:

The pooled analysis of variance for genotype x environment interactions of different characters are presented in Table 12 . Highly significant differences were observed among the genotypes for all the 10 characters under investigation. The differences among the environments were highly significant for all the characters under study except leaf thickness. The genotype x environment interactions were highly significant for all the characters except leaf length, stomatal length and stomatal breadth. The linear components of environment were significant for all the characters except leaf thickness. The

Table 12 : Pooled ANOVA for genotype x environment interaction of different characters

Characters	Source of variation (mean sum of squares)					
	Genotypes(G) d.f.=26	Environment d.f.=2	G X E d.f.=52	E(L) d.f.=1	G X E(L) d.f.=26	Pooled Deviation d.f.=27
1 Petiole length	3.418**	5.902**	0.419**	11.805**	0.783**	0.053
2 Leaves/vine	26.412**	99.225**	3.218**	198.449**	5.073**	1.312**
3 Leaf length	9.531**	42.934**	1.248	85.869**	1.498	0.961**
4 Leaf breadth	9.569**	30.417**	0.874**	60.832**	1.317**	0.415**
5 Avg. leaf area	2954.506**	7947.009**	250.688**	15893.987**	346.019**	149.605**
6 Leaf thickness	0.0015**	0.0003	0.0004**	0.00006	0.0001	0.0007**
7 Stomatal index	9.254**	39.808**	2.305**	79.622**	3.339**	1.113**
8 Stomatal length	13.330**	15.910**	1.26	31.783**	2.358**	0.157
9 Stomatal breadth	8.410**	5.024*	1.262	10.403*	0.951	1.516**
10 Total leaf area/vine	651480.500**	3745817.700**	148706.530**	7491621.700**	246528.060**	49000.890**
						27783.940

* Significant at 5% level

** Significant at 1% level

linear components of genotype X environment were significant for petiole length, leaf no/vine, leaf breadth, stomatal index, stomatal length, total leaf area/vine and for average leaf area. The pooled deviations were highly significant for all the characters under study except petiole length and stomatal length.

Stability Parameters:

Three stability parameters viz., mean (X_i), regression coefficient (b_i) i.e., the regression of the performance of each cultivar under different environments on the environmental means over all the cultivars, and mean square deviation from regression line (S^2_d) for 10 characters of 27 genotypes are presented in Table 13. These three stability parameters of each character are as follows.

i) **Petiole length:** The mean performance of 27 genotypes, computed over three seasons (environments), varied from 3.93 cm to 7.14 cm. Fourteen genotypes had higher mean values over general mean. Among them seven genotypes namely Simurali Deshi, Kare Bangla, Ayamal Bangla, Borghai, Adi Bangla, Chandrokona and Ramnagar Deshi showed considerably high mean value. With regard to regression coefficient, two genotypes (Chandrokona and Kalidhal Bangla) showed significance at 5% only but nine genotypes viz., Mitha Pan, Kali Bangla, Simurali Bangla, Kapoori (Sangli), Simurali Deshi, Simurali Bhabna, Kare Bangla, Borghai and Ramnagar Deshi showed significance even at 1% level. The rest 16 genotypes did not show significant b_i value at any level. Out of

Table.13 : Stability parameters for different characters of 27 genotypes

Genotypes	Petiole length (cm)			Leaves no/ vine			Leaf Length (cm)			Leaf breadth (cm)			Avg. leaf area (sq cm)		
	xi	bi	$\bar{S}^2d$	xi	bi	$\bar{S}^2d$	xi	bi	$\bar{S}^2d$	xi	bi	$\bar{S}^2d$	xi	bi	$\bar{S}^2d$
1 Mitha pan	5.19	2.21**	-0.06	8.17	0.45	-0.20	12.53	1.36	0.74	8.00	0.79	-0.11	67.95	1.06	-17.51
2 Kali Bangla	6.14	3.35**	0.01	12.12	2.91**	4.37**	13.04	1.07	-0.20	9.90	2.39**	0.24	88.22	2.46**	391.94**
3 Ghanagete Bangla	5.86	0.64	-0.02	13.14	2.31**	1.07	13.28	0.43	-0.24	10.78	0.55	-0.01	98.82	1.28	-11.19
4 Simurali Bangla	5.52	2.59**	-0.05	15.22	-0.25	6.05**	12.75	1.04	-0.31	10.31	0.76	-0.08	93.40	0.65	57.61
5 Sanchi (Tomluk)	3.93	0.02	-0.03	9.45	0.08	3.21**	13.24	0.69	-0.37	9.06	-0.07	0.41*	79.39	-0.06	214.82**
6 Sanchi (Halisahar)	4.15	-1.00	-0.03	14.57	0.10	0.75	13.24	-0.23	5.08**	9.14	-1.07	0.88**	77.68	-0.51	424.53**
7 Godi Bangla	4.66	0.05	-0.01	8.55	0.92	-0.34	11.83	1.38	0.63	9.17	1.53	0.17	62.63	0.78	-0.20
8 Halisahar Jhal	4.90	-0.06	-0.05	15.16	1.45	-0.22	11.77	1.12	-0.36	7.80	1.72	-0.08	48.07	0.60	42.43
9 Kapoori (Ramtek)	4.42	-0.15	-0.04	7.26	0.70	-0.08	12.00	1.23	-0.11	7.55	1.30	-0.02	47.39	0.27	-17.56
10 Karapaku Bangla	5.90	-0.05	0.00	5.94	0.51	0.14	11.74	1.40	0.26	8.97	1.33	0.24	59.18	0.49	77.64*
11 Noua Bangla	4.49	-0.23	-0.04	6.90	0.73	-0.14	11.12	-0.70	1.68*	8.15	-0.26	0.34	67.76	0.12	166.24**
12 Kapoori (Palghat)	3.95	0.01	-0.04	12.06	1.25	-0.45	11.56	1.29	0.04	7.61	1.25	-0.09	42.88	0.33	23.42
13 Kapoori (T.N.)	3.97	-0.18	0.00	8.04	0.68	-0.43	6.16	-0.16	0.44	4.24	0.32	0.43*	27.01	0.64	62.08
14 Kapoori (Sangli)	5.34	2.46**	-0.06	11.36	0.70	0.30	11.27	1.37	-0.21	7.28	0.57	0.41*	52.46	0.63	3.78
15 Haldi pan(B)	5.85	-0.35	0.05	7.35	1.13	-0.43	15.28	0.69	-0.29	11.86	1.29	0.13	123.53	1.56	-7.47
16 Birkuli (B)	6.46	-0.82	-0.03	6.26	0.64	1.02	9.82	0.83	-0.35	6.25	1.21	-0.09	36.44	0.50	11.97
17 Simurali Deshi(B)	6.81	2.16**	-0.03	9.39	1.32	0.43	13.36	1.19	9.82**	10.61	0.76	3.87**	96.45	1.39	1019.10**
18 Simurali Bhabna	5.59	2.50**	-0.05	17.53	0.00	0.61	12.80	1.18	-0.36	10.39	0.79	0.12	97.08	0.76	362.22**
19 Kare Bangla	7.07	2.61**	0.50**	11.18	1.07	1.06	14.46	0.69	0.57	10.80	1.55	0.17	122.83	1.00	26.85
20 Avamal Bangla	6.93	0.66	-0.06	11.67	1.60	1.86*	13.93	0.83	0.04	10.25	1.40	-0.11	120.99	1.16	65.89*
21 Borghai (B)	7.06	3.25**	0.00	11.80	1.28	0.21	15.18	1.32	-0.37	11.63	2.20**	0.13	147.16	2.34*	90.96**
22 Dhal Bangla	6.25	-0.34	-0.05	10.85	-1.01	0.91	13.75	-0.24	1.19	10.84	-0.06	0.64**	119.80	0.40	308.21**
23 Adi Bangla	6.93	0.90	-0.06	11.78	1.72	1.44	12.73	1.95	-0.37	10.03	1.34	-0.11	89.32	1.71	20.85
24 Tilak Bangla	4.74	0.74	-0.04	7.42	1.30	-0.34	11.59	1.42	-0.33	9.04	1.27	0.57**	73.93	1.41	15.26
25 Chandrokona (B)	6.57	1.93*	-0.04	9.75	1.61	0.79	13.71	1.61	-0.23	11.17	1.52	0.07	118.16	2.16*	28.33
26 Ramnagar Deshi	7.14	2.34**	0.12	10.29	1.18	0.96	12.28	1.62	-0.11	9.71	0.93	0.28	82.64	1.53	9.86
27 Kalidhal Bangla	5.94	1.73*	0.06	11.49	1.82	-0.39	13.66	1.63	-0.37	11.41	1.71	-0.01	122.25	2.33*	194.68**
Grand Mean (X)	5.62	1.00		10.54	1.00		12.52	1.00		9.33	1.00		83.83	1.00	

* Significant at 5% level

** Significant at 1% level

(B) represents Bangla

contd. next page

(Table.13 continued)

	Leaf thickness (mm)			Stomatal index			Stomatal length (μ)			Stomatal breadth (μ)			Total leaf area/vine (sq cm)		
	xi	bi	$\bar{S}^2_d$	xi	bi	$\bar{S}^2_d$	xi	bi	$\bar{S}^2_d$	xi	bi	$\bar{S}^2_d$	xi	bi	$\bar{S}^2_d$
1 Mitha pan	0.26	-0.97	0.00	29.59	-0.50	0.75	31.78	0.48	-0.63	20.08	1.59**	0.19	570.78	0.57	-8009.78
2 Kali Bangla	0.27	2.65**	0.00	30.46	0.30	-0.08	29.05	-1.62	-0.68	18.70	-0.74	-0.07	1233.78	3.12**	191221.70**
3 Ghanagete Bangla	0.26	4.26**	0.00	30.69	2.32*	1.07	31.83	2.16**	-0.51	22.19	-3.08**	10.80**	1414.10	2.25**	15786.89
4 Simurali Bangla	0.29	0.2	0.00	30.05	-0.05	0.60	31.83	1.75*	-0.68	20.10	-0.3	1.45**	1220.68	0.24	142515.36**
5 Sanchi (Tomluk)	0.25	4.20**	0.00	26.09	1.25	-0.37	29.52	-2.02**	-0.66	18.95	-0.19	0.56	759.62	-0.05	84878.28**
6 Sanchi (Halisahar)	0.27	5.94**	0.00	30.96	3.30**	3.66**	31.98	1.95*	-0.64	21.63	4.34**	10.60**	1140.08	-0.36	148765.19**
7 Godi Bangla	0.27	0.73	0.00	26.55	-0.19	1.20	27.99	-0.06	-0.67	18.67	0.22	-0.06	549.52	0.62	-9226.21
8 Halisahar jhal	0.25	-0.29	0.00	26.41	0.09	0.92	31.98	0.59	-0.60	19.95	0.95	0.88	748.07	0.85	6782.44
9 Kapoori (Ramtek)	0.24	0.91	0.00	25.77	-0.06	0.62	26.33	-0.27	-0.57	15.69	0.03	-0.29	347.13	0.26	-7921.08
10 Karapaku Bangla	0.26	1.81	0.00	26.93	0.03	1.90**	31.33	0.66	-0.50	19.94	0.44	-0.17	359.62	0.26	2929.37
11 Noua Bangla	0.30	-0.29	0.00	27.20	1.02	-0.34	29.55	1.28	-0.68	19.46	0.87	-0.08	469.26	0.25	10850.88
12 Kapoori (Palghut)	0.30	3.18**	0.00	26.30	0.34	0.07	31.03	1.02	-0.47	19.01	-0.4	0.1	529.60	0.50	-4009.24
13 Kapoori (T.N.)	0.28	-0.74	0.00	29.51	-0.13	-0.15	25.01	3.78**	-0.54	16.32	-0.38	0.00	229.99	0.31	-4320.07
14 Kapoori (Sangli)	0.29	-2.87**	0.00	26.12	0.77	0.69	27.97	-0.36	-0.42	16.78	0.96	0.03	602.67	0.52	-9245.25
15 Haldi pan(B)	0.32	1.23	0.00	32.05	-0.51	2.34**	30.71	0.56	-0.68	17.74	0.26	-0.29	947.97	1.28	-8037.03
16 Birkuli (B)	0.23	1.70	0.00	27.47	0.06	1.63*	29.18	-0.13	-0.12	15.79	0.54	-0.22	237.88	0.25	-9249.03
17 Simurali Deshi(B)	0.26	3.91**	0.00	28.32	0.11	0.02	29.57	0.76	-0.68	20.07	2.91**	6.23**	943.48	1.41	76146.55**
18 Simurali Bhabna	0.29	-0.62	0.00	28.68	1.59	-0.11	32.27	2.21**	-0.53	20.06	-0.91	0.23	1705.65	0.53	216147.80**
19 Karel Bangla	0.27	-0.77	0.00	27.57	2.47*	-0.09	31.20	2.01*	-0.67	19.16	2.82**	-0.26	1415.94	1.74	-1707.26
20 Ayanal Bangla	0.30	-0.29	0.00	28.45	2.00	0.77	31.75	2.23**	-0.04	17.87	2.79**	0.32	1447.36	1.63	-5550.12
21 Barghai (B)	0.27	0.41	0.00	27.10	1.28	1.63*	33.90	2.58**	0.03	19.65	2.46**	0.42	1803.86	2.37**	37329.98*
22 Dhal Bangla	0.27	1.26	0.00	28.89	2.47*	0.06	28.88	-1.69	-0.31	20.40	2.02**	0.85	1298.58	-0.46	108275.17**
23 Adi Bangla	0.28	1.06	0.00	28.83	2.08	1.45*	32.48	2.21**	-0.60	21.42	1.96**	0.83	1120.14	1.84	25785.87
24 Tilak Bangla	0.29	0.28	0.00	27.04	1.54	1.32	32.29	0.91	-0.43	19.01	2.41**	0.81	592.02	1.05	-4026.03
25 Chandrakona (B)	0.27	1.54	0.00	27.04	1.55	0.34	30.95	1.43	-0.58	19.01	2.78**	0.36	1244.63	2.13*	31546.34
26 Ramnagar Deshi	0.24	-1.57	0.00	27.01	1.71	0.76	33.46	2.44**	-0.63	17.88	1.47*	-0.28	898.23	1.32	10024.67
27 Kalidhal Bangla	0.30	0.17	0.00	30.46	2.16	-0.33	32.18	2.15**	-0.63	17.20	1.17	-0.16	1503.15	2.55**	35283.18*
Grand Mean (X)	0.27	1.00		28.20	1.00		30.59	1.00		18.99	1.00		945.50	1.00	

* Significant at 5% level
 ** Significant at 1% level
 (B) represents Bangla

27 genotypes only one genotype, Kare Bangla, recorded highly significant mean square deviation ($S^{-2}d$) from linear regression.

(ii) **Leaf no/vine:** Mean performance over the seasons varied from 5.94 to 17.53. Fourteen genotypes showed relatively higher mean values than the general mean. Out of them six genotypes namely Kali Bangla, Ghanagete Bangla, Simurali Bangla, Halisahar Sanchi, Kapoori (Palghat) and Simurali Bhabna showed exceptionally higher value. Regarding regression coefficient (b_i) two genotypes namely Kali Bangla and Ghanagete Bangla showed significantly higher b_i value from unity. With regard to deviation from linear regression ($S^{-2}d$) four genotypes namely Kali Bangla, Simurali Bangla, Sanchi (Tomluk), and Ayamal Bangla showed significant deviation from regression line of which the first three genotypes registered highly significant $S^{-2}d$ values from zero. The rest of the genotypes showed insignificant $S^{-2}d$ value.

(iii) **Leaf length:** Sixteen genotypes showed higher mean value as compared to general mean of 12.52 cm. Out of these seven genotypes namely Haldi pan, Kare Bangla, Ayamal Bangla, Borghai, Dhal Bangla, Chandrokona and Kalidhal Bangla showed remarkably higher value (above 13.50 cm). None of the 27 genotypes registered significant b_i value from unity. Only three genotypes namely Halisahar Sanchi, Noua Bangla and Simurali Deshi showed significant deviation from regression line.

(iv) **Leaf breadth:** Fourteen genotypes recorded higher

mean performance over the environments (seasons) than the general mean (9.33 cm). Eight genotypes namely Ghanagete Bangla, Haldi Pan, Simurali Deshi, Kare Bangla, Borghai, Dhal Bangla, Chandrokona and Kalidhal Bangla recorded very high mean performance (above 10.50 cm). Two genotypes namely Kali Bangla and Borghai showed significantly higher bi value from unity. With regard to mean square deviation from regression line (S^{-2}_d), seven genotypes viz., Halisahar Sanchi, Simurali Deshi, Dhal Bangla, Tilak Bangla, Sanchi (Tomluk), Kapoori (T.N.) and Kapoori (Sangli) showed significant deviation from zero (i.e., $S^{-2}_d \neq 0$).

(v) **Average leaf area:** The mean performance of the genotypes under study over the environments varied from 27.01 sq cm to 147.16 sq cm. Thirteen genotypes recorded higher mean performance as compared to the general mean of 83.83 sq cm. Out of these, seven genotypes namely Haldi Pan, Kare Bangla, Ayamal Bangla, Borghai, Dhal Bangla, Chandrokona and Kalidhal Bangla registered remarkably high mean value (above 100.00 sq cm). Four genotypes namely Kali Bangla, Borghai, Chandrokona and Kalidhal Bangla showed significantly higher regression coefficient (bi) from unity. With regard to mean square deviation from linear regression, eleven genotypes (namely Kali Bangla, Sanchi (Tomluk), Sanchi (Halisahar), Karapaku Bangla, Noua Bangla, Simurali Deshi, Simurali Bhabna, Ayamal Bangla, Borghai, Dhal Bangla and Kalidhal Bangla) showed significant either at 5% or 1% level.

(vi) **Leaf thickness:** Remarkable variation in mean performance was not observed in this character. Only four

genotypes viz., Noua Bangla, Kapoori (Palghat), Ayamal Bangla and Kalidhal Bangla showed a little higher value (0.30 mm.) than the general mean of 0.27 mm. With regard to b_i value, seven genotypes namely Kali Bangla, Ghanagete Bangla, Sanchi (Tomluk), Sanchi (Halisahar), Kapoori (Palghat), Kapoori (Sangli) and Simurali Deshi showed highly significant regression coefficient (b_i). None of the genotypes showed significant deviation from regression line (i.e., $S^{-2}d = 0$ in each genotype).

(vii) **Stomatal index:** Six genotypes namely Kali Bangla, Ghanagete Bangla, Simurali Bangla, Halisahar Sanchi, Haldi Pan and Kalidhal Bangla showed remarkably higher mean value (above 30.00) than the general mean of 28.20. Four genotypes viz., Ghanagete Bangla, Sanchi (Halisahar), Kare Bangla and Dhal Bangla registered significant b_i value and six genotypes namely Sanchi (Halisahar), Karapaku Bangla, Haldi Pan, Birkuli, Borghai and Adi Bangla recorded significant mean square deviation from regression line (i.e., $S^{-2}d \neq 0$).

(viii) **Stomatal length:** Seventeen genotypes showed higher mean value than the general mean (30.59 μ). Out of them six, namely Simurali Bhabna, Borghai, Adi Bangla, Tilak Bangla, Ramnagar Deshi and Kalidhal Bangla had remarkably higher mean value (above 32.00 μ) as compared to other genotypes. Out of these six genotypes, five showed highly significant regression coefficient (i.e., $b_i \neq 1$). None of the genotypes showed significant deviation from regression line (i.e., $S^{-2}d = 0$).

(ix) **Stomatal breadth:** Sixteen genotypes recorded higher mean value than the experimental mean of 18.99 μ . Out of these, 10 showed highly significant regression coefficient (i.e. $b_i \neq 1$). Four genotypes namely Ghanagete Bangla, Simurali Bangla, Sanchi (Halisahar) and Simurali Deshi registered highly significant mean square deviation from zero. The rest 23 genotypes showed insignificant deviation from linear regression ($S^{-2}_d = 0$).

(x) **Total leaf area/vine:** Twelve, out of 27 genotypes showed remarkably higher mean performance (above 1100.00 sq cm) as compared to general mean (945.50 sq cm). Of these 12 high yielding genotypes, five, namely Kali Bangla, Ghanagete Bangla, Borghai, Kalidhal Bangla and Chandrokona showed significant regression coefficient (i.e. $b_i \neq 1$). With regard to mean square deviation from regression line, nine genotypes (viz., Kali Bangla, Simurali Bangla, Sanchi (Tomluk), Sanchi (Halisahar), Simurali Deshi, Simurali Bhabna, Borghai, Dhal Bangla and Kalidhal Bangla) showed significant deviation from zero. When all the three parameters of stability (X_i , b_i and S^{-2}_d) were considered simultaneously, three genotypes namely Kare Bangla, Ayamal Bangla and Adi Bangla showed remarkably higher mean value having insignificant regression coefficient (b_i) from unity and mean square deviation from zero (i.e., both $b_i = 1$ and $S^{-2}_d = 0$).

4.6 GENETIC VARIABILITY INDUCED BY CHEMICAL MUTAGEN

The effect of ethylmethane sulphonate (EMS) on different quantitative characters alongwith survivality of three betelvine genotypes namely Simurali Bangla, Sanchi (Tomluk) and Halisahar Jhal are presented in Table 15 and 14 respectively. The results as observed in M_1V_3 generation are described under the following heads.

Survivality: The three genotypes showed differential sensitivity to EMS treatment with respect to survivality. The concentrations of 0.025% and 0.05% for both 4 and 8 hours treatment had almost no effect on the survivality in Simurali Bangla and Sanchi. But the other genotype, Halisahar registered sensitivity for these concentrations particularly for 8 hours treatment. More than 50% reduction in survivality was recorded at 0.10% for 8 hours and 0.20% for 4 hours treatment in Halisahar Jhal. It is quite likely that the LD_{50} for this genotype lied in between 0.05% and 0.10% for 8 hours treatment and in between 0.10% and 0.20% for 4 hours treatment. On the other hand, the two genotypes (Simurali Bangla and Sanchi) exhibited reduction more than 50% only at 0.2% for 4 hours treatment. This showed, the LD_{50} for these genotypes must be in between 0.1% and 0.2% for 4 hours treatment. With respect to survivality, Simurali and Sanchi had the same sensitivity to mutagen while Halisahar showed higher sensitivity. The results also indicated the higher effect for higher duration of treatment from the moderately higher dose of

Table.14 : Percentage of survivality with respect to EMS treatment

Concen- tration	Duration (hours)	Simurahi Bangla			Sanchi (Tomluk)			Halisahar Jhal		
		No.of plants treated	No.of plants survived	Surviva- lity (%)	No.of plants treated	No.of plants survived	Surviva- lity (%)	No.of plants treated	No.of plants survived	Surviva- lity (%)
0.025%	4	16	16	100.00	12	12	100.00	15	15	100.00
	8	16	16	100.00	12	12	100.00	15	12	80.00
0.05%	4	16	16	100.00	12	12	100.00	15	12	80.00
	8	16	14	87.50	12	12	100.00	15	9	60.00
0.10%	4	16	12	75.00	12	9	75.00	15	12	80.00
	8	16	9	56.25	12	7	58.33	15	6	40.00
0.20%	4	16	5	31.25	12	3	25.00	15	3	20.00
	8	16	-	-	12	-	-	15	-	-
0.35%	4	16	-	-	12	-	-	15	-	-
	8	16	-	-	12	-	-	15	-	-
0.50%	4	16	-	-	12	-	-	15	-	-
	8	16	-	-	12	-	-	15	-	-
Control	-	16	16	100.00	12	12	100.00	15	15	100.00

EMS mutagen.

Plant height: Plant height decreased with the increase of concentration of EMS in Sanchi and Halisahar. The Bangla genotype did not show such trend. In Simurali Bangla the lower concentration (0.025%) produced more than 50% dwarf plant type as compared to other treatments. The 0.05% concentration also produced dwarf plant only at 4 hours treatment whereas eight hours treatment produced no significant effect. The higher concentrations (0.10% and 0.20%) also produced no significant variation.

In Sanchi (Tomluk) significant variation was noticed at 0.05% concentration and onwards. The plant height decreased significantly with the increase in concentration of EMS as well as duration of treatment. More than 50% reduction in plant height was noticed at 0.20% concentration applied for 4 hours.

In Halisahar Jhal, plant height also decreased significantly with the increase of concentration but not in a definite trend. The 0.025% concentration produced no significant variation but 0.05% concentration produced highly significant dwarf plant in only 4 hours treatment. Higher concentration (0.10%) also produced dwarf plant (more than 50% reduction) in both 4 and 8 hours treatment. Similar effect was observed at 0.20% concentration for 4 hours treatment.

Internodal length: This trait was also affected due to EMS application. In Simurali Bangla highly significant mean

Table 15 : Effect of EMS on various characters of different genotypes

Characters	Dose	Simurali Bangla		Sanchi (Tomluk)		Halisahar Jhal	
		4 hours	8 hours	4 hours	8 hours	4 hours	8 hours
1 Plant height (cm)	0.025%	25.23**	26.20**	46.98**	45.20**	56.00**	43.00
	0.05%	48.33**	70.66	46.16**	38.96**	37.80**	59.60
	0.10%	61.36	53.38	35.18**	21.58**	18.80**	19.80**
	0.20%	62.88		24.36**		32.00*	
	Control	66.14	66.14	54.80	54.80	55.20	55.20
2 Internodal length (cm)	0.025%	2.24**	2.29**	3.52	3.33	2.65*	3.54
	0.05%	4.00**	3.28**	3.57	2.54	2.17**	4.35*
	0.10%	3.25**	2.43**	2.81**	2.56	2.24**	2.31*
	0.20%	3.06*		2.03*		3.05*	
	Control	5.55	5.55	3.40	3.40	4.27	4.27
3 Petiole length (cm)	0.025%	3.47**	3.45**	2.66**	2.58	3.01*	2.94
	0.05%	4.23**	4.48**	1.82**	2.84	2.86*	3.70
	0.10%	3.57**	4.43**	2.90**	2.42	2.74*	2.67
	0.20%	2.55		1.70**		2.73	
	Control	5.26	5.26	3.17	3.17	3.44	3.44
4 Leaf length (cm)	0.025%	7.13**	7.83**	8.30**	8.40**	7.49	6.79
	0.05%	7.83**	8.10**	6.06**	8.12**	6.77**	8.05
	0.10%	7.73*	10.17	8.79**	8.02**	5.94	6.20*
	0.20%	8.26*		6.22**		6.80	
	Control	9.78	9.78	12.07	12.07	8.13	8.13

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(Table 15 continued).

Characters	Dose	Simurali Bangla		Sanchi (Tomluk)		Halisahar Jhal	
		4 hours	8 hours	4 hours	8 hours	4 hours	8 hours
5 Leaf breadth (cm)	0.025%	5.41**HS1	6.27**	6.00**	5.47**	5.46*	4.95**
	0.05%	6.15**	6.54**	4.63**HS1	5.78*	5.31**HS1	5.96**
	0.10%	6.03**HS2	7.87	6.22**	6.56*	4.17**	3.95**
	0.20%	5.40**		4.00**		4.96*	
	Control	8.48	8.48	8.37	8.37	6.38	6.38
6 Leaf no/vine (no)	0.025%	5.60**	6.00**	11.40	11.80	15.60HS1	8.80*
	0.05%	10.20	11.40	12.60	12.00	13.00HS1	21.20
	0.10%	14.60	9.40	11.00	8.80*	13.40	9.60*
	0.20%	11.00		8.60		18.00	
	Control	13.60	13.60	12.40	12.40	16.00	16.00
7 Avg. leaf area (sq cm)	0.025%	54.50	36.72**	41.28*	41.22	48.83**HS2	32.05
	0.05%	37.00**	30.74**	23.32*	28.62	38.13	36.38
	0.10%	48.20**	40.20**	29.37	26.75	25.48**	19.03**
	0.20%	31.82**		22.28*		28.45**	
	Control	65.82	65.82	40.56	40.56	38.93	38.93
8 Total leaf area/ vine (sq cm)	0.025%	296.86**	217.24**	471.46*	479.94	714.33HS2	284.55**
	0.05%	371.90**	360.52**	295.58*	345.08**	499.47	778.80**
	0.10%	727.20HS1	381.20	322.43*	230.66**	262.36**	185.10**
	0.20%	375.56**		205.86**		222.40	
	Control	908.98	908.98	491.88	491.88	615.53	615.53

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(Table 15 continued)

Characters	Dose	Simurali Bangla		Sanchi (Tomluk)		Halisahar Jhal	
		4 hours	8 hours	4 hours	8 hours	4 hours	8 hours
9 Leaf thickness (cm)	0.025%	0.224*	0.227**	0.236	0.237	0.219**	0.235
	0.05%	0.262**	0.256	0.247 ^{HS2}	0.294**	0.258	0.247
	0.10%	0.308**	0.276	0.250 ^{HS1}	0.218**	0.241	0.224
	0.20%	0.260		0.308**		0.307**	
	Control	0.255	0.255	0.250	0.250	0.246	0.246
10 Shelf-life (no of day)	0.025%	11.80**	15.80	15.29	15.17	13.80**	13.20*
	0.05%	14.67 ^{HS1}	12.00**	11.38	14.25	14.60**	13.00**
	0.10%	15.20	13.80	13.17	11.83	15.80**	11.00*
	0.20%	15.40		14.50		15.25**	
	Control	14.60	14.60	13.33	13.33	9.43	9.43
11 Stomatal frequency (no./sq mm)	0.025%	151.41	153.48	169.24	176.71	119.38	121.78
	0.05%	136.89	139.38	164.27	160.49**	99.56*	108.53
	0.10%	128.60 ^{HS2}	145.18	209.07**	188.74**	161.78**	136.89**
	0.20%	145.18		204.09**		139.38**	
	Control	138.96	138.96	149.33	149.33	118.13	118.13
12 Stomatal index	0.025%	8.52 ^{HS1}	8.79	10.83	9.88	7.59	7.81
	0.05%	7.91**	11.25**	8.90	9.63	7.19	7.64
	0.10%	11.12**	10.95**	9.55 ^{HS2}	12.17*	7.80	9.28**
	0.20%	9.65		13.55**		9.29**	
	Control	8.80	8.80	9.59	9.59	7.37	7.37

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Table 15 continued

Characters	Dose	Simurali Bangla		Sanchi (Tomluk)		Halisahar Jhal	
		4 hours	8 hours	4 hours	8 hours	4 hours	8 hours
13 Stomatal length(μ)	0.025%	32.48**HS1	30.77**	31.87*	31.64*	30.53HS1	27.94**
	0.05%	32.48*HS1	28.80**	31.64*	30.77	29.35	31.01
	0.10%	33.93**	33.40**	27.77HS1	30.57	28.41**HS2	33.14
	0.20%	31.69**		28.34		29.94	
	Control	27.62	27.62	29.82	29.82	31.48	31.48
14 Stomatal breadth(μ)	0.025%	21.44	20.25**	20.83*	20.75**	18.61**HS2	16.83**
	0.05%	20.25*HS2	17.10	20.28*HS1	19.41	18.15**	18.62**
	0.10%	19.86*	23.41	18.30	19.65	19.96*	19.41**
	0.20%	19.59*		18.54		18.70**	
	Control	23.57	23.57	19.41	19.41	22.01	22.01
15 Chlorophyll-a (mg/g leaf)	0.025%	1.076*HS1	0.823**	1.060*	1.447**	1.571HS2	2.135**
	0.05%	1.062*HS1	1.730**	1.393HS1	0.774**	1.991*	1.902**
	0.10%	0.901**	0.820	1.367**	1.262	1.864**	1.872**
	0.20%	0.918**		0.918**		1.962**	
	Control	1.761	1.761	1.523	1.523	1.421	1.421
16 Chlorophyll-b (mg/g leaf)	0.025	0.764	0.615	0.391	0.438	0.904*HS2	1.163
	0.05%	0.682	0.787*	0.553	0.445	0.566**HS2	1.118
	0.10%	0.712HS2	0.465	0.635*	0.801*	0.434**HS2	1.026
	0.20%	0.560		0.252**		1.190*	
	Control	0.520	0.520	0.410	0.410	1.068	1.066

* & ** represent significant mean difference between control and treatment at 5% & 1% level respectively

HS1 & HS2 represent significant mean difference between different hours (4 & 8) of treatment at 5% & 1% level respectively

difference between the treatment and control was observed in all concentrations applied for both 4 and 8 hours. More than 50% reduction in internodal length was noticed at 0.025% concentration applied for 4 and 8 hours. There was no linear relation between the concentration and the reduction in internodal length.

In Sanchi (Tomluk) the effect was just opposite to that of Bangla. Only the 0.20% concentration treated for 4 hours produced highly significant variation while other concentrations did not produce significant changes.

In Halisahar Jhal significant variation was observed in all concentrations without any definite trend. In this genotype 0.025%, 0.05% and 0.20% concentrations were effective only in 4 hours treatment and 0.10% concentration was effective in both the 4 and 8 hours treatment.

Petiole length: This trait was also affected due to treatment of mutagen. In Simurali Bangla, all treatments exhibited highly significant difference from the control. More than 50% reduction was noticed in 0.20% concentration applied for 4 hours. For 0.10% concentration the duration of treatment showed differential variation. The treatment of 4 hours resulted significantly shorter petiole length than that of 8 hours treatment.

In Sanchi (Tomluk) 0.05% and 0.20% concentrations for 4 hours and 0.10% concentration for 8 hours produced highly

significant short petiole. The remaining treatments did not produce any significant variation.

In Halisahar Jhal also , the treatments resulted short petiole length but significant variation was noticed only at 0.05% and 0.10% concentration for 4 hours treatment.

Leaf length: Mutagenic treatment (EMS) exhibited shorter leaf length in all genotypes. In this trait, irrespective of genotypes, any concentration of EMS at shorter duration (4 hours) produced reduced leaf length as compared to that in longer duration (8 hours) of treatment. In Simurali Bangla, 0.025% and 0.05% concentrations for both 4 and 8 hours showed significant reduction and 0.10% and 0.20% concentrations treated for 4 hours showed significant mean deviation from control. In this genotype, there was a slight increment in leaf length with the increase of concentration as well as duration of treatment.

In Sanchi (Tomluk) all treatment combinations in the present investigation produced highly significant reduction in mean value from that in the control. The concentration of 0.05% treated for 4 hours produced significantly smaller leaf length as compared to that in 8 hours treatment.

In Halisahar Jhal only 0.05% concentration for 4 hours and 0.10% concentration for 8 hours treatment produced significantly smaller leaf length. In this genotype differential response with respect to duration of treatment was noticed.

Leaf breadth: Mutagenic treatment produced reduced leaf breadth accompanied with reduced length in each genotype without any definite trend. The concentrations of EMS applied for shorter duration (4 hours) produced reduced leaf breadth as compared to that in longer duration (8 hours) of treatment irrespective of genotypes.

In Simurali Bangla, all the treatment combinations except 0.10% concentration for 8 hours resulted highly significant reduction in leaf breadth. The concentrations of 0.025% and 0.10% showed differential response with respect to duration of treatment.

In Sanchi (Tomluk) all the concentrations showed highly significant mean difference for both durations of treatment. In this genotype, more than 50% reduction in leaf breadth was noticed at 0.20% concentration for 4 hours treatment.

In Halisahar Jhal, all the treated combinations, except 0.05% concentration applied for 8 hours, produced significantly reduced leaf breadth. In this genotype, the 0.05% concentration proved its effectiveness in reducing leaf breadth for 4 hours treatment but not in 8 hours treatment.

Leaf number/vine: This trait was not much affected due to mutagenic treatment. In Simurali Bangla, 0.025% concentration for 4 and 8 hours, in Sanchi (Tomluk) 0.10% concentration for 8

hours and in Halisahar Jhal 0.025% and 0.10% concentrations for 8 hours treatment produced significantly less number of leaves/vine. The remaining treatments for different durations did not produce any significant variation. In Simurali Bangla more than 50% reduction in leaf number was noticed at 0.025% concentration applied for both 4 and 8 hours. On the contrary, higher number of leaves per vine was noticed at 0.10% for 4 hours treatment in Simurali Bangla, 0.05% for 4 hours in Sanchi (Tomluk) and 0.05% and 0.20% for 8 and 4 hours respectively in Halisahar Jhal but the more number of leaf/vine was not significantly different from that of control.

Average leaf area: In general, all the treatment combinations produced significantly less leaf area irrespective of genotypes except at 0.025% concentration applied for 4 hours in Halisahar Jhal.

In Simurali Bangla, leaf area was severely affected in all treatment combinations except at 0.025% concentration treated for 4 hours. Here the leaf area decreased with the increase of concentration as well as duration of treatment but this trend was more pronounced with the period of treatment than the concentration of EMS. In this genotype more than 50% reduction in leaf area was noticed in 0.05% concentration applied for 8 hours and in 0.20% concentration applied for 4 hours.

The genotype Sanchi (Tomluk) has less reducing effect. Only the concentrations of 0.05% and 0.20% produced

significantly reduced leaf area .The remaining treatments did not produce any significant variation.

In Halisahar Jhal, the reduction in leaf area showed descending trend with the increased duration of treatment. Here all the treatment combinations, except 0.05% concentration, resulted highly significant variation for this trait. One interesting point was that the 0.025% concentration for 4 hours treatment resulted highly significant increased area. On the other hand, the 0.10% concentration for 8 hours treatment produced more than 50% reduction.

Total leaf area/vine: Mutagenic effect was observed in total leaf area/vine in each genotype without any definite trend. In Simurali Bangla all the treatment combinations except 0.10% concentration for 4 hours treatment produced significant reduction (more than 50%) in total leaf area/vine. In this genotype 0.10% concentration for 4 hours treatment proved its ineffectiveness in producing a mutagenic effect.

In Sanchi (Tomluk), 0.05% and 0.20% concentrations for 4 hours and 0.10% at both 4 and 8 hours treatment resulted significantly reduced leaf area/vine. More than 50% reduction in leaf area was noticed in 0.10% concentration for 8 hours and 0.20% concentration for 4 hours treatment. The remaining treatment combinations did not produce any significant variation.

In Halisahar Jhal, 0.025% concentration for 8 hours and 0.10% concentration for both 4 and 8 hours treatment produced

significant reduction. The concentrations, 0.025% and 0.10% for 8 hours produced more than 50% reduction. The concentration 0.025% for 4 hours treatment produced higher leaf area/vine but this increment was not statistically significant.

Leaf thickness : In this trait mutagenic effect showed both positive and negative effects. In Simurali Bangla, while 0.025% concentration for both 4 and 8 hours treatment produced significantly thinner leaf, the 0.10% concentration for 4 hours treatment resulted significant thicker leaf. The remaining combinations did not produce any significant variation.

In Sanchi (Tomluk), 0.05% and 0.20% concentrations for 8 and 4 hours respectively resulted significant thicker leaf. On the other hand, 0.01% concentration for 8 hours produced significantly less leaf thickness (0.218 mm) as compared to that in the control (0.250 mm). In this genotype the 0.05% and 0.10% concentrations produced their significant effects only at 8 hours treatment indicating thereby, the differential response in changing leaf thickness with respect to duration of treatment.

In Halisahar Jhal 0.025% and 0.20% concentrations for 4 hours produced highly significant thinner (0.219 mm and 0.207 mm respectively) leaf as compared to that in the control (0.246 mm) while the former concentration (0.025%) produced significantly higher leaf thickness at 8 hours (0.235 mm) as compared to that for 4 hours (0.219 mm) treatment. The remaining treatment combinations did not show any significant variation.

Shelf-life: In Simurali Bangla 0.025% concentration for 4 hours and 0.05% concentration for 8 hours treatment produced highly significant lower (11.80 and 12.00 day respectively) shelf-life than that in control (14.60 days). In this genotype, EMS treatment, in general, did not induce much variation. In Sanchi(Tomluk) only numerical variation was noticed due to application of EMS. On the other hand, the genotype Halisahar Jhal responded significantly. It produced significantly higher shelf-life than the control in each treatment. In this genotype, the same treatment for higher duration (8 hours) showed lower shelf-life as compared to that in lower duration (4 hours) of treatment.

Stomatal frequency: The mutagen produced differential effects on the genotypes. There was no definite trend in the expression of this character in any genotype. Simurali Bangla had no significant variation at all, but Sanchi(Tomluk) had significantly large number of stomata per unit leaf area at 0.10% and 0.20% concentrations. In this genotype, the 0.10% concentration for 4 hours showed more number of stomata (209.07) per unit leaf area as compared to that for 8 hours treatment (188.74). On the other hand, in Halisahar Jhal, while 0.05% concentration for 4 hours showed significantly less number of stomata (99.56), the 0.01% concentration for both 4 (161.78) and 8 hours (136.89) and 0.20% concentration for 4 hours (139.38) produced significantly more number of stomata per unit leaf area

as compared to that in the control (188.13). Like Sanchi (Tomluk) in this genotype also, the 0.10% concentration for 4 hours treatment produced significantly more number of stomata as compared to that for 8 hours treatment, indicating the differential response with respect to duration of treatment in these two genotypes.

Stomatal index: This trait showed effects of EMS treatment in positive direction in each genotype. In Simurali Bangla 0.05% concentration for 8 hours (11.25) and 0.10% concentration for both 4 (11.12) and 8 hours (10.95) resulted significantly greater index than in control (8.80). Similarly, in Sanchi (Tomluk), the 0.10% for 8 hours (12.17) and 0.20% for 4 hours (13.55) and in Halisahar Jhal 0.10% for 8 hours (9.28) and 0.20% for 4 hours (9.29) treatment also produced significantly higher index. In Sanchi (Tomluk) the 0.10% concentration applied for 8 hours exhibited significantly higher index as compared to that in 4 hours treatment.

Stomatal length: EMS treatment induced significant variation in this trait without any definite trend. In Simurali Bangla all the treatments except 0.05% for 8 hours had highly significant higher stomatal length as compared to that in control. In Sanchi (Tomluk), 0.025% concentration for both 4 and 8 hours and 0.05% concentration for 4 hours produced significantly longer stomata than that in the control. Also in Halisahar Jhal both the 0.025% and 0.10% concentrations for 8 and 4 hours respectively registered significantly shorter length than in

control.

Stomatal breadth: Differential genotypic responses were noticed in this trait in response to EMS treatment . In Simurali Bangla, 0.025% and 0.05% concentrations for 8 hours and 0.10% and 0.20% concentrations for 4 hours produced significant less breadth than in control. In this genotype stomatal breadth decreased with the increase of concentration of EMS. This trend was not noticed in Sanchi (Tomluk) . In this genotype 0.025% concentration for both 4 and 8 hours and 0.05% concentration for 4 hours treatment resulted significant higher breadth. On the other hand, in Halisahar Jhal all the combinations produced highly significant less breadth compared to that in control. In this genotype, 0.025% concentration for 8 hours showed less breadth as compared to that in 4 hours treatment indicating differential responses with respect to duration of treatment.

Chlorophyll a : With respect to chlorophyll a content Simurali Bangla and Sanchi (Tomluk) produced significant less amount of chlorophyll. But genotype Halisahar Jhal produced significant high amount as compared to that in control. In Simurali Bangla all the treatments except 0.05% concentration for 8 hours and in Sanchi (Tomluk) 0.025% and 0.20% concentrations for 4 hours and 0.05% concentration for 8 hours treatment exhibited significant less amount of chlorophyll than the respective controls. Unlike these two genotypes, Halisahar Jhal for all the treatments produced significant higher amount

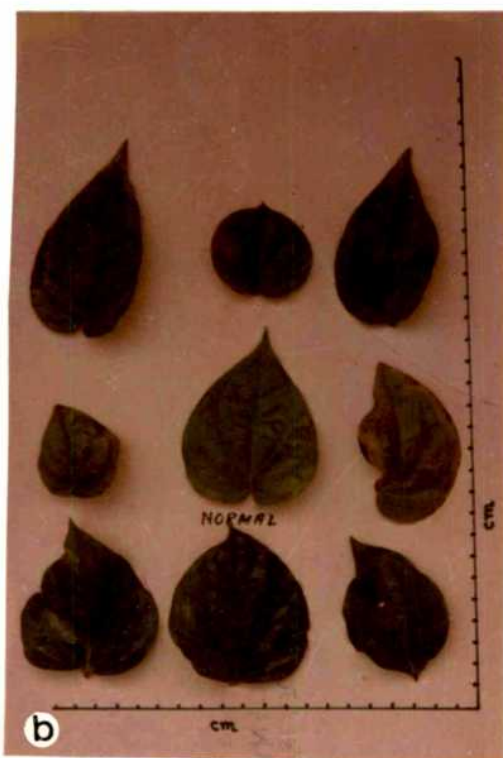
of chlorophyll a than in control.

Chlorophyll b : The genotypes Simurali Bangla and Sanchi (Tomluk) showed less variation than Halisahar Jhal to EMS treatment. In Simurali Bangla, 0.05% concentration for 8 hours registered significant high amount of chlorophyll b. In Sanchi (Tomluk) the 0.10% concentration for both 4 and 8 hours treatment produced significant high amount of chlorophyll b while 0.20% concentration for 4 hours treatment produced significant low amount (0.252 mg/g) as compared to that in the control (0.410 mg/g). Similarly, in Halisahar Jhal the concentrations like 0.025%, 0.05% and 0.10% for 4 hours treatment exhibited significant low amount but the 0.020% concentration for 4 hours produced significant high amount (1.190 mg/g) of chlorophyll b as compared to control (1.068 mg/g). In this genotype, the former concentrations (0.025%, 0.05% and 0.10%) for 4 hours induced highly significant less amount than that in 8 hours treatment. In Halisahar Jhal, the significant differential response with respect to duration of treatment was noticed.

Leaf deformity: Apart from the significant variation in different quantitative traits, stated above, remarkable changes were also noticed in leaf shape and size of each genotype under study. In Simurali Bangla, the leaves of M_1V_1 generation were irregular, asymmetrical with respect to midrib and with wavy margins (Photograph a and b). Some of the leaves were more or less circular in shape without any prominent tip. Similarly, Sanchi (Tomluk) had oval to semi-lanceolate type without any

EXPLANATION OF PLATES
(a-b)

- a) The genotype, Simurali Bangla shows leaf deformity due to EMS treatment. The lower most leaf is normal. The leaves above the red band (point of EMS treatment) show the deformity in shape and size.
- b) The genotype Simurali Bangla shows leaf deformity due to application of various doses of EMS. The central leaf represents the normal shape and size of the genotype. The leaves surrounding the normal leaf (central) are of deformed type.

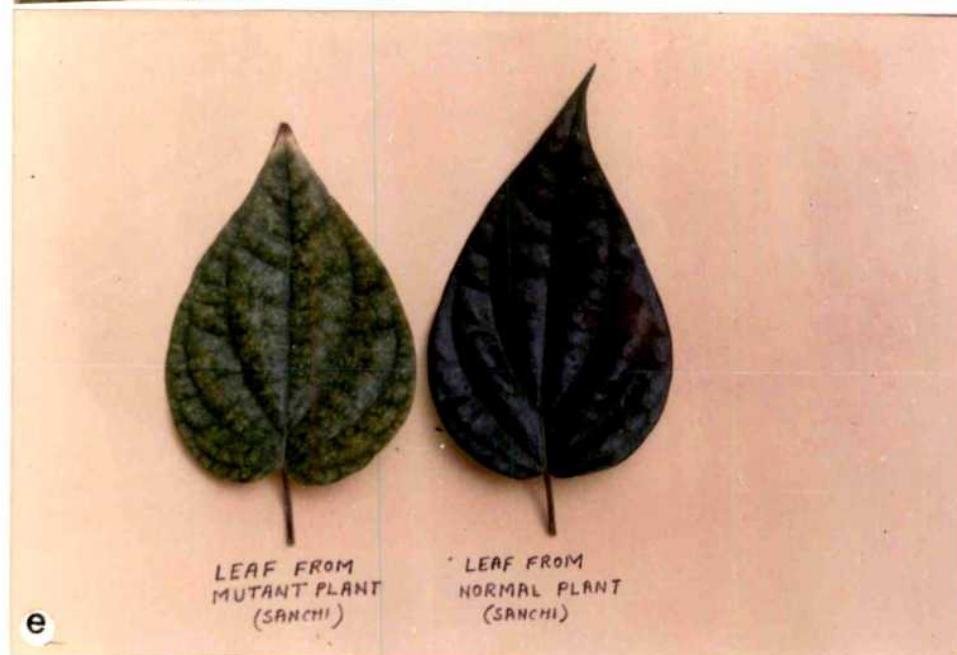


clear margin (Photograph c and d) . A few leaves were also deformed spirally without any definite shape.

On the other hand, in Halisahar Jhal MORE significant change in leaf shape and size was noticed in M_1V_1 generation as compared to above two genotypes. In this genotype , a large number of leaves were completely circular type without regular margin and leaf tip (Photograph f). A few number of treated leaves were more or less tri-lobed in appearance with a reduced petiole (Photograph g). Again in some cases the leaves were completely lanceolate with wavy margins (Photograph h). In general, all mutated leaves of each genotype were reduced in size.

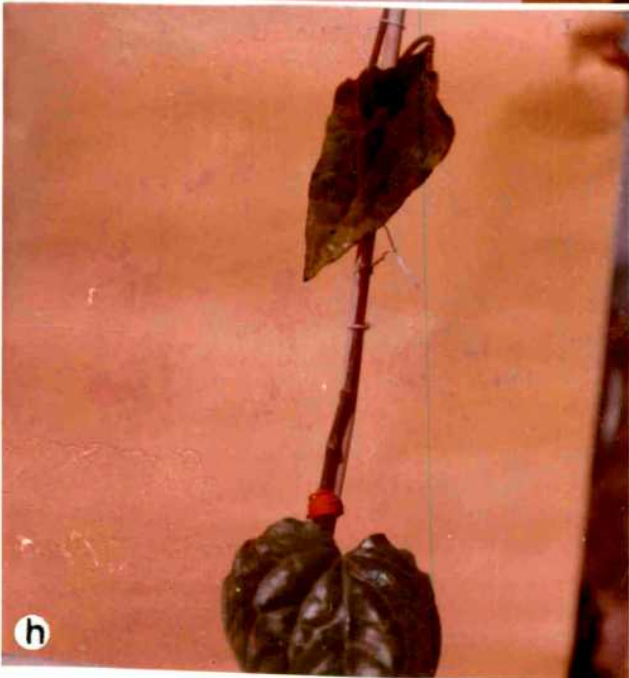
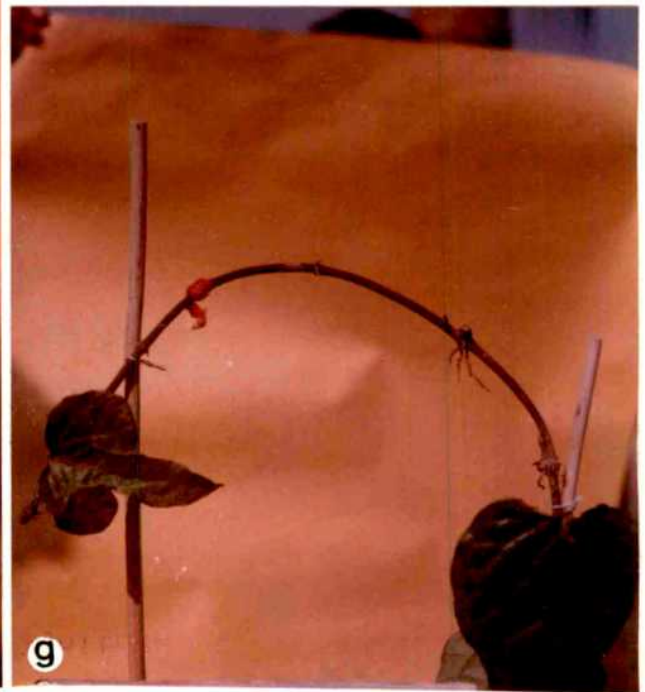
EXPLANATION OF PLATES
(c-e)

- c) The genotype, Sanchi (Tomluk) shows leaf deformity due to application of EMS. The lower most leaf is normal. The leaves above the red band (point of EMS treatment) show deformity in shape.
- d) The central leaf represents the normal leaf of the genotype, Sanchi (Tomluk) whereas the surrounding are deformed as a result of EMS treatment.
- e) Sanchi (Tomluk) shows chlorophyll deficiency in leaf (slightly yellowish) as mosaic due to EMS treatment.



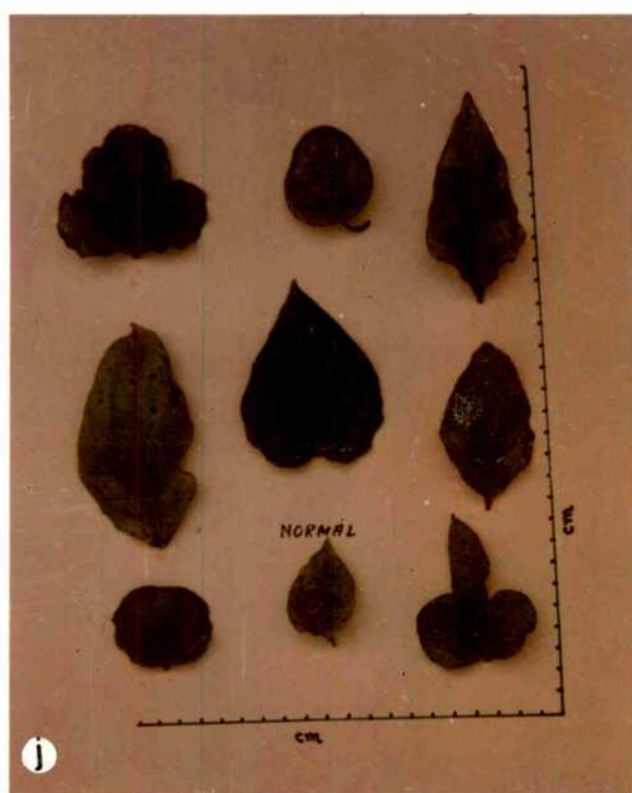
EXPLANATION OF PLATES
(f-i)

- f) The genotype, Halisahar Jhal represents deformed leaf of circular type (lower most of the left hand side). The leaves of the right hand side (below red band) are of normal type.
- g) Above the red band , the genotype, Halisahar Jhal shows deformed leaf (trilobed). The leaves of the right hand side (below red band) are of normal shape and size.
- h) The same genotype shows lanceolate leaf (above red band) of smaller size than the normal leaf (below red band).
- i) The deformed leaves (above the red band) of the genotype, Halisahar Jhal are of no definite shape and size.



EXPLANATION OF PLATE
(j)

Various types of leaf deformity of the genotype, Halisahar Jhal are presented in this plate. The central leaf is of normal shape and size whereas the surrounding leaves represent leaf deformities as a result of treatments of EMS.



4.7 GENETIC VARIABILITY INDUCED BY GAMMA-RAYS

The effect of gamma-ray irradiation on survivality and other characters of the genotype, Simurali Bangla, are presented in Table 16 and 17 respectively.

With respect to survivality, it was observed that the increase of radiation dosage resulted decreased survivality (Table 16). More than 50% reduction in survivality was noticed in 5 KR and onwards and LD_{50} must be in between 2 KR and 5 KR doses while the control had 87.50% survivality under this situation.

With respect to plant height (Photograph k-n) no definite trend was noticed (Table 17) and the lowest dose(2 KR) showed highly significant reduction (46.20 cm) but 5 KR treatment showed only numerical decrease (59.80 cm) over the control(66.40 cm).On the other hand , 10 KR treatment also had significantly lower height(54.60 cm). Similiarly, in case of internodal and petiole length, the mean values decreased significantly without showing any definite trend. Though leaf number /vine did not exhibit any remarkable variation except in 10 KR treatment,the average leaf area decreased significantly with the increase of dosage showing declining trend and more than 50% reduction was noticed in 10 KR treatment.

In case of total leaf area/vine and leaf length, only 10 KR treatment resulted significant lower mean value than in

Table 16 : Percentage of survivality of the genotype Simurali
 Bangla with respect to gamma-ray irradiation

Dose	No.of plant treated	No.of plant survived	Survivality (%)
2KR	40	24	60.00
5KR	40	12	30.00
10KR	40	7	17.50
Control	40	35	87.50

EXPLANATION OF PLATES
(k-n)

k) Control vine of the genotype, Simurali Bangla.

l) Vine after treatment of gamma-rays (2 KR)

m) Vine after treatment of gamma-rays (5 KR)

n) Vine after treatment of gamma-rays (10 KR)

The photographs (k-n) indicate the reduction in plant height in Simurali Bangla as a result of irradiation of gamma-rays.

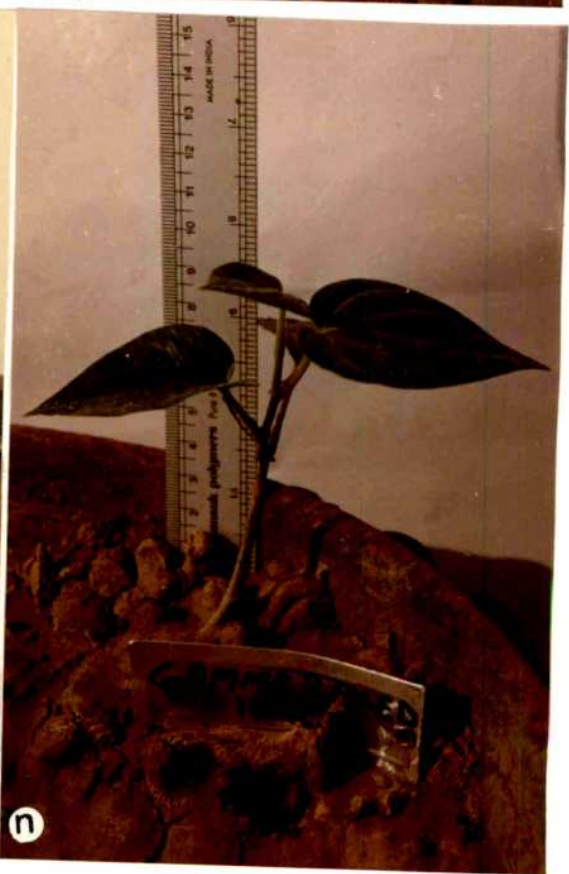


Table.17 : Effect of gamma-ray irradiation on different quantitative characters of Simurahi Bangla

Dose	Plant height (cm) (1)	Internodal length(cm) (2)	Petiol length (cm) (3)	Leaf no./ vine (4)
2KR	46.20**	3.65**	3.45**	9.40
5KR	59.80*	4.28**	4.52**	11.80
10KR	54.60*	3.78**	3.37**	7.80*
Control	66.4	5.61	5.33	10.40

Dose	Av.leaf area (sq cm) (5)	Total leaf area/ vine (sq cm) (6)	leaf length (cm) (7)	Leaf breadth (cm) (8)
2KR	64.28	601.36	9.73	7.96*
5KR	63.14	736.40	9.84	7.70
10KR	29.83**	222.27**	7.11**	5.88**
Control	62.70	660.40	9.78	8.48

contd.next page

(Table 17 continued)

Dose	Leaf thickness (mm) (9)	Shelf-life (days) (10)	Stomatal freq. no./sq mm (11)	Stomatal index (12)
2KR	0.258	16.30	114.22*	9.48
5KR	0.282*	15.00	101.63**	10.51
10KR	0.303**	13.50**	93.35**	9.63
Control	0.256	15.60	138.97	9.43

Dose	Stomatal length (μ) (13)	Stomatal breadth (μ) (14)	Chlorophyll-a (mg/g leaf) (15)	Chlorophyll-b (mg/g leaf) (16)
2KR	31.25*	19.73**	0.884**	0.481
5KR	32.27**	23.27	1.317*	0.655
10KR	34.08**	23.59	0.862**	0.436
Control	27.54	23.83	1.762	0.512

* and ** indicate the significant mean difference between control & treatment for a given character at 5% and 1% level respectively

control. The other two treatments did not produce any significant variation. In leaf breadth, significant variation was noticed in 10 KR treatment but not in 2 KR and 5 KR treatments. With respect to leaf thickness, the trait increased significantly with the increase of dosage. At 10 KR treatment it increased significantly (0.303 mm) as compared to that of control (0.256 mm). On the contrary, a declining trend was noticed in shelf-life in 5 KR dose and onwards. With respect to stomatal frequency, the declining trend was noticed and at 10 KR treatment 32.83% reduction in the number of stomata per unit area was observed. Regarding stomatal index, no significant variation was observed at any treatment indicating the ineffectiveness of the applied doses in the present study to modify this trait, significantly. On the contrary, for stomatal length a significantly increasing trend was noticed with the increase of dosage. In case of stomatal breadth significant variation in negative direction was noticed in only 2 KR treatment. The other higher doses did not produce any significant variation.

With respect to estimated chlorophyll a content, 2 KR and 10 KR treatments resulted highly significant lower amount (0.880 mg/g and 0.862 mg/g respectively) and 5 KR treatment produced slightly lower amount (1.317 mg/g) as compared to control (1.762 mg/g). Unlike chlorophyll a, chlorophyll b did not produce any significant variation in response to gamma-ray irradiation.

Apart from the above mutagenic changes, a remarkable variation in branching habit was observed at 5 KR treatment

EXPLANATION OF PHOTOGRAPHS
(o-p)

- o) Branch primordia from each axil of leaf emerge as a result of treatment of gamma-rays (5 KR).

- p) Pruning gave forth new branches from several nodes. This was done to eliminate the chimera effect.



(Photograph o). Some of the treated vines produced auxillary buds form each node which ultimately developed into completely new vines. Such type of branching habit is extremely rare in the present genotype, Simurali Bangla.

CHAPTER - V

DISCUSSION

4.1 ASSESSMENT OF VARIABILITY

The general analysis of variances in the three seasons were highly significant for all the characters under study indicating thereby the significant differences among the genotypes taken in this investigation.

It was observed that maximum of the economic traits like leaves/vine, average leaf area, total leaf area/vine etc. produced their highest performance (highest mean values) in rainy season and lowest in winter season. This differential growth behaviour in betelvine depending upon seasonal changes was also noticed by Das and Chattopadhyay (1982a). They stated that the highest growth behaviour in rainy season is due to presence of medium seasonal temperature, high rainfall and consequent high humidity.

In the variability studies, for the respective character in the three seasons, the differences between genotypic and phenotypic variances and their corresponding phenotypic and genotypic coefficients of variation were more or less similar in magnitude except total leaf area /vine. This nature of variation pointed out the lesser effect of environment on the quantitative characters under study. In maximum of the cases the heritability percentage in broad sense were sufficiently higher than 60 percent in magnitude. The heritability percentage (in broad sense) was maximum for leaf breadth (91.59%) and that of minimum magnitude was 57.90% for total leaf area/vine on an average of

the three seasons. Average heritability for leaves no/vine, leaf length, and average leaf area were respectively 67.60%, 76.02% and 65.32% . Shelf-life in betelvine is an important character from the economic point of view and its average heritability in broad sense was 82.89%. This indicates that out of total variation, 82.89% variation is due to genetic cause.

GCV alone is not a correct measure to know the heritable variance present and should be considered together with heritability estimates to get the better idea about the amount of advance to be expected from the selection (Burton, 1952). High GCVs along with high heritability estimates were observed for petiole length, leaf length, leaf breadth, stomatal frequency, chlorophyll a and b and shelf-life over the seasons. High GCVs along with moderate to high estimates of heritability were recorded for leaves/vine and average leaf area. Due to the close correspondence between genotype and phenotype, those characters can be improved through selection.

On the other hand total leaf area/vine showed high GCV coupled with low heritability indicating thereby masking effect of environment on the genotypic effects. Leaf yield in betelvine, expressed in terms of total leaf area/vine, is itself a dependable character and direct selection for such trait sometimes may be misleading.

Again high heritability along with high genetic advance was advocated more useful than the heritability or genetic

advance alone in predicting the resultant effect of selection to an additive character (Johnson *et al*, 1955). Hence, one has to consider high heritability and high genetic advance together to select better segregant with desirable additive effect (Panse 1987). In the present study high genetic advances alongwith high heritability estimates were recorded for leaves/vine, leaf breadth, chlorophyll a, b and shelf-life suggesting a conventional breeding method i.e., selection on the basis of the phenotype of the segregant in the segregating generation will be rewarding for further improvement of these traits. High genetic advance alongwith moderate to high heritability was observed for leaves/vine and average leaf area. Therefore, by restoring to straight selection based on these two characters, further improvement can be achieved through a number of cycle for selection. On the other hand, total leaf area/vine has high genetic advance coupled with low heritability in every season indicating thereby non-additive gene effect for the expression of this most important economic trait which can be improved by heterosis breeding.

4.2 CORRELATION COEFFICIENTS

The strength and direction of relationship between various pairs of variables followed almost similar trend of association at both phenotypic and genotypic levels. The result revealed that the magnitude of association at genotypic level was always higher than that at the phenotypic level over the seasons. In most of the cases, strong significant association in the same direction both at genotypic and phenotypic level implied the minimum influence of environment in the expression of those characters. The phenotypic correlation may be genetic and/or environmental in origin and provides information about association between two observable characters whereas the genetic correlation mainly accounts for linkage or pleiotropic action of genes or more likely for both.

Among the associations between leaf yield and other 14 attributes, the correlation^{CO} coefficients of leaf length and breadth and average leaf area with leaf yield over seasons were significant and positive in nature both at phenotypic and genotypic levels. These result supported the assumption of genetic control of these characters either by constitution of linkage group or by the pleiotropic effect of the genes which was less influenced by the environment. Hence these characters are important in manifestation of ultimate leaf production and deserve due attention in yield component analysis. The inter-relationships between these three characters were also highly

significant and positive. The results indicated that increase of leaf length and/or leaf breadth and/or average leaf area will cause conducive morphological framework towards increased leaf yield.

Leaves/vine exhibited highly significant positive correlation with leaf yield (total leaf area/vine) at both phenotypic and genotypic levels but its correlations with above three characters were insignificant except in rainy season. However it indicated that increase in leaf number/vine will tend to reflect increase in leaf yield.

Petiole length in rainy season showed significant correlations not only with leaf yield but also with leaves/vine, leaf length, leaf breadth and average leaf area which were in turn significantly and positively correlated with leaf yield. Therefore, the result indicated that longer petiole length in betel leaves is a desirable attribute and should be given due attention during selection programme.

Similarly leaf thickness in only rainy season, stomatal index and stomatal length in summer and rainy season, and stomatal breadth in only summer season showed significant positive correlation with leaf yield at both phenotypic and genotypic levels. However, the coefficients of those associations were considerably low and showed a seasonal variation indicating a weak relationship.

Stomatal frequency revealed significant negative correlation coefficient with leaf yield at both phenotypic and genotypic levels in rainy season and at genotypic level in winter season indicating that the increase in stomatal number in the epidermal layer will result decrease in total leaf area/vine. The significantly negative correlation between stomatal frequency and shelf-life in winter season also indicated the undesirability of more stomata in betel leaves.

The correlation studies thus revealed that a betel vine creeper having increased leaves/vine, leaf length, leaf breadth, average leaf area along with higher petiole length, stomatal length, stomatal breadth and less number of stomata in the epidermal layer may be more productive in terms of leaf yield.

4.3 PATH-CO EFFICIENTS

The path analysis is used as a tool in plant breeding for effective selection of an independent character on a logical ground resulting the maximization of dependent character like yield. The analysis has been found useful in finding out direct and indirect causes in relation to correlation and permits a detailed analysis of specific forces acting to produce a given correlation.

In the present study the correlation coefficients between average leaf area and leaf yield (i.e. total leaf area/vine) were more or less equal to its direct effect over the seasons at both phenotypic and genotypic levels. So, the correlation explains the true relationship and a direct selection through this trait will be effective. In case of leaves/vine, the direct effect was positive with considerable magnitude but slightly deviated from the total correlation with leaf yield (i.e. total leaf area/vine) at both phenotypic and genotypic levels. Apart from its direct effect this character exerted its remarkable positive indirect effect through average leaf area. Thus, during selection emphasis on average leaf area will ascertain the increase of total leaf area/vine at an optimum level.

In case of leaf length, breadth and stomatal length (except in winter at penotypic level), their correlation coefficients with total leaf area/vine were positive with highly

significant value but their direct path effects were negative with very lower in magnitude. Their indirect effects through the average leaf area showed a great role in the relationship with total leaf area/vine. These components of leaf yield (i.e. total leaf area/vine) also revealed that selection based on average leaf area will maximise the possibility to increase the total leaf area/vine.

Thus, considering the direct and indirect effects of various components on leaf yield it can be concluded from the present study that a plant possessing more number of leaves with maximum leaf length and breadth resulting higher average leaf area will ensure the increase of leaf yield over the seasons.

Furthermore, the above components were found to possess moderate to high heritability and genetic advance over the seasons. Hence, these components may be safely included in selection programme in anticipation of the chance of advancement resulting high yielding genotypes in terms of leaf yield in betel vine.

4.4 GENETIC DIVERGENCE

In view of the great importance of genetic diversity to breeding, multivariate analysis by means of Mahalanobis's D^2 statistic (1936), the powerful tool in quantifying the degree of divergence between biological populations, were carried out. The objective of this work was to group a set of parental varieties into different clusters according to the genetic divergence and such grouping would help to initiate crossing programme between widely divergent groups. This would enable to get more desirable recombinants in the segregating populations.

The distribution of the genotypes into different clusters based on relative magnitude of D^2 values were found to be random. Differences in genetic constitution and the presence of unabated influence of environmental factors (Murty and Arunachalam, 1966; Murty, 1977) may be responsible for this type of clustering pattern. In spite of emphasis laid by Joshi and Dhawan (1966), the clustering pattern here indicated that the genetic diversity was not necessarily related with geographical distribution. It may be mentioned that no direct relationship had been found between geographical distribution and genetic divergence in a variety of crops with variable breeding systems (Murty and Arunachalam, 1966; Singh and Gupta, 1968; Das and Dasgupta, 1984; Choudhury *et al.* 1985 and others). Murty and Arunachalam (1966) stated that genetic drift and selection on environment could cause greater diversity than geographic

distance. Furthermore free exchange of propagating materials from one location to another or a fixed criterion being used during selection in different centres could have enabled the genotypes from different geographic regions to lie together in the same cluster. Thus, the characters constellation that might be associated with a particular region loses its individuality and rhythm under human interference.

The highest intracluster distance in cluster V was indicative of wide genetic divergence between the constituent genotypes (Mandal and Banerjee, 1991) which could be used in yield improvement of a crop species through intervarietal hybridization. It has been also reported earlier that varieties within a cluster with high degree of divergence would be the best breeding materials for achieving maximum genetic advance with regard to yield per se (Angadi, 1976). The minimum intracluster value was recorded by cluster III indicating gross genetic similarity among the constituent genotypes viz. Godi Bangla and Karapaku Bangla (both are Bangla type) probably because of unidirectional selection pressure which might have been exerted on them during the process of their development or might be due to their pedigree similarity.

Maximum divergence at inter-cluster level was observed between clusters VII and X which can be expected to exert high heterotic effect in the hybrids when crossed and consequently may generate desirable segregants, as highly divergent genotypes

would produce a broad spectrum of variability enabling further selection and improvement (Bhatt, 1973). The inter-cluster distance between clusters VII and VIII was also relatively higher as compared to other inter-cluster distances. The cluster VII was made up of a single genotype (Borghai, a Bangla type) which had larger internodal and petiolar length, more number of leaves/vine, largest individual leaf area and total leaf area/vine but with short shelf-life (15.13 days only). On the other hand, the cluster VIII was made up of a single genotype Sanchi (Halisahar), a sanchi type, which was characterised by smaller internodal and petiolar length, more number of leaves/vine, smaller individual leaf area and total leaf area/vine but having longer shelf-life (22.81 days). Therefore, these two genotypes, coming from distantly related clusters, may be selected as parents for hybridization programme. This type of assumption has already been made by Rawat and Balasubrahmanyam (1988) for evolving betelvine cultivars by combining the vigour and high yield of Bangla type with the excellent quality of Sanchi type.

In view of the above discussion six genotypes viz. Borghai of cluster VII and Kare Bangla, Ayamal Bangla, Chandrokona, Haldi pan and Kalidhal Bangla of cluster II were emerged for hybridization programme in view of their superior performance in respect of leaves/vine, average leaf area and total leaf area/vine. And for evolving high yielding varieties with longer shelf-life, varieties like Sanchi (Halisahar) of cluster VIII and Halisahar Jhal and Kapoori (Palghat) of cluster IV can be considered in selecting parents for hybridization programmes.

4.5 PHENOTYPIC STABILITY

Stability analysis in plant breeding helps tremendously in understanding the adaptability of crop varieties over a wide range of environmental conditions and in the identification of stable genotypes. The use of these stable genotypes in turn helps in achieving stabilization in crop production over locations and years. Since yield stability is genetically controlled, the use of stable genotypes in hybridization programme will lead to development of phenotypically stable high potential cultivars and hence selection for yield stability can be effective. Stability analysis is also an important tool for plant breeders in predicting response of various genotypes over changing environments (Singh *et al*, 1975 & Singh, 1981).

The importance of genotype X environment (G X E) interaction has been recognised from very beginning. Knowledge of G X E is important in making decisions concerning breeding objectives, methods, selection programmes and testing procedure in crop plants. Therefore, the investigation was to find out the G X E interactions of a number of betelvine genotypes with respect to leaf yield.

Partitioning of G X E interaction on the basis of Eberhart and Russell (1966) model, shows two points: (i) the variation due to response of varieties to varying indices (sum of square due to regression) and (ii) the deviations from the regression on the environmental index. In other words, the

regression analysis partitions the G X E interactions into two components; (i) the heterogeneity among fitted lines or regression coefficients and (ii) deviations from regression to determine if the G X E interactions are a linear function of environmental effect. This means that this is a test to determine if differential response of genotypes to environment is explained as a linear function of environment in the environmental mean yields. Significant differences among slopes or regression coefficients indicate that each genotype has its own specific linear response to a change in environment, while significant deviation indicates non-linear responses. The significant deviations from linearity arise due to specific cultivar environment interaction (Joppa *et al*, 1971).

The analysis of variance for stability parameters in the present investigation clearly indicated that both linear and non-linear component of G X E interaction played an important role in the expression of all the characters under study except leaf length, leaf thickness and stomatal length and breadth.

Regarding stability parameters three kinds of linear responses viz. $b_i > 1$, $b_i = 1$ and $b_i < 1$ were observed in present study. Assuming $S^{-2}_d = 0$, a high value of b_i indicate the more responsiveness of a variety. Such variety may, therefore, can be recommended only for highly favourable environments because those varieties can take the advantages of favourable growing conditions. Higher b_i values also imply serious yield decline as conditions worsen. A lower value of b_i i.e., around 1, mean less

responsiveness to the environmental changes and therefore, more adaptive. The varieties having unit regression coefficient ($b_i=1$) also indicate that these varieties will perform by an average amount as conditions improve (average in response). If, however, b_i is negative, the variety may be grown only in poor environment. The smaller b_i values imply failure to take advantage of better conditions. If S^{-2}_d is non significant, the performance of a genotype for a given environment may be predicted. Accordingly, a variety whose performance can be predicted (i.e., $S^{-2}_d=0$) is said to be stable.

Depending on these two parameters of stability i.e., b_i and S^{-2}_d along with mean performance, the betelvine genotypes were screened out or grouped as suitable for high, medium and low yielding environments or may be selected as parents in a hybridization programme.

(i) For petiole length the genotypes Ghanagete Bangla, Ayamal Bangla and Adi Bangla had high mean performance alongwith $b_i=1$ and $S^{-2}_d=0$. These genotypes, therefore, be expected to exhibit greater stability for this character over wide range of environments. Five genotypes namely Kali Bangla, Simurali Deshi, Borghai, Chandrokona, Ramnagar Deshi and Kalidhal Bangla showed higher mean value with significantly high b_i from unity and $S^{-2}_d=0$. These genotypes, therefore, indicated their responsiveness to environmental changes. The genotype Kale Bangla showed high mean value but its both b_i and S^{-2}_d values were highly

significant, indicating thereby the unstability of this genotype over the environments. On the other hand three genotypes namely Karapaku Bangla, Birkuli and Dhal Bangla had high mean value alongwith negative b_i and $S^{-2}d=0$. So, these stable genotypes are expected to perform better under poor environments.

(ii) For leaves no/vine the genotypes like Sanchi (Halisahar), Halisahar Jhal, Kapoori (Palghat), Kapoori (Sangli), Simurali Bhabna, Borghai and Adi Bangla showed higher mean value alongwith $b_i=1$ and $S^{-2}d=0$ indicating thereby, greater stability over the environments under study. One genotype like Kali Bangla, had higher mean value with $b_i \neq 1$ and $S^{-2}d \neq 0$. This genotype is therefore, responsive to specific environment. The genotype, Dhal Bangla exhibited higher mean with negative b_i and $S^2d_i=0$. These stability parameters indicated its suitability in poor environmental conditions.

(iii) For leaf length a large number of genotypes viz. Mitha Pan, Kali Bangla, Ghanageta Bangla, Simurali Bangla, Sanchi (Tomluk), Haldi Pan, Simurali Deshi, Simurali Bhabna, Kare Bangla, Ayamal Bangla, Borghai, Dhal Bangla, Adi Bangla, Chandrokona, and Kalidhal Bangla showed higher mean value with $b_i=1$ and $S^{-2}d=0$. These genotypes are therefore more resistant to environmental changes for leaf length. On the other hand leaf length, in general, can be considered as a stable character in betelvine. Three genotypes namely Sanchi (Halisahar), Noua Bangla and Simurali Deshi showed higher mean performance with $b_i=1$ but coupled with significant deviation from regression line (i.e.

$S^{-2}_d \neq 0$). So, these genotypes are expected to be unstable to express this character for changing environments.

(iv) Like leaf length, leaf breadth also showed $b_i=1$ and $S^{-2}_d=0$ in maximum of the genotypes under study suggesting thereby wider stability under varying environments. For leaf breadth, Borghai and Kali Bangla were the only genotypes which registered higher mean alongwith significantly higher b_i value and $S^{-2}_d=0$. These two genotypes therefore indicated their suitability under high fertility conditions for leaf breadth.

(v) For average leaf area five genotypes like Ghanagete Bangla, Simurali Bangla, Haldi Pan, Kare Bangla, and Adi Bangla showed higher mean performance over the seasons alongwith $b_i=1$ and $S^{-2}_d=0$, thus indicating their wider adaptability to varying environments. The genotype, Chandrokona showed remarkably higher mean value than the general mean and $S^{-2}_d=0$, but registered with significantly higher b_i value from unity. Therefore, it may be expected that this genotype may take the advantage of favourable growing conditions for the expression of average leaf area, an important yield component in betelvine. A few number of genotypes like Kali Bangla, Simurali Deshi, Simurali Bhabna, Ayamal Bangla, Borghai, Dhal Bangla and Kalidhal Bangla showed higher mean performance over the environments but their significant mean square deviation from regression line (i.e., $S^{-2}_d \neq 0$) indicated unstability to changing environments for growth with regard to average leaf area.

(vi) For the character, leaf thickness all the 27 genotypes showed stable performance over the environments, being the $S^{-2}d=0$. Seven genotypes namely Simurali Bangla, Noua Bangla, Kapoori (T.N.), Haldi Pan, Simurali Bhabna, Ayamal Bangla and Adi Bangla showed more leaf thickness with $b_i=1$ indicating thereby, above the average stability to changing environments. The genotype, Kapoori (Palghat) having higher mean value exhibited significantly high b_i value and $S^{-2}d=0$ which suggested that this genotype is expected to perform better in highly favourable growing conditions. On the other side, higher mean value alongwith significantly negative b_i value and $S^{-2}d=0$ was observed in the genotype Kapoori (Sangli) indicating thereby, its adaptability in poor growing conditions with regard to leaf thickness.

(vii) With regard to stomatal index, the genotypes like Mitha pan, Kali Bangla, Simurali Bangla, Kapoori (T.N.), Simurali Deshi, Simurali Bhabna, Ayamal Bangla and Kalidhal Bangla showed higher mean value with $b_i=1$ and $S^{-2}d=0$ indicating their stable performance for this trait. Three genotypes viz., Ghanagete Bangla, Kare Bangla and Dhal Bangla had higher mean value alongwith $S^{-2}d=0$ but coupled with significantly higher regression coefficients from unity which expressed suitability of these genotypes to favourable growing conditions. The higher mean value having significantly higher b_i than unity and $S^2d \neq 0$ for the genotype Sanchi (Halisahar), suggested its nonadaptability under varying environments for this trait.

(viii) For stomatal length Mitha Pan, Halisahar Jhal, Karapaku Bangla, Kapoori (Palghat), Haldi Pan, Tilak Bangla and Chandrokona having higher mean value alongwith $b_i=1$ and $S^{-2}d=0$ indicated their stable performance to varying environmental conditions. On the other hand the genotypes like Ghanagete Bangla, Simurali Bangla, Sanchi (Halisahar), Simurali Bhabna, Kare Bangla, Ayamal Bangla, Borghai, Adi Bangla, Ramnagar Deshi and Kalidhal Bangla having significantly higher b_i value from unity indicated their suitability to only highly favourable growing conditions.

ix) With regard to stomatal breadth, the genotypes like Halisahar Jhal, Karapaku Bangla, Noua Bangla, Kapoori (Palghat), Simurali Bhabna, showed higher mean value alongwith $b_i=1$ and $S^{-2}d=0$ indicating thereby phenotypic stability under varying conditions for this trait. Some genotypes like Mitha Pan, Kare Bangla, Borghai, Dhal Bangla, Adi Bangla, Tilak Bangla and Chandrokona exhibited high mean value and $S^{-2}d=0$ but significantly higher b_i value from unity which indicated their high phenotypic expression under favourable growing conditions. Three genotypes namely Ghanagete Bangla, Sanchi (Halisahar) and Simurali, though recorded high mean value but their significantly higher or lower b_i value alongwith significant deviation from regression line (i.e. $S^{-2}d \neq 0$) suggested their unstable phenotypic expression to varying environmental conditions.

(x) For leaf yield (i.e., total leaf area/vine) it was generally observed that most of the genotypes under study react violently with environmental changes. Only three genotypes viz. Kare Bangla, Ayamal Bangla and Adi Bangla recorded higher mean value along with $b_i=1$ and $S^{-2}d=0$ indicating, more or less similar response to the environmental changes and, therefore, more adaptive. Only a single genotype, Ghanagete Bangla, showed higher mean value with significantly higher b_i and in significant $S^{-2}d$, indicating thereby, its suitability under high fertility or highly favourable growing conditions because it is physiologically advantageous to favourable growing environments. On the other hand a large number of genotypes namely Kali Bangla, Simurali Bangla, Sanchi (Halisahar), Simurali Bhabna, Borghai, Dhal Bangla, and Kalidhal Bangla having high mean value with significant deviation of $S^{-2}d$ from zero suggested unstable performance under changing environments and consequently invalidate their linear prediction for this trait.

Finally, if the major yield components like leaves no/vine, average leaf area etc. (as identified through correlations and path-coefficients analyses) including total leaf area/vine are considered together, two genotypes namely Kare Bangla and Adi Bangla can be selected for general cultivation under wider environmental conditions due to presence of their low responsiveness to environmental changes along with higher yield potential. These two genotypes can be selected for hybridization programme in view of having phenotypically

stable high potential cultivars through a process of selection for yield stability which is genetically controlled (Scott, 1967). Again if some one wish to develop stable genotypes specific to a favourable growing conditions, the genotype, Ghanagete Bangla can be used since it recorded high mean value and insignificant S^2_d from zero and with significantly higher b_i value from unity for each of the major components of leaf yield (total leaf area/vine). And if only leaf yield is considered, the high yielding genotype, Ayamal Bangla can be selected for general cultivation under varying conditions or as parents in a hybridization programme due to presence of its remarkably high mean performance alongwith insignificant regression coefficient from unity and mean square deviation from zero (i.e., both $b_i=1$ and $S^2_d=0$).

4.6 GENETIC VARIABILITY INDUCED BY CHEMICAL MUTAGEN

The chemical mutagen, EMS, applied to the growing tips of the betelvine seedlings, raised by vegetative means induced variation in survivality and other morphological traits like plant height, leaf characters etc.

The three genotypes (Simurali Bangla, Sanchi (Tomluk) and Halisahar Jhal) showed sensitivity to EMS treatment and their survivality was affected substantially at higher doses. Though the genotypes had differential responses at lower doses, more than 50% reduction was noted at 0.20% concentration treated for 4 hours. The results showed that the LD₅₀ lied between 0.10% and 0.20% concentration of EMS for 4 hours treatment. The results on survivality also confirmed higher sensitivity at higher duration of treatment of any concentration of EMS. Hence, 0.1% concentration for 4 hours treatment is the critical dose for betelvine as far as these three genotypes are concerned.

This mutagen also reduced plant height similar to the report of Gaul (1970) and Khamankar (1984) in tomato. The plant height of Simurali Bangla reduced at the lowest concentration (0.025%) for both 4 and 8 hours treatment. But the higher doses did not show significant difference. On the other hand, Sanchi and Halisahar had the opposite picture showing significantly higher reduction at higher doses and with higher duration of treatments. This type of differential sensitivity of the genotypes to mutagen was noticed by Khamankar (1984) in tomato,

Sarkar *et al* ((1985) in sweet potato and Singh and Singh (1989) in *Trigonella* spp.

Similar trend of reduction was also observed in internodal length in the three genotypes as in plant height. Simurali Bangla showed highest reduction at the lowest concentration for both durations of treatment .But other two genotypes had maximum reduction at higher concentrations (0.10% and 0.20%) particularly for 4 hours treatment. Nybom (1970) also reported such effect due to mutagen treatment.

On the contrary all the three genotypes showed highest reduction in petiole length at the highest concentration (0.20%) for 4 hours treatment. Of course, Simurali Bangla exhibited comparatively more sensitivity having more than 50% reduction at 0.20% concentration.

The mutagen also affected the leaf length in general. The maximum reduction was noticed at the lowest concentration (0.025%) for the shorter duration (4 hours) of treatment in Simurali Bangla. But the other two genotypes showed maximum reduction at the higher concentrations. This trend was also noticed in plant height.

The leaf length and breadth were equally affected in Sanchi and Halisahar Jhal just in opposite to the trend noticed in Simurali Bangla. This indicated the opposite sensitivity of Sanchi and Halisahar Jhal in contrast to Simurali Bangla.

The effect of mutagen was also noticed on the number of leaf per vine in all genotypes. The trend of reduction was in the same direction in the genotypes where less concentration at 4 hours treatment induced maximum reduction in Simurali Bangla against higher concentration in the rest two genotypes with one exception. Halisahar had the more number of leaf compared to that in control. Reduction in internodal length might have induced more number of nodes bearing leaves.

Since leaf length and breadth were reduced, the average area of mature leaf was reduced obviously. All the three genotypes exhibited similar trend of reduction in leaf area i.e., decreasing trend with the increase of mutagenic dosage. Even in Simurali Bangla and Halisahar Jhal more than 50% reduction was noticed at 0.20% concentration for 4 hours and 0.10% concentration for 8 hours respectively showing their higher sensitivity at only higher dosage of this mutagen. Such type of changes in leaf area was in conformity with the findings of Nybom (1970). The decreased leaf area was compensated by the increased number of leaf.

Consequently the total leaf area (including both mature and immature leaf at a certain period) showed the same trend of reduction when the maximum was at lowest concentration for Simurali Bangla opposite to that in Sanchi and Halisahar. One exception was noticed in Halisahar which had increased total leaf area at 0.025% and 0.05% concentrations. Here the leaf no/vine was maximum, more than the control.

In contrast to the above observations, all the genotypes showed increased leaf thickness with the increase of concentration at 4 hours treatment. The reduced leaf area might have influenced in increasing leaf thickness. This observation supported the view of Nybom (1970). It was noticed that the longer duration of treatment produced comparatively thinner leaf than in 4 hours treatment. In Simurali Bangla and Halisahar Jhal the maximum reduction in leaf thickness was recorded at the lowest concentration (0.025%) applied for 4 hours period contrary to Sanchi with maximum reduction at higher concentration (0.10%) for 8 hours treatment. So far, Sanchi showed similar sensitivity with Halisahar for other traits.

The shelf -life of leaf was affected in both directions. Insignificant increase and decrease in shelf-life were noticed in Simurali Bangla and Sanchi. But Halisahar had significant increase in shelf - life for all doses of mutagen as well as duration of treatments. The change in shelf-life must be due to change in components responsible for physiology controlling shelf-life.

The relation of leaf thickness to shelf-life showed that the thinner leaf had highest shelf-life as against that in thicker leaf.

Stomatal frequency increased in all the genotypes in all concentrations and duration of treatments except at 0.10% for

4 hours treatment in Simurali Bangla having less frequency compared to that in control. It was interesting to note that higher concentration produced higher frequency particularly in Sanchi and Halisahar. The frequency of stoma showed the inverse relationship with the leaf area.

Similar trend was also noticed for the stomatal index. It was observed that the leaf having more stomatal frequency had less stomatal index. This observation indicated mutagenic effect increasing epidermal (lower) cell.

Stomatal length increased in all genotypes for all concentrations except a few. But it was observed that the stomata having increased length showed decreased breath particularly in Simurali and Sanchi. Length and breadth of stoma had also no relationship with the stomatal frequency or index. It was independently affected by mutagen.

The effect of the mutagen on the quantity of chlorophyll a and b showed opposite trend. More or less, chlorophyll a decreased with the increase of concentration irrespective of duration of treatments except in Halisahar, while chlorophyll b increased in quantity without any definite trend. However, total quantity of chlorophyll a and b was always less than that in control except in Halisahar where increased quantity was observed. This showed Halisahar is different from the rest two with regard to sensitivity to mutagen. Such type of variation in the quantity of chlorophyll was reported by Nyham

(1970); Hossain and Sen (1973) and Jayabalan and Rao (1988).

The maximum deformity in leaf shape and size was noticed in Halisahar Jhal as compared to other two genotypes. The leaves of the treated vines of Halisahar were lanceolate to completely circular even with highly notched margins. The other two genotypes showed more or less similar type of variation in magnitude. This type of changes in leaf shape and size even in flatness was reported by Nybom (1970).

Thus the genotypic differences for mutagenic (EMS) response were well evident from the above study. Singh and Singh (1989) recorded that the differences in response exist even at genotypic level, which may have differences with regard to only few genes in their nature or may be in positions. Lifschytz and Falk (1969) also suggested that the mutagen specificity may arise from differences between genes in the number of essential sites in their code message. Again Khamankar (1984) also opined that some mutagens appears to be preferential in inducing mutations at specific loci. Therefore, the observed mutagenic response due to application of EMS appears to be genetically conditioned in the present study.

4.7 GENETIC VARIABILITY INDUCED BY GAMMA-RAYS

The irradiation of gamma-rays produced undoubtedly a range of variation but maximum of those were deleterious. All the treatments affected survivality which decreased with the increase of dosage. Such type of decreased survival with increasing dose of radiation was in conformity with the findings of Gaul (1970) in general, Khamankar (1984) in tomato, Veeresh *et al* (1992) in winged bean and Potdukhe *et al* (1992) in wheat. In the present investigation LD₅₀ was observed in between 2 KR and 5 KR treatments. Irulappan *et al* (1982) has also reported the LD₅₀ for rooting in between 2.5 KR to 5 KR in pepper (*piper nigrum*), a closely related species of betelvine.

In the prersent investigation significantly dwarf plant type was obtained at 2 KR and 10 KR treatments. A similiar result also reported by Sinha (1988) in lentil; Kothekar (1989) in *Solanum* spp; Veeresh *et al* (1992) in winged been and Potdukhe *et al* (1992) in wheat. In case of internodal length also the mean values decreased significantly after irradiation. Such type of variation in nodal density was observed by Nybom (1970). With respect to leaf number/vine, average leaf area, leaf length, leaf breadth and total leaf area/vine, significant variation in negative direction were noticed at only 10 KR treatment. The 2 KR and 5 Kr treatments did not produce any significant variation in those traits. Variation in leaf number, leaf size and shape after irradiation was also noticed by

Kothekar(1989) and Sonnino *et al*.(1984) in potato. In case of leaf thickness a beneficial effect of increasing trend was noticed with the increase of irradiation dosage which supported the findings of Nybom(1970).

In case of shelf-life and stomatal frequency a declining trend was noticed in the present investigation, but in stomatal length a gradual increasing trend was observed after irradiation of gamma-rays. On the other hand, in petiole length and chlorophyll content (chlorophyll a) the mean values changed significantly without any definite trend which supported the views of Scossiroli (1970) that the genetic variability increase with the radiation dose, but the relationship between increase of variance and dose is not linear.

In case of stomatal index and chlorophyll b content significant variations were not recorded in the present investigation indicating the ineffectiveness of the applied doses to produce variations in those traits.

It was interesting to note that in 5 KR treatment maximum of the vines produced excessive branching from each node. A similar observation of marked stimulatory effect on branching was noticed by Kothekar (1989) in potato after irradiation of gamma-rays. Such type of excessive branching in betelvine should be considered as a beneficial effect because it may help in rapid multiplication of this vegetatively propagated climber.

In the present investigation, only one genotype, Simurali Bangla was treated with both gamma-rays and ethylmethane sulphonate. The picture of variation was different. Lower dose of EMS induced more effect than that of higher doses. Of course, higher duration of treatment of one concentration induced more variation in the morphological features as well as chlorophyll content. There was no linear relationship between the effect and the dose of EMS. On the other hand, gamma-rays treatment produced linear relationships between the doses and the effects. Gamma-rays induced more variation compared to that of EMS treatment. However, survivality was less affected by EMS treatment in comparison to that of gamma-rays treatment. This might be due to the fact that chemical mutagen affects normally the base sequence of DNA, whereas gamma-rays disturb phisiological processess, chromosomes, bases of DNA and cell organells.

CHAPTER - VI

SUMMARY AND CONCLUSION

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6.1 SUMMARY

Betelvine (*Piper betle* L. Family-Piperaceae) is an important commercial crop in India. The native country of this perennial dioecious climber is probably Malaysia particularly the Islands of Java. Betel leaves are traditionally used for chewing which are fairly rich in vitamin B, vitamin C and several essential amino acids. The leaf extract is aromatic, carminative and astringent and possess activity against several gram - positive and gram-negative bacteria. It has also significant fungicidal and nematocidal properties.

In our country the crop is cultivated in about 40,000 hectares of land . It's trade provides livelihood to over 1.5 million families in the country. The leaves exported in 1991-92 was 1051 metric tonnes, amounting to Rs.208.54 lakhs. In spite of these, the crop has received very little scientific attention. It has not attracted the attention of agricultural scientists and botanists in a measure commensurate with its importance in our daily life , its country wide consumption and export potential. There has been virtually no attempt ever made to improve its productivity.

The recent occurence of flowering and fruiting in Bangalore conditions, has opened an avenue for the improvement of

betelvine through hybridization. Accordingly, successful hybridization has been made to combine desirable characters. But unfortunately this crop lacks information about the parameters of genetic variability for different economic characters. Till to-date there is no detail report of genetic variability including heritability and genetic advance or relationship showing direct and indirect effects of different component characters on leaf yield or grouping of existing genotypes into different clusters based on genetic divergence. There is also no report of induced genetic variability and selection of desirable germplasms.

Keeping the above facts in mind, (the present investigation was undertaken to study the existing natural variability along with heritability, genetic advance etc. in different environments. The correlation coefficients among different characters and their direct and indirect effects on leaf yield for different environmental situations were also estimated. Geographically isolated 27 genotypes were grouped into different clusters to study the genetic divergence. The pattern of adaptability of the genotypes to various climatic stressess was also estimated. And finally an attempt was made to develop new strains through mutation induced by both chemical and physical mutagens.)

(Twenty seven cultivars/types of betelvine were collected from different parts of West Bengal and out side of

West Bengal as well) for the present study. The stem cuttings were planted in the well prepared conservatory of betelvine at Kalyani, West Bengal in July, 1991 in Completely Randomized Block Design with three replications. At the end of October, 1991, the vines were lowered for rejuvenation and this practice (lowering) was continued upto October, 1993, with an interval of four months. Data were recorded season-wise (winter, summer and rainy) and the same procedure was repeated. (The following quantitative characters were selected for study: (1) internodal length (2) petiole length, (3) number of leaves/vine, (4) leaf length, (5) leaf breadth, (6) average leaf area, (7) leaf thickness, (8) stomatal frequency, (9) stomatal index, (10) stomatal length, (11) stomatal breadth, (12) chlorophyll a, (13) chlorophyll b, (14) shelf-life and (15) total leaf yield (leaf area/vine)). (For estimation of genotypic and phenotypic coefficients of variation, heritability (broad sense) and genetic advance, the methods followed by Burton (1929), Hanson *et al* (1956) and Johnson *et al* (1955) respectively were utilised. The correlation coefficients and path coefficients analyses were computed following the methods suggested by Johnson *et al*. (1955) and Dewey and Lu (1959) respectively. Classificatory analysis was done by employing the concept of generalised D^2 statistic (Mahalanobis, 1936 and Rao 1952). The stability analysis was carried out using the model of Eberhart and Russell (1966).)

(For study of induced variability by ethylmethane sulphonate (EMS), three cultivars viz. Simurali Bangla, Sanchi

(Tomluk) and Halisahar Jhal were selected.) The cuttings of each cultivar were transplanted in large earthen pots in July, 1991. The pots were kept within the conservatory. When the new axuillary shoot appeared at two node stage the tender and juvenile stem tips were treated with 0.025%, 0.05%, 0.10%, 0.20%, 0.35% and 0.50% EMS solution (dissolved in phosphate buffer) at 28.1°C for four and eight hours durations.

(For study of variability induced by gamma-rays, the cultivar, Simurali Bangla was selected.) Cuttings comprising two nodes and one internode were subjected to 2 KR, 5 KR and 10 KR radiation at Jute Agricultural Research Institute, Barrackpore, West Bengal. All the irradiated cuttings including control were planted in large earthen pots in August, 1991. The pots were kept within the well maintained conservatory and nourished properly.

The surviving vines following EMS and gamma-rays treatment were pruned at 7-8 leaf stage to eliminate chimera by encouraging the mutant cells to develop into entire shoots. The pruning resulted in the formation of M_1V_2 generation which was allowed to develop for a period of 10 months. At this stage when the vines (M_1V_2) became 12-14 leaf stage, the entire stem was cut into small pieces (15 cm length) and planted again to raise M_1V_3 generation. This newly developed M_1V_3 vines were allowed to grow for a period of another 10 months and finally lowering was done to have more vigorous climbers. Data were collected from these vines (M_1V_3) after six months on different plant characters (as indicated earlier + plant height and survivality) for

statistical analysis.

The study showed a wide range of natural variability in respect of all the characters under investigation. The comparison between phenotypic and genotypic coefficient of variations indicated that characters like total leaf area/vine, leaf number /vine, average leaf area and stomatal length were much more prone to environmental fluctuations as compared to other characters. High degree of heritability were observed in case of leaf breadth, internodal length, petiole length, stomatal frequency, chlorophyll a and chlorophyll b. High genetic advances as per cent of mean were observed in petiole length ,leaves per vine, leaf breadth, stomatal frequency, chlorophyll a and b and shelf-life.) The high amount of variability may be due to presence of great diversity in somatic chromosome number ($2n=26, 32, 42, 52, 58, 64, 78$ and 195), size and shape among the different genotypes of *Piper betle* L.

The analysis of correlation coefficient revealed that total leaf area/vine was significantly correlated with average leaf area, leaves/vine , leaf breadth and leaf length over the seasons at phenotypic and genotypic levels.) The stomatal frequency recorded significantly negative correlation at genotypic level with total leaf area/vine in winter and rainy season . No significant correlation was found between the shelf-life and total leaf area/vine.) It was also observed that the associations among leaf length, leaf breadth and average leaf

area were strong and positive over the season at both phenotypic and genotypic levels.)

Path coefficient analysis revealed that average leaf area and leaves number/vine influenced the leaf yield (total leaf area/vine) directly and positively over the seasons, whereas leaf length, leaf thickness and stomatal index exerted their influences on leaf yield negatively but in a lower magnitude. Again average leaf area registered strong and positive correlations with leaf length and leaf breadth as well as high genetic advance. So, selection based on this characters may be more meaningful as compared to other yield contributing characters.

(On the basis of Mahalanobis D^2 statistic, applied on 15 characters all the genotypes (27) were classified into 10 clusters. The clustering pattern) of the genotypes was random and did not follow geographical adaptation (indicating^{ed} that geographical isolation may not be the only factor causing genetic diversity.) Cluster VII, VIII, IX and X showed maximum inter-cluster distances among themselves as well as with rest of the clusters. These four genetically divergent group can demand special consideration for selection of parents for hybridization programme to obtain substantial heterosis in respect of economic traits.

For stability analysis 27 genotypes were evaluated in winter, summer and rainy season for 10 yield components viz.,

petiole length, leaves no /vine, leaf length, leaf breadth, average leaf area, leaf thickness, stomatal index, stomatal length, stomatal breadth and total leaf area/vine to study the extent and nature of genotype x environment interaction for leaf yield and to identify, if possible, some phenotypically stable genotypes which could be exploited through hybridization programmes. The differences among the seasons were highly significant for all the characters under study except leaf thickness. The G x E interaction for leaves number per vine, average leaf area and leaf yield (i.e. total leaf area/vine) were highly significant along with petiole length, leaf breadth, leaf thickness and stomatal index.

The stability parameters (x_i , b_i and S^2_d) showed that for number of leaves per vine, seven genotypes like Sanchi (Halisahar), Halisahar Jhal, Kapoori (Palghat), Kapoori (Sangli), Simurali Bhabna, Borghai, and Adi Bangla; for average leaf area five genotypes like Ghanagete Bangla, Simurali Bangla, Haldi Pan, Kare Bangla and Adi Bangla and for total leaf area per vine only three genotypes like Kare Bangla, Ayamal Bangla and Adi Bangla recorded higher mean values along with regression coefficient = unity and insignificant deviation from linear regression, indicating their low responsiveness to environmental changes and therefore more stability. But if the above three major yield (leaf yield) components are considered together, two genotypes namely Kare Bangla and Adi Bangla can be selected for general cultivation under wider environmental fluctuation as well as the desirable parents for hybridization programmes.

To study the mutagenic effect of EMS , data on survivality, plant height and other 15 characters (indicated earlier) were recorded. The differences among treatments were highly significant for all the characters under study. The mutagenic treatment thus proved effective in increasing genetic variability. The cultivars showed differential genotypic reactions to EMS. The traits like plant height, petiole length, leaf length and breadth, average leaf area and total leaf area/vine showed significantly negative effect in all the cultivars (except in Halisahar Jhal for leaf no/vine and total leaf area/vine) whereas rest of the characters exhibited the mutagenic response in both positive and negative directions (i.e., effect was random). The results indicated the possibility of achieving significant improvement in some economic traits like leaf thickness, shelf-life and chlorophyll content. In leaf shape and size havoc deformities were noticed.

The physical mutagen like gamma-rays also produced significant variation in all the characters under study except stomatal index and chlorophyll b content. Among the doses 10 KR produced maximum variation as compared to other doses. Maximum variation was observed in survivality, plant height, internodal length, petiole length, stomatal frequency, stomatal length and chlorophyll a content. Among the traits studied, survivality, average leaf area, shelf-life and stomatal frequency showed declining trend with the increase of mutagenic treatment whereas

leaf thickness and stomatal length showed increasing trends with the increase of dosage. The other characters showed no definite trend of variation. The 5 KR treatment resulted significant branching habit.

6.2 CONCLUSION

The presence of wide range of variability (both phenotypic and genotypic) in betelvine could be exploited through clonal selection and/or hybridization. During selection maximum emphasis should be given to leaf number/vine and average leaf area. The path-coefficient analysis indicated that the betelvine creeper possessing more number of leaf with higher average leaf area will ensure the increase of total leaf area/vine. (From D^2 statistic eleven cultivars of four groups viz., Ghanagete Bangla, Kali Bangla, Adi Bangla and Simurali Bhabna of group A; Kare Bangla, Ayamal Bangla, Chandrokona and Kalidhal Bangla of group B; Simurali Deshi and Ramnagar Deshi of group C; and Borghai of group D were identified for hybridization programmes for their remarkable magnitude of genetic divergence as well as superior performance in respect of leaves/vine, average leaf area and consequently total leaf area per vine over the seasons.) The stability parameters also indicated that Adi Bangla of group A and Kare Bangla of group B can be selected for general cultivation under wide range of environments and/or as parents in the hybridization programmes.

For induction of variability by artificial means, the

chemical mutagen like EMS could be used. In Simurali Bangla and Sanchi (Tomluk) , the LD₅₀ lied in between 0.10% for 8 hours and 0.20% for 4 hours of EMS where as in Halisahar Jhal it was 0.10% for 4-8 hours treatment. Some economic traits like leaf thickness, shelf-life and chlorophyll content in betelvine can be improved through EMS treatment. The physical mutagen like gamma-rays might also be used for induction of variability where LD₅₀ lied at 2 KR - 5 KR treatment in Simurali Bangla. The 10 KR treatment resulted maximum variation as compared to other treatments. To obtain more leaf thickness, gamma-rays also proved its effectiveness in betelvine. This physical mutagen was more effective for induction of variability in this creeper than that of EMS.

CHAPTER - VII

FUTURE SCOPE OF RESEARCH

FUTURE SCOPE OF RESEARCH

The results obtained from the present studies indicated clearly the presence of a wide range of natural variability particularly in major yield components of betelvine. Correlation and path-coefficient analyses in different environments also permitted a critical examination of the specific forces acting on the production of leaf. Multivariate analysis by means of Mahalanobis's D^2 technique has helped in grouping a set of genotypes into different clusters according to the relative genetic distances. The stable genotypes under fluctuating environments have been identified and finally the induction of new variants by means of induced mutation have enriched the germplasm stock of betelvine.

These information and results provide scope of research work in future on the following aspects that would produce useful information for practical purposes.

(i) Hybridization programmes between stable parents with high genetic distance to be carried out for obtaining desirable recombinants in the segregating generations.

(ii) Ethylmethane sulphonate (EMS) resulted significantly higher number of leaves/vine along with larger leaf area in Halisahar Jhal. This potentiality of producing high yielding clone with the treatment of EMS may be exploited in other genotypes in future breeding work.

(iii) Again leaf thickness in Simurali Bangla and Sanchi (Tomluk) and shelf-life in Halisahar Jhal had increased in the present investigation with the application of EMS. This information encourage further work in depth that may generate a number of desirable traits in betelvine.

(iv) Like EMS, gamma-rays also produced significantly thicker leaf along with remarkably higher branching habit and more leaf area/vine in Simurali Bangla at 5 KR treatment. Therefore, the possibility of producing high yielding mutants/ clone with the irradiation of gamma-rays is high and may be exploited in the future breeding work.

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*Original not seen

APPENDIX

Appendix-I: Mean performance of 27 genotypes in winter season

Entry No.	Genotypes	Internod- al length (cm)	Petiole length (cm)	Leaves/ vine (No.)	Leaf length (cm)	Leaf breadth (cm)	Avg. leaf area (sq. cm)	Leaf thickness (mm)	Stomatal freq. (no/sq mm)	Stomatal index	Stomatal length (μ)	Stomatal breadth (μ)	Chloro- phyll a (mg/g)	Chloro- phyll b (mg/g)	Shelf- life (days)	Total leaf area/vine (sq. cm)
1	Mitha pan	5.02	4.51	7.10	10.41	7.19	50.58	0.24	133.28	30.61	31.36	19.29	0.88	0.38	16.82	360.32
2	Kali Bangla	7.78	5.22	7.68	10.75	7.75	56.94	0.29	143.51	30.31	30.49	19.07	0.68	0.41	23.38	405.14
3	Bhanagete Bangla	5.19	5.52	9.55	12.93	10.19	76.56	0.31	144.72	27.37	29.92	23.67	0.44	0.43	12.86	731.45
4	Simuruli Bangla	7.78	7.73	14.55	11.39	9.46	78.70	0.27	144.74	30.49	30.27	20.22	0.70	0.37	20.92	1144.69
5	Sanchi (Tomluk)	4.81	3.80	8.44	12.40	8.80	73.50	0.30	92.64	24.54	31.31	19.02	0.47	0.29	20.23	622.02
6	Sanchi (Halisahar)	6.58	4.36	13.89	12.44	9.77	76.48	0.33	160.84	26.12	30.26	19.50	0.71	0.43	28.74	1061.56
7	Godi Bangla	6.04	4.50	6.68	10.63	7.87	51.68	0.27	157.72	27.27	28.05	18.55	0.76	0.64	21.97	342.70
8	Halisahar Jhal	5.39	4.85	12.70	10.39	6.14	41.78	0.24	106.60	26.75	31.45	19.44	0.60	0.53	26.42	525.11
9	Kapoori (Ramtek)	5.36	4.39	5.69	10.76	6.38	32.85	0.24	175.31	26.23	26.56	15.67	0.38	0.23	20.94	242.33
10	Karabaku Bangla	4.95	5.75	4.65	10.43	7.90	46.61	0.26	153.14	27.49	30.74	19.71	0.72	0.53	23.32	216.01
11	Noua Bangla	7.32	4.48	5.29	11.30	8.11	59.61	0.27	153.98	25.88	28.42	19.03	0.62	0.23	20.80	313.62
12	Kapoori (Palghat)	4.45	3.86	9.78	10.30	6.40	40.37	0.30	184.39	26.14	30.12	19.20	0.65	0.39	21.08	398.20
13	Kapoori (T.N.)	7.74	3.87	6.70	5.94	3.58	12.39	0.25	278.64	29.49	21.65	16.52	0.65	0.29	9.43	83.41
14	Kapoori (Sangli)	6.23	4.50	9.68	9.81	6.38	44.25	0.25	192.44	25.58	28.29	16.31	0.70	0.35	17.66	426.28
15	Haldi pan(B)	6.97	5.75	5.33	13.58	10.33	99.38	0.33	223.29	33.33	30.22	17.62	0.60	0.32	16.69	533.11
16	Birkuli (B)	9.54	6.62	4.53	8.89	5.08	30.78	0.22	197.14	27.96	29.31	15.51	0.76	0.58	20.24	152.19
17	Simuruli Deshi(B)	7.98	6.22	7.02	13.41	10.75	88.34	0.29	165.70	28.43	28.90	18.65	1.24	0.94	13.78	613.88
18	Simuruli Bhabna	7.99	4.82	17.06	11.34	9.81	75.78	0.27	137.81	26.53	30.30	20.51	0.72	0.39	20.14	1288.01
19	Kare Bangla	5.53	6.70	8.38	13.20	8.99	103.35	0.26	106.42	24.33	29.42	17.73	1.23	0.36	23.55	870.17
20	Ayamal Bangla	5.54	6.74	9.37	12.65	8.85	97.72	0.29	131.09	25.58	29.77	16.44	0.98	0.60	21.03	910.05
21	Borghai (B)	6.70	6.16	9.78	13.62	6.62	113.41	0.28	113.81	24.97	31.63	18.42	0.95	0.39	21.69	1111.28
22	Dhal Bangla	6.29	6.30	12.21	13.46	10.51	104.97	0.28	136.06	25.59	30.39	19.36	1.01	0.52	18.27	1281.58
23	Adi Bangla	5.84	6.69	9.19	10.41	8.69	64.08	0.28	128.89	25.75	30.52	20.45	1.01	0.43	22.93	593.16
24	Tilak Bangla	5.41	4.59	5.15	9.97	7.37	53.33	0.23	107.34	24.63	31.50	17.81	0.84	0.28	18.17	278.63
25	Chandrokona (B)	5.06	5.99	7.26	11.94	9.82	85.79	0.28	104.52	24.81	29.69	17.61	1.13	0.51	24.35	626.03
26	Ramnagar Deshi	5.71	6.65	8.62	10.57	9.05	59.97	0.24	87.90	24.49	31.30	17.14	0.81	0.26	19.83	520.67
27	Kalidhal Bangla	5.22	5.40	8.23	11.73	9.83	90.52	0.29	145.45	27.73	30.28	16.60	1.14	0.69	20.81	748.23
Grand Mean (X)		6.24	5.29	8.69	11.32	8.34	67.40	0.27	148.42	26.98	29.71	18.48	0.79	0.44	20.22	607.22
S.E.		0.36	0.35	0.86	0.84	0.40	4.80	0.01	10.97	0.81	0.91	0.64	0.06	0.04	1.17	74.26
C.D(P=0.05)		0.72	0.70	1.73	1.69	0.80	9.65	0.02	22.05	1.63	1.83	1.29	0.12	0.08	2.35	149.26

(B) represents Bangla

Appendix-II: Mean performance of 27 genotypes in summer season

Entry	Internod- al length (cm)	Petiole length (cm.)	Leaves/ vine (no.)	Leaf length (cm)	Leaf breadth (cm)	Avg. leaf area (sq. cm)	Leaf thickness (mm)	Stomatal freq. (no/sq mm)	Stomatal index	Stomatal length (μ)	Stomatal breadth (μ)	Chloro- phyll a (mg/g)	Chloro- phyll b (mg/g)	Shelf- life (days)	Total leaf area/vine (sq cm)
1 Mitha pan	5.31	4.67	8.54	13.28	7.96	66.30	0.28	156.41	28.70	32.15	19.96	1.44	0.92	15.69	564.72
2 Kali Bangla	4.98	5.23	9.99	12.48	9.20	68.38	0.26	140.59	30.30	28.34	18.87	1.28	0.75	13.78	682.16
3 Ghanagete Bangla	5.44	5.87	10.60	12.94	10.79	99.13	0.23	166.07	31.73	32.45	23.84	1.19	0.69	11.00	1148.99
4 Simuruli Bangla	6.15	4.91	17.32	12.83	10.37	99.57	0.30	164.68	29.24	32.62	20.98	1.37	0.91	13.72	1721.26
5 Sanchi (Tomluk)	6.10	4.06	11.00	13.19	9.66	91.90	0.24	126.56	26.17	28.57	19.57	1.02	0.66	15.53	1010.70
6 Sanchi (Halisahar)	4.82	4.50	15.46	15.17	10.05	95.50	0.24	191.69	32.69	32.67	20.31	1.67	0.87	20.87	1483.33
7 Godi Bangla	5.77	4.81	8.73	10.86	8.60	58.17	0.27	183.96	25.52	28.02	19.08	1.44	1.03	18.03	506.96
8 Halisahar Jhal	5.29	4.99	14.59	11.72	7.51	40.94	0.25	124.53	25.49	42.43	20.96	1.11	0.93	21.96	594.08
9 Kapoori (Ramtek)	5.10	4.55	7.69	11.44	7.19	47.11	0.24	192.27	24.95	26.43	15.79	0.74	0.43	18.83	361.19
10 Karabaku Bangla	4.84	6.09	6.51	10.94	8.37	66.45	0.27	166.91	25.70	31.92	20.30	1.24	0.87	20.27	433.04
11 Noua Bangla	4.04	4.64	7.28	12.36	8.72	78.64	0.31	116.47	27.38	30.07	19.34	1.21	0.57	16.93	568.75
12 Kapoori (Palghat)	4.03	4.04	11.83	10.89	7.39	37.21	0.31	186.29	25.76	31.79	19.37	1.28	0.88	19.49	440.80
13 Kapoori (T.N.)	3.32	4.20	8.10	6.91	4.81	33.41	0.30	189.27	29.89	26.88	15.84	1.34	0.59	12.27	262.71
14 Kapoori (Sangli)	6.07	4.87	12.00	10.79	7.82	47.84	0.32	148.62	25.29	27.45	16.60	1.37	0.62	17.26	574.55
15 Haldi pan(B)	7.11	6.18	7.06	14.97	12.14	118.82	0.32	226.08	30.70	30.99	17.72	1.09	0.64	16.68	841.71
16 Birkuli (B)	9.25	6.76	7.18	9.61	6.04	41.33	0.24	213.99	26.31	28.59	16.12	1.41	0.91	19.36	225.61
17 Simuruli Deshi(B)	5.22	6.23	9.10	10.63	8.91	68.34	0.25	132.45	27.81	29.89	18.93	1.44	0.88	9.52	621.45
18 Simuruli Bhabna	7.55	5.00	18.37	12.73	9.92	111.93	0.30	172.24	29.14	33.49	20.36	1.37	0.70	15.11	2057.33
19 Kare Bangla	5.83	5.96	9.75	15.19	11.09	126.90	0.28	102.30	28.07	32.11	19.99	1.08	0.59	15.66	239.60
20 Ayasal Bangla	6.64	6.77	10.24	14.36	10.08	126.85	0.31	117.35	29.38	33.27	19.11	0.81	0.49	20.57	1295.92
21 Borghai (B)	7.45	6.20	10.98	14.98	11.03	135.49	0.27	103.61	28.29	34.39	19.63	1.44	0.88	14.12	1485.19
22 Dhal Bangla	7.16	6.39	11.92	14.80	11.55	133.95	0.27	139.12	29.49	27.73	21.66	1.31	0.54	13.38	1603.73
23 Adi Bangla	6.64	6.69	10.46	12.47	9.89	81.95	0.28	128.40	29.99	33.63	21.13	1.39	0.87	20.28	857.02
24 Tilak Bangla	6.08	4.48	6.98	11.26	9.59	67.34	0.24	106.72	28.14	32.32	18.83	0.91	0.45	15.95	469.68
25 Chandrakona (B)	5.73	6.12	8.65	13.22	10.69	109.71	0.27	114.77	27.77	31.33	19.09	1.28	0.79	24.77	951.72
26 Ramnagar Deshi	6.39	6.33	9.18	11.69	9.12	76.30	0.23	87.90	27.92	34.66	18.12	0.78	0.48	17.70	705.45
27 Kalidhal Bangla	5.78	5.55	11.05	13.42	11.01	107.20	0.31	120.35	30.70	33.26	17.75	1.56	0.52	19.94	117.58
Grand Mean ($\bar{X}$)	5.85	5.41	10.43	12.41	9.24	82.47	0.27	148.87	28.23	31.02	19.23	1.24	0.72	16.99	884.64
S.E.	0.39	0.32	0.84	0.98	0.47	4.76	0.01	12.25	0.95	1.32	0.86	0.09	0.07	1.23	96.54
C.D(P=0.05)	0.78	0.64	1.69	1.97	0.94	9.57	0.02	24.62	1.91	2.65	1.73	0.18	0.14	2.47	194.02

(B) represents Bangla

Appendix-III: Mean performance of 27 genotypes in rainy season

Entry No.	Genotypes	Internod- al length (cm)	Petiole length (cm)	Leaves/ vine (no.)	Leaf length (cm)	Leaf breadth (cm)	Avg. leaf area (sq. cm)	Leaf thickness (mm)	Stomatal freq. (no./sq mm)	Stomatal index	Stomatal length (μ)	Stomatal breadth (μ)	Chloro- phyll a (mg/g)	Chloro- phyll b (mg/g)	Shelf- life (days)	Total leaf area/vine (sq cm)
1	Mitha pan	6.05	6.38	8.87	13.94	8.87	86.97	0.27	152.47	29.42	31.84	21.00	1.58	1.00	16.83	787.30
2	Kali Bangla	5.47	7.96	18.68	15.90	12.74	139.34	0.26	129.92	31.05	28.33	18.17	1.35	0.83	15.87	2614.04
3	Ghanagete Bangla	6.06	6.18	18.27	13.98	11.35	120.78	0.23	161.41	32.96	33.11	19.05	1.37	0.86	13.53	2361.86
4	Simurali Bangla	6.64	6.91	13.78	14.03	11.09	101.92	0.29	158.96	30.41	32.58	19.10	1.52	1.02	15.74	1396.09
5	Sanchi (Touluk)	6.35	3.92	8.90	14.14	8.73	72.77	0.23	122.91	27.57	28.67	18.25	1.14	0.74	17.68	646.16
6	Sanchi (Halisahar)	4.48	3.60	14.36	12.11	7.60	61.05	0.23	187.75	34.09	33.02	25.08	1.81	1.17	22.81	875.37
7	Godi Bangla	6.36	4.67	10.22	13.99	11.05	78.04	0.27	160.27	26.85	27.91	18.39	1.50	1.22	20.05	798.88
8	Halisahar Jhal	5.44	4.86	18.20	13.20	9.76	61.47	0.25	121.56	27.01	32.05	19.44	1.16	1.01	22.71	1125.01
9	Kapoori (Ramtek)	5.53	4.33	8.40	13.79	9.09	52.19	0.24	193.11	26.11	25.98	15.62	0.86	0.46	20.68	437.88
10	Karapaku Bangla	4.92	5.85	6.65	13.86	10.65	64.47	0.25	163.05	27.60	31.34	19.81	1.44	1.13	21.63	429.82
11	Noua Bangla	4.63	4.36	8.12	9.69	7.63	65.02	0.31	111.11	28.36	30.16	20.02	1.34	0.70	19.14	525.42
12	Kapoori (Palghat)	4.80	3.94	14.57	13.49	9.02	51.05	0.29	182.96	27.00	31.18	18.46	1.41	0.93	21.58	749.79
13	Kapoori (T.N.)	3.78	3.85	9.32	5.62	4.34	35.24	0.29	189.78	29.15	26.49	16.60	1.46	0.70	14.11	328.85
14	Kapoori (Sangli)	6.81	6.65	12.42	13.21	7.65	65.30	0.32	141.81	27.48	28.16	17.44	1.45	0.76	20.04	807.17
15	Haldi pan(B)	7.51	5.63	9.64	16.29	13.11	152.40	0.32	218.11	32.14	30.92	17.89	1.03	0.73	18.66	1468.54
16	Birkuli (B)	11.06	6.01	7.07	10.95	7.64	47.20	0.23	205.54	28.14	29.64	15.74	1.50	0.99	20.99	355.83
17	Simurali Deshi(B)	6.16	7.99	12.05	16.05	12.16	132.68	0.24	134.12	28.71	29.91	22.64	1.63	0.34	11.87	1595.10
18	Simurali Bhabna	6.88	6.94	17.15	14.31	11.43	103.54	0.30	165.32	30.37	33.01	19.31	1.51	0.86	17.45	1771.62
19	Kare Bangla	6.61	8.54	15.42	15.03	12.33	138.25	0.28	96.17	30.32	32.07	19.77	1.14	0.69	17.12	2138.05
20	Ayaaal Bangla	7.54	7.29	15.40	14.79	11.81	138.41	0.31	115.97	30.40	33.22	18.06	0.91	0.59	21.14	2136.12
21	Borghai (B)	8.22	8.83	14.63	16.93	14.23	192.60	0.27	104.83	28.05	35.68	20.89	1.53	0.96	15.13	2815.10
22	Dhal Bangla	7.92	6.06	8.41	13.00	10.47	120.47	0.27	138.76	31.58	28.53	20.19	1.35	0.63	14.60	1010.43
23	Adi Bangla	7.50	7.42	15.69	15.31	11.52	121.94	0.27	125.60	30.76	33.30	22.68	1.54	0.92	21.66	1910.23
24	Tilak Bangla	6.83	5.15	10.12	13.53	10.15	101.13	0.24	104.92	28.34	33.06	20.38	0.94	0.42	17.11	1032.75
25	Chandrokona (B)	6.41	7.62	13.33	15.96	13.00	159.00	0.27	112.32	28.55	31.83	20.31	1.38	0.86	25.08	2156.13
26	Ramnagar Deshi	7.29	8.43	13.07	14.60	10.95	111.66	0.24	85.78	28.61	34.43	18.38	0.89	0.56	18.64	1468.57
27	Kalidhal Bangla	6.60	6.87	15.18	15.83	13.41	169.02	0.30	121.76	32.97	33.02	17.25	1.70	0.60	20.55	2583.64
Grand Mean (X)		6.45	6.16	12.56	13.03	10.44	101.63	0.27	144.68	29.41	31.05	19.26	1.35	0.80	18.61	1344.66
S.E.		0.34	0.37	1.16	0.75	0.51	7.73	0.01	12.22	0.83	1.23	0.80	0.10	0.06	1.21	201.83
C.D(P=0.05)		0.68	0.74	2.33	1.51	1.02	15.54	0.02	24.56	1.67	2.47	1.61	0.20	0.12	2.43	405.68

(B) represents Bangla

Appendix-IV: D^2 values among 27 genotypes

Genotypes	q2	q3	q4	q5	q6	q7	q8	q9	q10	q11	q12	q13	q14	q15	q16	q17	q18	q19	q20	q21	q22	q23	q24	q25	q26	q27
q1	127.21	102.36	43.58	81.18	226.43	74.52	174.50	180.11	66.25	144.69	158.08	376.33	113.41	271.07	270.08	189.61	76.62	139.00	184.45	351.82	92.42	100.98	109.41	190.36	150.81	235.38
q2		90.18	76.07	256.57	444.83	192.97	308.40	342.93	203.04	342.81	350.22	699.18	234.77	210.44	458.45	170.21	80.95	40.16	97.28	195.48	140.64	71.26	215.22	87.13	130.08	102.32
q3			61.07	185.90	270.59	181.91	242.37	288.01	198.51	328.83	256.30	531.22	266.70	229.80	349.97	242.04	71.12	145.01	183.09	318.57	146.02	128.08	167.35	244.35	180.61	214.59
q4				159.18	295.65	84.13	175.72	250.39	114.51	264.07	190.95	520.98	151.69	170.20	269.12	200.94	17.81	90.97	122.63	249.99	92.66	65.45	145.06	143.84	118.30	166.18
q5					300.30	112.41	152.14	81.13	132.62	124.18	138.94	323.40	150.85	382.60	297.92	254.01	188.72	257.61	271.28	526.64	147.35	245.73	55.61	324.02	187.83	375.83
q6						256.75	209.45	394.02	235.47	278.36	170.78	382.63	366.77	626.95	537.89	651.75	299.13	544.81	555.72	910.39	440.92	341.97	418.41	555.72	583.32	605.15
q7							124.49	192.32	45.64	214.83	128.29	449.20	182.23	301.13	276.39	338.10	129.13	241.73	271.98	430.23	182.89	172.86	195.15	213.87	249.57	326.12
q8								216.81	168.97	229.91	57.02	429.64	191.05	496.03	417.40	442.66	168.45	335.52	338.33	656.38	344.23	247.98	212.96	359.36	292.47	489.57
q9									172.34	137.00	124.40	242.77	140.59	440.93	310.33	388.73	245.47	348.25	322.00	762.70	276.08	372.75	163.22	444.52	284.59	453.74
q10										158.36	136.76	392.91	189.49	357.61	344.91	359.01	161.70	250.60	291.53	510.28	233.15	197.24	215.40	235.70	244.82	333.35
q11											135.52	155.35	131.00	562.66	467.72	407.09	248.43	349.06	357.92	792.07	292.50	337.71	200.72	432.05	358.14	428.59
q12												241.06	143.59	488.08	385.09	494.94	176.99	406.14	374.21	795.02	357.22	310.35	242.13	441.14	361.60	485.63
q13													310.79	944.36	546.31	770.36	523.05	786.62	761.66	1328.45	606.14	728.95	501.52	928.13	735.67	840.67
q14														428.60	242.74	325.16	121.98	228.58	971.79	584.18	218.86	187.64	202.13	306.25	201.22	310.32
q15															513.34	319.27	183.53	186.55	143.20	250.09	151.44	212.83	276.76	183.84	349.34	155.60
q16																571.58	276.21	440.35	410.66	666.16	318.78	360.65	382.22	541.41	370.12	555.28
q17																	219.43	125.18	231.83	217.68	96.36	206.82	142.69	215.44	148.00	223.77
q18																		92.41	92.61	295.60	123.11	55.13	160.61	157.28	120.72	148.86
q19																			42.97	133.31	99.62	56.18	154.01	59.82	51.05	86.68
q20																				234.33	130.15	78.16	170.38	94.67	78.67	77.62
q21																					212.57	204.82	360.65	144.96	211.97	216.01
q22																						122.19	84.12	158.88	115.95	158.55
q23																							191.66	70.38	120.19	119.78
q24																								242.29	87.16	274.21
q25																									142.61	92.30
q26																										195.58

g represents genotype