

PHENOLOGICAL STUDIES IN NUTMEG
(*Myristica fragrans* Houtt.)

A thesis submitted to the
FACULTY OF AGRICULTURE
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Dist. Ratnagiri (Maharashtra State)

in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in
HORTICULTURE

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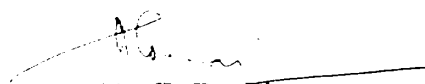


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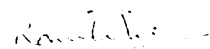
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CERTIFICATE

This is to certify that the thesis entitle "**PHENOLOGICAL STUDIES IN NUTMEG (*Myristica fragrans* Houtt.)**" submitted to the Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) in HORTICULTURE** is a faithful record of a *bona fide* research carried out by **Shri. PARAG MANOHAR HALDANKAR** under my guidance and supervision. No part of this thesis has been submitted for any other degree or published in other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

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CONTENTS

CHAPTER	TITLE	PAGE
I	INTRODUCTION	1 – 5
II	REVIEW OF LITERATURE	6 – 22
III	MATERIAL AND METHODS	21 – 49
IV	EXPERIMENTAL RESULTS	50 – 120
V	DISCUSSION	121 – 152
VI	SUMMARY AND CONCLUSION	153 – 163
	LITERATURE CITED	i – xiii
	APPENDICES	I - XIII

LIST OF TABLES

Table No.	Title	Page No.
1.	Period of emergence of new shoot, flowering initiation and fruit set in nutmeg genotypes.	51
2.	Temporal variation in the length of terminal shoots (cm) in nutmeg genotypes.	53-54
3.	Temporal variation in the number of leaves on developing new shoots in nutmeg genotypes	53-54
4.	Yield (no. of fruits/ tree) and related plant architecture components of female and hermaphrodite nutmeg genotypes	54
5.	Plant architecture components of male nutmeg genotypes	56
6.	Correlation coefficients for the yield of nutmeg (number of fruits).	56-57
7.	Regression equation for the yield of nutmeg (number of fruits) on the basis of plant architecture characters	58
8.	Multiple regression equations for yield of nutmeg (number of fruits) on the basis of various related characters.	59
9.	Leaf parameters of nutmeg genotypes.	61
10.	Regression equations for predicting area of individual leaf (cm ²) on the basis of ancillary characters.	63
11.	Period for anthesis and fruit set in nutmeg genotypes	64
12.	Magnitudes of variance for days required for flowering and fruit set (%) in nutmeg genotypes.	66
13.	Genetic parameters for days required for flowering and fruitset (%) in nutmeg genotypes.	67
14.	Dry pericarp weight at various stages of fruit development in nutmeg.	68-69
15.	The polynomial equations explaining changes in dry weight of fleshy pericarp during fruit growth of some nutmeg genotypes	69
16.	Dry nut weight at various stages of development of nutmeg fruit	70-71
17.	The polynomial equations explaining changes in dry weight of nut during fruit growth of some nutmeg genotypes	71
18.	Dry mace weight at various stages of fruit development in nutmeg	73-74
19.	The polynomial equations explaining changes in dry weight of mace during fruit growth of some nutmeg genotypes.	74
20.	Length, breadth and weight of fruits of different nutmeg genotypes	76
21.	Genetic parameters for fruit length, fruit breadth and fruit weight in nutmeg	78

Table No.	Title	Page No.
22.	Length, breadth, fresh and dry weight of nut of different nutmeg genotypes	80
23.	Genetic parameters for length, breadth, fresh weight and dry weight of nut in nutmeg	81
24.	Pericarp weight, fresh and dry mace weight of different nutmeg genotypes	83
25.	Genetic parameters for pericarp weight, fresh and dry mace weight in nutmeg	85
26.	Kernel weight, shell weight and recovery (%) of different nutmeg genotypes	86
27.	Genetic parameters for kernel weight, shell weight and recovery (%) in nutmeg	88
28.	Nutmeg butter and mace oil (%) of nutmeg genotypes	89
29.	Genetic parameters for nutmeg butter and mace oil in nutmeg	91
30.	Fresh and dry Pericarp : Nut : Mace ratio of different nutmeg genotypes	92
31.	Yield in number of fruits per tree of nutmeg genotypes	94
32.	Yield in nut weight (kg) per tree of nutmeg genotypes	95
33.	Yield in mace weight (kg) per tree of nutmeg genotypes.	97
34.	Yield in kernel (kg) per tree of different nutmeg genotypes.	99
35.	Mean sum of squares for yield of nutmeg	100
36.	Coefficient of repeatability and its 95% confidence limits for yield in nutmeg genotypes	101
37.	Corrected yield of number of nuts per tree per year of nutmeg genotypes (on first year basis)	102
38.	Corrected yield (kg nuts/ tree) of nutmeg genotypes (on first year basis).	103
39.	Corrected yield of mace (kg/tree) of nutmeg genotypes (On first year basis).	104
40.	Corrected yield of kernel (kg/tree) on first yield.	105
41.	Duration (days) for germination and germination (%) of different nutmeg genotypes	107
42.	Shoot characters of seedling in different nutmeg genotypes	109
43.	Leaf characters of seedlings of different nutmeg genotypes.	111
44.	Root characters of seedling of different nutmeg genotypes.	112

Table No.	Title	Page No.
45.	Mean squares and components of variance of different seedling characters in nutmeg genotypes	113
46.	Genetic parameters of seedling characters in nutmeg genotypes	114
47.	Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient of seedling characters in nutmeg genotypes	114 - 115
48.	Graft sprouting, survival and mortality of different nutmeg genotypes	115 - 116
49.	Period required for graft sprouting and new shoot length of the grafts prepared from nutmeg genotypes.	117
50.	Growth parameters of graft prepared from nutmeg genotypes	117 - 118
51.	Mean, Mean sum of squares and genetic variance of graft parameters of nutmeg genotypes	118
52.	Genetic components of graft parameters of nutmeg genotypes	119
53.	Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients of graft parameters in nutmeg genotypes	119 - 120
54.	Proportion of fruit component at various stages in developing nutmeg fruit	124 - 125
55.	Genetic parameters of some characters in nutmeg genotype	132
56.	Path analysis for weight of individual fruit in nutmeg genotypes	134 - 135
57.	Relative ranking of some nutmeg genotypes for overall performance	138
58.	Average intra and inter cluster distance $(D) = \left(\sqrt{D^2} \right)$ value of nutmeg clusters.	141 - 142
59.	Intra cluster means for different fruit characters of nutmeg genotypes.	142 - 143

LIST OF FIGURES

Fig. No.	Title	Between pages
1	Crown volume and crown surface area of nutmeg female and hermaphrodite genotypes.	55-56
2.	Leaf area of nutmeg genotypes.	62-63
3.	Period for anthesis and fruitset (%) in nutmeg types.	66-67
4.	Weight of fruit of nutmeg genotypes.	77-78
5.	Weight of pericarp, nut and mace of nutmeg genotypes.	79-80
6.	Dry nut and mace weight of nutmeg genotypes.	80-81
7.	Kernel weight and recovery of nutmeg genotypes.	87-88
8.	Nutmeg butter (%) and mace oil (%) in nutmeg genotypes.	90-91
9.	Fresh pericarp : Nut : Mace ratio of nutmeg genotypes.	91-92
10.	Dry pericarp : Nut : Mace ratio of nutmeg genotypes.	91-92
11.	Yield of nuts and mace in nutmeg genotypes.	96-97
12.	Period required for germination and germination (%) of nutmeg genotypes.	108-109
13.	Total height and number of leaves of seedlings of nutmeg genotypes.	110-111
14.	Graft survival and mortality of nutmeg genotypes.	115-116
15.	Shoot length and number of leaves during different period of growth.	121-123
16.	Dry Pericarp, nut and mace weight during fruit development.	124-125
17.	Dry Pericarp, nut and mace – proportion during fruit development.	124-125

LIST OF PLATES

Plate No.	Title
1.	A view of experimental nutmeg plantation under coconut
2.	Female nutmeg genotype N1
3.	Male nutmeg genotype N69
4.	Hermaphrodite nutmeg genotype N61
5.	One year old shoot in nutmeg genotypes N1, N30 and N51
6.	Flowering habit in female (N10), hermaphrodite (N61) and male (N69) genotypes
7.	Fruitset in nutmeg genotypes N66, N38 and N30
8.	Fruitset in nutmeg genotypes N11, N33 and N74
9.	Fruit development in nutmeg genotype N72
10.	Fruit development in nutmeg genotype N42
11.	Fruits at harvest of various nutmeg genotypes
12.	Pericarp, nut and mace in fruit of nutmeg genotypes N1, N5, N7
13.	Pericarp, nut and mace in fruit of nutmeg genotypes N27, N30 and N38
14.	Pericarp, nut and mace in fruit of nutmeg genotypes N42, N46 and N49.
15.	Pericarp, nut and mace in fruit of nutmeg genotypes N63, N66, N70 and N72.
16.	Nutmeg seedlings (90 days old) of nutmeg genotypes N29, N5 and N23
17.	Nutmeg seedlings (90 days old) of nutmeg genotypes N36, N30 and N33
18.	Nutmeg seedlings (90 days old) of nutmeg genotypes N56, N22 and N55
19.	Pericarp, nut and mace development in nutmeg genotype N7.

INTRODUCTION



CHAPTER I

INTRODUCTION

Nutmeg (*Myristica fragrans* Houtt.) is an important tree spice which produces two distinctly different spices namely nutmeg and mace. It belongs to the family Myristicaceae which is small group comprising 16 genera and about 380 species. It is mainly distributed to the low land tropical forests of the World. *Myristica* is the most important genus of this family. Sinclair (1958) considered this genus as the most primitive and basic, consisting of 100 species.

Nutmeg is native of Moluccas (North-West Borneo) and parts of South-East Asia. It is a dioecious, evergreen tree with beautiful architecture. The branches having slender and spreading. The bark is of gray colour. The leaves are alternate, lanceolate and acuminate with long point and narrowed towards base, to the start of leaf stalk. They are coriaceous and shining, moderately dark green above, paler beneath and glabrous. The tree is normally unisexual bearing either male or female flowers. Sometimes tree bearing bisexual flowers is also noticed. Flowers are borne in leaf axils. Male flowers are in clusters while female flowers are often solitary. The fruit is fleshy drupe, spherical or slightly ovoid in shape and pale yellow in colour, with a longitudinal groove in the centre (Anon., 1989).

The nutmeg seed kernel is rich in various quality parameters such as moisture (14.3%) protein (7.5%); ether extract (36.4%), carbohydrates (28.5%) fibre (11.6%) mineral matter (1.7%) calcium (0.12%), phosphorus (0.24%) iron (4.6 mg/100g). The principal constituents of nutmeg are fixed oil (fat), volatile oil, and starch. The flavour and therapeutic action are due to the volatile oil whose content varies from 6 to 16 per cent based on the origin and quality of nutmeg. Commercial nutmeg butter is usually obtained by pressing of the ground and cooked or steamed kernels, rather than by extraction. The yield is 24.30 per cent. It is a solid yellowish red fat possessing the nutmeg colour. Nutmeg fat contains of 8 fatty acids, myristic acid forming the largest component. The mace contains the following :

moisture 15.9%; protein 6.5%; ether extract 24.4%; carbohydrates 47.8%; phosphorus 0.10%; and iron 12.6 mg/100 g. The oil closely resembles nutmeg oil in odour, flavour and composition. Mace yields a fat similar to that from nutmeg, but in much smaller amount. (Josy Joseph, 1980).

Both nutmeg and mace are used as spice and in medicine. Nutmeg is the dried seed and mace is the dried aril, a net like structure surrounding the seed. Nutmeg is a stimulant, carminative, astringent and aphrodisiac. It is used in tonics and electuaries and forms a constituent of preparations prescribed for dysentery, stomach ache, flatulence, nausea, vomiting, malaria, rheumatism, sciatica and early stages of leprosy. It is also used in inducing abortion. Mace is used for flavouring cigarettes and chewing to mask foul breath. Oil of nutmeg or mace is employed for flavouring food products and liquors, soaps, tobacco dental creams and perfumery products. It is also used in medicine. Nutmeg butter is used as a mild external stimulant in ointments, hair lotions and plasters and is used in cases of rheumatism, paralysis and sprains. It is also used in perfumes for imparting a spicy odour and in manufacture of soaps and candles. Alcoholic extracts of nutmeg show antibacterial activity against *Micrococcus pyrogenes* var. aureus. Aqueous decoctions are toxic to cockroaches. Myristicin present in the Kernel may be employed as an additive to pyrethrum to enhance the toxicity of the later to house flies. The volatile oil from the nutmeg leaf has weedicidal properties (Josy Joseph, 1980). The fleshy pericarp of the fruit which is also somewhat aromatic is used for making value added products such as jam, jelly, preserve, candies and pickle.

Nutmeg performs well under humid tropical climate and grows upto an elevation of 1000 m above MSL. A well distributed rainfall of 150-250 cm and an annual mean temperature of 20 to 30°C are ideal for nutmeg. It is grown in clays in Malaysia and volcanic loams in Moluccas. Well drained soils rich in humus are the best for its cultivation. Water logged or soils having inadequate moisture may be avoided (Thankamani *et al.* 1994). Area with soils of clay loam, sandy loam and red laterite are ideal for nutmeg (Anon., 1989).

The major nutmeg growing regions are Indonesia and Grenada (W. Indies). In Indonesia, they are grown in Moluccus, Minehassa (Northern Celebes), Sanguish Islands, Benkulen (W. Sumatra), Achin (N. Sumatra) and Nias Inlands. It is also grown in a small scale in Srilanka, Trinidad, China, India the Windward Islands, St. Thomas and St. Vincent, Tobago, Zanzibar and Mauritius (Josy Joseph, 1980). Indonesia is words largest producer of nutmeg. Indonesia's nutmeg production is about 8000 tonnes which represents 80 per cent of the worlds total production (Anon., 1992).

In India nutmeg plantation are at Courtallam of Tirunelveli, Burliar on eastern slopes of Nilgiris in Tamil Nadu, Ernakulam, Kottayam and Thiruvananthapuram districts in Kerala. It is also cultivated in homsestead in Karla state. It is also cultivated on small scale in Andhra Pradesh and Assam (Radhakrishnan *et al.* 1992), Karnataka (Josy Joseph, 1980), Goa and Konkan region of Maharashtra State.

In India it has occupied an area of about 3763 ha with an annual production of 3457 Mt. Since 1981-85 the area and production of nutmeg in India has increased by 19 and 27 per cent respectively (Sivaraman and Peter, 1999). The production of nutmeg in the country is still insufficient to meet the demand of the nation and hence a substantial quantity of nutmeg is imported causing a huge loss of valuable foreign exchange (Rema *et al.*, 1997).

In Konkan region of Maharashtra nutmeg was introduced by Portuguese in some pockets. However, its cultivation remained neglected since long. In late 70's the Konkan Krishi Vidyapeeth initiated research work on this crop with main aim to test its performance as mixed crop in coconut plantation. It was observed that nutmeg is the best-mixed crop in coconut plantation in comparison with other tree spices. The planting of nutmeg under coconut has been found to increase the productivity of coconut plantation by about 84 per cent (Patil *et al.* 1991) which ultimately has resulted in the high levels of net profit from the nutmeg + coconut combination.

The Government of Maharashtra has launched an unique and ambitious horticulture development programme linked with Employment Guarantee Scheme since 1989. Since then the area under coconut

plantation in the Konkan region has substantially increased to about 15100 ha. The area expansion is expected further more in near future. All the area under coconut plantation is the potential area for mixed cropping of spices and nutmeg will have major share in it.

Long prebearing age, dioeciousness, non-availability of sufficient planting material of quality genotypes are some of the major hurdles in nutmeg cultivation. Being an obligatory cross pollinated crop a wide natural variability is observed in nutmeg not only with respect to vegetative characters but also fruit shape, size, colour, quality and yield (Anon., 1989). So far very little attention has been paid towards the nutmeg crop with respect to the identification and perpetuation of elite genotype as well as the important agrotechniques leading to increase in the production of the quality produce. In a precious crop like nutmeg the research work is confined mainly to standardization of propagation techniques. The other aspects are neglected so far (Thankamani *et al.*, 1994). Krishnamoorthy *et al.* (1996) also opined that the literature on nutmeg is limited.

In nutmeg it is necessary to identify a genotype possessing maximum essential economical characters with respect to morphology and regeneration. Such an ideotype should be utilized for planting programme in future on large scale. It is also essential to establish a sound base for breeding programme in nutmeg. For this it is necessary to understand the variability among the available nutmeg progeny. The success of breeding programme depends upon the genetic variability present in the available germplasm. Optimizing the plant architecture for maximizing production is necessary to be attempted in this crop. It is also essential to study the timings of recurring phenological events in nutmeg. It will be helpful in manipulating the physiological processes of plant in favourable way. The information on growth and development can be employed for constructing a planned growth simulator. A model gives simplified description of plant system under consideration. Little attention has been paid so far with this respect in tree spices in general and nutmeg in particular. In the potential crop like nutmeg not only identification of ideotype is required but its rapid

multiplication in large quantity is also essential so that rapid establishment of the meritorious genotype will be possible. The response of nutmeg genotypes for regeneration and grafting ability needs critical evaluation.

Considering the importance of nutmeg cultivation in near future and lack of scientific information in this crop the field investigation was proposed to be taken up on "Phenological studies in nutmeg (*Myristica fragrans* Houtt.) with the following objectives.

1. To study the variability in nutmeg for vegetative growth characters.
2. To study the phenological growth events and assess the possibility of growth models in nutmeg.
3. To study the variability for flowering pattern and the fruit characters in nutmeg genotypes.
4. To study the seedling characters and regeneration ability of nutmeg genotypes.
5. To study the grafting ability of nutmeg genotypes.

**REVIEW
OF
LITERATURE**



CHAPTER II

REVIEW OF LITERATURE

The genus *Myristica* was established for the nutmeg tree by Linnaeus (1742). He placed it under a special appendix "*framenta varia*" apparently because of Linnaeus could not determine the basis of the available material, whether the plant was dioecious or monoecious.

Nutmeg (*Myristica fragrans* Houtt.), a native of Moluccas islands belongs to the family Myristicaceae (Guenther, 1952, Flach and Cruickshank, 1969). Joshi (1946) and Rendle (1971) indicated the close relationship between Myristicaceae and Annonaceae. Garret (1933), Smith and Woodhouse (1938) and Eames (1961) indicated its better relationship with Lauraceae.

Eventhough nutmeg belongs to one of the primitive families, very little attention has been given to it and the work done on it is scattered and very scanty. The research work is confined mainly to standardization of propagation techniques and the other aspects are neglected so far (Thankamani *et al.* 1994). Krishnamoorthy *et al.* (1996) also reported that available literature on variability in nutmeg is limited to a few studies on growth rate, productivity, size and shape of leaf, flower size, shape and size of fruit and nut and correlation of fruit characters. Hence the work carried out in nutmeg as well as other crops relevant to the present study is reviewed as below under following sub-heads.

- 2.1 Nutmeg tree
- 2.2 Growth
- 2.3 Flowering and fruitset
- 2.4 Fruit characters
- 2.5 Fruit development
- 2.6 Yield
- 2.7 Germination and seedling characters
- 2.8 Grafting
- 2.9 Variability, heritability, genetic advance, correlation and path analysis
- 2.10 Plant growth models

2.1 The nutmeg tree :

Nutmeg is a handsome, evergreen tree with dense foliage. Trees are 10-20 m tall; branches are spreading with dark gray bark; leaves are shiny and oblong to ovate in shape. (Shanmugavelu and Madhava Rao, 1977).

Purselove *et al.* (1981) described the nutmeg tree as a spreading evergreen tree 4-10 m tall sometimes attaining 20 m height. It is usually dioecious, but sometimes male and female flowers are found on the same tree. They also opined that all parts of nutmeg are aromatic. Further, there are numerous spreading branches with the main branches arising low on the trunk. The bark is greyish black and slightly fissured longitudinally in the older trees; the twigs are glabrous, slender and grayish brown.

Nutmeg being a strictly cross pollinated crop the plants differ in growth and vigour (Anon., 1989).

Krishnamoorthy *et al.* (1996) observed the total canopy of nutmeg tree to be 40.0 to 109.4 m³ among the genotypes they studied. The girth at 140 cm ranged from 30 to 47 cm.

2.2 Growth :

Nutmeg is slow grower as compared to other perennial crops (Flach and Cruickshank, 1969). According to them a good growing plantation in New Guinea attained an average height of approximately 3 m and a girth of 15.7 cm at 40 cm above ground level in four years. Growth continued upto 60 to 80 years. Plants differed much in growth, vigour, productivity, sex of flowers, size and shape of leaves.

Nazeem (1979) observed the shoot growth in nutmeg to be cyclic. Under Kerala conditions she observed six flushes with two peaks in May and September. Further, the growth recorded in different trees did not differ significantly. The growth was found to be very slow with a mean extension of 11.31 cm in a period of one year.

Ram (1982) noticed the growth in nutmeg trees to be continuous at varying intensities and recorded the total growth output for the year to be 10.27 cm for adult and 10.89 cm for young trees.

Thomas (1997) noticed the nutmeg tree to be slow grower when compared to other perennial trees. She reported shoot growth in nutmeg to be cyclic, a period of growth followed by a quiescence.

2.3 Flowering and fruit set :

Flowering and fruitset are very important in any horticultural crop. The nutmeg tree usually flowers throughout the year with peaks in fixed months. The climatic factors are responsible for such variations although it is not possible to pinpoint any factor (Flach and Cruickshank, 1969). Under New Guinea conditions Flach (1966) observed that approximately 50 per cent of the female flowers set fruits.

The inflorescence of nutmeg is described by various workers. According to Gamble (1967) the number of flowers per inflorescence varied from 3 to 5 in male and fewer in female.

Nazeem (1979) observed that male and female trees differed in their flowering pattern. In female trees flowering continued from June to October and extended upto January February whereas in male the flowering was throughout the year with varying intensities. The period from visible induction to anthesis was 84.20 days for male and 154.10 days for female flowers. Open pollination recorded 33.10 per cent set, whereas hand pollination recorded a much higher fruitset percentage i.e. 88.75 per cent (Nazeem *et al.*, 1981).

Ram (1982) reported that in female trees flowers were mostly borne in singles, while in male trees the flowers were mostly in clusters of four to eight. The total days required by a male and a female flower bud from pinhead stage upto anthesis were 42.66 and 42.45, respectively. The fruit set observed by open pollination was 0.00 (December) to 44.33 (November) per cent. The flower flushes observed in male and female were 7 and 6, respectively.

Under coastal conditions of Maharashtra it took 188 days from bud initiation to anthesis in clove. Later the fruit development took in about 91 days (Bagade, 1989).

George *et al.* (1992) studied flowering in *Garcinia cambogia* and reported that on an average male flowers took longer time (26 days) for anthesis compared to bisexual flowers (19 days). The fruit set observed was 20 per cent.

In cocoa the flower production was found to be throughout the year with two peak seasons viz May-June and November- December. The per cent fruit set on the main bank (main stem) was 13.51 per cent (Rajamony and Mohankumaran, 1996).

2.4 Fruit characters :

Nutmeg fruit composes of fleshy pericarp, scarlet red mace and nut. These fruit components vary among the plants. Deinum (1949) reported the proportion of the fruit components in fresh nutmeg fruit to be 77.8% (pericarp) : 18.2% (nut) : 4.0% (Mace). He estimated dry weight of nutmeg to be 7 g in island of Banda.

Flach (1966) observed that the average weight of shell was approximately 30.2% of the weight of nutmeg. The variation was considerable among the lot form 25 to 36 per cent. He further noticed that the number of nutmegs varied from 100 to 165 in 500 g weight.

In New Guinea the nut and mace of *Myristica argentea* weighed 6.38 to 6.89 g and 1.75 to 2.15 g, respectively (Flach, 1966).

Individual nutmeg fruits weighed on an average 60g of which the seed weighed 6.79, mace 3-4 g and the rest pericarp (Shanmugavelu and Madhava Rao, 1977). The proportion of dried-shelled nutmeg to dried mace was approximately 20:3. During drying, nutmegs lose about 25 per cent of their weight (Purseglove *et al.* 1981). The colour of dried nut was greyish brown and varied in size upto 3 cm long and 2 cm wide (Farrel, 1990).

Krishnamoorthy *et al.* (1996) found that the fruit weight of nutmeg ranged from 60.5 to 80.0 g, the seed weight from 8.4 to 12.2 g and the mace weight from 2.5 to 3.7 g under Kerala conditions.

2.5 Fruit Development :

The period required for fruit development in nutmeg is substantially long. The time required for the fruits to attain maturity from flowering was reported to be nine months (Flach, 1966; Flach and Cruickshank 1969).

Nazeem (1979) noticed that the development of nutmeg fruit was quicker during the period between 6th and 16th week after fruit set and thereafter it decreased gradually till eighteenth week. The increase in growth was very low between 18th and 25th week and there was no growth thereafter. The fruits started splitting in 206 to 237 days (seven to eight months) after set. The developing fruits followed a sigmoid growth pattern.

Hittalmani *et al.* (1977) opined that the Kagzi lime fruit followed a sigmoid pattern of growth and took 6½ months to mature from the time of fruit set. The growth pattern could be divided into 3 distinct periods based on the rate of growth. The period I being the period of rapid growth from first to fourth fortnight, period II being the stage of steady increase in weight from fifth to ninth fortnight and period III marked by an accelerated growth rate from tenth to thirteenth fortnight.

In India the nutmeg fruit become ready for harvest in about 9 months after flowering (Anon., 1989).

In muskmelon the dry weight of fruit increased upto 30 days from flowering. However, the changes in dry weight after 26 days from flowering were marginal (Srinivas *et al.*, 1983).

An observational study made on the rate of fruit development and dry matter accumulation in chilli cultivars indicated that chilli fruit required 48 days for ripening after anthesis although the physiological maturity was attained within 36 days after anthesis (Ramarao *et al.*, 1990).

Geetha *et al.* (1992) studied fruit development in Jamun and found that the pattern of growth of the fruit followed a sigmoid curve with the first phase of slow growth (7-14 days after fruit set), second phase of rapid growth (14-35 days) and the last phase (35-42 days) of slow growth.

In sapota fruit there was initial faster growth rate. The growth was slow from 45th day from fruitset (Ponnuswami *et al.*, 1992).

In bilimbi fruit, the study indicated that the growth and development followed a linear pattern of growth for the important characters viz. length, girth, volume and weight of fruit (Lila Mathew *et al.*, 1993).

It took 133 days from fruit set to ripening in *Garcinia cambogia*. The maximum length, girth, fruit weight, rind weight, seed weight and rind thickness were attained by 112 days after fruit set with varying rate of growth at different periods (Muthulakshmi, 1998).

In mango Ram and Rajput (1999) reported that the daily fruit growth rate for the whole growth period for “Langra” fruits was significantly higher than that for “Dashehari” which substantiated the high rate of assimilates deposition in Langra.

Sathesan (2000) observed in black pepper that the fresh weight of spikes increased up to 150 days after berry set. The rate of increase in fresh weight was highest during the first month of berry set and thereafter it declined till berry maturity up to 150 days.

2.6 Yield :

Yield is the ultimate important parameter in almost all crops. In nutmeg two spices items namely, nutmeg and mace are obtained. Lot of variation in nutmeg yield within the country and among countries has been reported.

Deinum (1949) observed that in 1930 the islands of Banda yielded an average of 70kg mace/ha or approximately 600 g of mace/ tree. The average production per tree was 300 fruits. Further, he recorded that plantation in

Java (Indonesia) produced 320 to 1679 fruits per tree. This plantation was spaced at 8 to 9 m and only lightly shaded by *Albizia* and interplanted with cocoa and kapok.

Landes (1949) reported that in Grenada the best nutmeg plantations showed an average production of 1500 fruits per tree per year.

Almost every tree of nutmeg in a plantation in New Guinea showed different yield pattern (Flach, 1966). Similar observation have been recorded in India under Kerala conditions (Nazeem, 1979).

According to Purseglove *et al.* (1981) the nutmeg yield varied greatly between trees and between plantations. The average yield of a good tree in full bearing is about 1500 to 2000 fruits per annum. The yield of mace varied between 500-1000 lb. per acre (560-1120 kg/ha) and 75-150 lb. per acre (84-168 kg/ha) per annum. They also reported that on Government stations in Grenada the average yield was 2500 lb. of green nuts per acre (2800 kg/ha) after about 14 years which was equivalent to 1875 lb. per acre (2100 kg/ha) of dry nuts.

A ten year old nutmeg tree was expected to yield 500-800 fruits and a twenty year old tree 2000-3000 fruits (Shanmugavelu and Madhava Rao, 1977).

Khanvilkar (1984) reported that in *Garcinia indica* there was variation in respect of fruit yield and fruit number in the population studied. The variation was due to two factors viz. Genotype and environment.

Krishnamoorthy *et al.* (1996) noticed mean yield of 525 (No. 25) to 843 (No. 22) number of fruits per tree among the nutmeg seedlings they studied.

2.7 Germination and seedling characters :

In nutmeg the conventional method of propagation is by seeds collected from regular bearing and high yielding trees.

According to Flach (1966), nutmeg seed took 4 to 6 weeks for germination. He further noticed that higher the monthly yield of a tree the higher was the percentage of germinating seeds. The germination in nutmeg varied from 35 to 70 per cent.

Under Dapoli (M.S.) conditions Prabhu (1978) observed 71.7 days period for germination in nutmeg with 89.3 per cent germination on a sand bed.

Shanmugavelu and Madhava Rao (1977) could not notice any difference in germination among various sizes of seeds except in the case of very small and immature seeds which did not germinate satisfactorily. However, Lila Mathew (1979) reported highest percentage of germination in heavy seeds (above 9 g) as compared to light seeds (below 9 g). The time taken for germination also varied from 55.63 to 60.50 days (heavy) to 57.62 to 64.76 days (light). There was significant difference in the growth of seedlings with respect to girth. However there was no significant difference in respect of height and number of leaves.

Purseglove (1981) observed that germination took after one month or more in nutmeg.

Selecting and sowing heavier seed was necessary for obtaining a higher germination percentage as well as for raising better and vigorous seedling clones in nutmeg (Lila Mathew, 1992).

Thangaraj *et al.* (1992) reported that the seedling height in rangpur lime seedlings ranged widely from 20.0 to 130.3 cm while the girth varied from 0.1 to 4.8 cm. The coefficient of variation was higher for seedling girth (69.3%) followed by seedling height (47.7%).

Madhusud^hanan and Babu (1994) observed that the germination in nutmeg was 50 per cent and could be increased to 100 per cent by seed treatment.

Chezhiyan *et al.* (1996) noticed that the nutmeg seed weighing between 7 to 9 g recorded higher germination (71%) and also produced taller plants

(17 cm) with maximum number of leaves (7) sixty days after planting. The smallest seeds of 4-5 grams and biggest seeds of 9-11 grams were mediocre in germination and growth as the grades produced lesser percentage of germination, plant height and number of leaves.

Jyothi (2000) while studying variability and character association in pickle genotype mango noticed that the germination among the genotypes under study ranged from 12 to 93 per cent. The plant height after three months ranged from 10.3 to 23.6 cm in the different genotypes. The girth varied from 0.3 to 0.7 cm, the root length varied between 13.65 and 32.95 cm whereas the number of secondary roots ranged between 6.00 and 23.00 in the different genotypes of mango studied.

2.8 Grafting :

Nutmeg is a dioecious crop and the tree being obligatory cross-pollinated (Deinum, 1949) variation existed in its seedling progenies. To get uniformly high yielding and desirable populations of nutmeg, vegetative propagation is the only alternative. Experiments on grafting of nutmeg were carried out as early as 1894 in the Botanical Gardens at Bogor, Indonesia (Deinum, 1932). Various vegetative methods have been studied in nutmeg.

Mathew and Joseph (1982) reported that epicotyl grafting can be done successfully in nutmeg.

Haldankar *et al.* (1997) observed that softwood grafting can be successfully performed in nutmeg under Konkan condition of Maharashtra. Similarly epicotyl grafting was also observed to be successful under coastal Maharashtra conditions (Haldankar *et al.*, 1999).

2.8.1 Effect of scion :

Dhakal (1979) conducted studies to find out the response of selected seven varieties of mango for stone grafting and obtained 86, 85, 70, 66, 65, 64 and 61 per cent success, respectively in Kesar, Totapuri, Pairi, Vanraj, Fernandin, Goamankur and Alphonso varieties when used as scion. Maiti

and Biswas (1980) studied the effect of 14 scion varieties on stone grafting in mango. Among the varieties tried Fazli recorded the highest percentage of success (96%) followed by Ranipasand (94%). The lowest percentage of success was noticed in Kishenbhog (29%).

Kulwal and Tayde (1985) reported varietal differences in soft wood grafting of mango under Akola conditions. The varieties, Pairi, Kesar and Panchadara Kalsa showed nearly 100 per cent success while varieties Neelum, Locat-1, Locat-2, Totapuri and Banganpalli recorded only 72 to 85 per cent success.

Radhamony (1987) evaluated the response of different varieties of scion in mango stone grafting and noticed that highest percentage of sprouting (84%) was noticed in the variety Banganpalli, whereas the sprouting was the lowest in variety Alphonso (58%). The variety Priur recorded maximum graft survival (54%) whereas the variety Mulgoa had minimum survival (12%). The variety Mulgoa showed maximum mean growth followed by variety Banganpalli upto 4th fortnight. The lowest growth was noticed in the variety Bangalora upto 5th fortnight. The leaf production was maximum in the variety Bainganpally and minimum in the variety Mulgoa (Radhamony *et al.*, 1989).

The success by using different scions for grafting varied from 35.50 to 71.00 per cent in pickle genotype mangoes (Jyothi, 2000).

2.9 Variability, heritability, genetic advance, correlation and path analysis :

Nutmeg is one of the most important tree spice. The area under this crop is increasing slowly but steadily. The improvement programme in this crop aims at achieving the maximum productivity with high quality. It is necessary to understand the genetic variability and association of various components with each other and the ultimate component yield. Correlation studies prove very useful in selecting promising genotypes. Various biometrical techniques have been developed for studying the genetics of quantitative traits. This information can be used for developing more

sophisticated and efficient approach to select the parents. Very meagre information on such aspect is available in nutmeg hence some of the relevant evidences from other crops have also been quoted.

2.9.1 Variability, heritability and genetic advance :

Singh *et al.* (1980) studied thirteen different varieties of mandarin and observed high GCV for acidity, T.S.S./ Acidity ratio, number of juice sac and fruit weight. Average fruit weight, number of juice sacs and number of seeds per fruit exhibited high heritability. Average fruit weight appeared to be governed by additive gene effect while non-additive gene effect was observed for the number of seeds.

In cinnamon the plant girth registered a variability of 5.202 per cent. Similarly, the presence of variability of larger magnitude was noticed for tree spread and top volume (Ponnuswami *et al.*, 1982).

Singh and Jalikop (1986) studied bunch attributed of twenty grape varieties. For all the character they observed wide variation. Maximum PCV and GCV was noticed for number of bunches/ vine. It was indicated from the genetic advance and heritability values that number of bunches per vine and berry weight will respond to selection as these traits were controlled by additive gene action.

In ber high variability was recorded for growth characters in 30 genotypes. The heritability estimates were quite high for the growth characters except spread of the tree (22.36%). Fruit set per cent itself provided a lot of variability, high heritability as well as maximum genetic gain (142.82). The study indicated that for the selection of high yielding genotypes in ber attention should be paid to selection for more fruit set and less fruit drop. (Bisla and Daulta, 1988).

Nutmeg is an obligatory cross-pollinated crop and considerable variation was observed with respect to growth and vigour, sex expression, size and shape of nutmeg and quantity of mace (Anon. 1989).

Rosamma and Narayanan Namboodiri (1990) reported high heritability (over 80%) estimates in banana for eleven components.

In cinnamon high coefficient of variation was noticed for dry and fresh bark yield, bark oleoresin, leaf oil, bark oil, leaf size index and percentage recovery of bark (Krishnamoorthy *et al.*, 1992).

Patil *et al.* (1993 a) studied 13 genotypes of coconut and noticed significant variation for nut characters except kernel thickness. The characters like weight and volume of husked nut, shell and kernel were found to be under control of additive gene action, whereas the characters weight of husk and copra were found to be governed by additive as well as nonadditive gene action. The study on inflorescence characters in coconut revealed that female flowers per spadix were under control of additive gene action (Patil *et al.*, 1993 b).

In papaya height of plant, days required for first flowering, spread of plant, yield per plant and number of leaves per plant showed high genetic coefficient of variation. Further the estimates of heritability and genetic advance as per cent mean were substantively high for height of plant, number of leaves per plant, fruit yield per plant, length of petiole, number of nodes per plant, days required for first flowering, spread and girth of plant (Ghanta and Mandal, 1992). In acid lime very high heritability was noticed for fifteen important characters inducing growth, yield and physicochemical characters of fruit (Ranpise and Desai, 1994 b).

Ghanta *et al.* (1994) noticed wide variability in litch for peel, seed, aril and fruit weight. The heritability and genetic advance were also very high for these characters. The high heritability and genetic advance for weight of 100 leaves and leaf area of 100 leaves has been recorded in betel wine (Reddy, 1994).

In nutmeg Krishnamoorthy *et al.* (1996) observed more PCV than GCV for height, mean girth of stem and weight of fruit. Further, they also noticed low estimates of genetic parameters for mean girth, canopy size,

yield, weight of seed and mace. It was opined that available literature on variability in nutmeg was very limited.

Patil *et al.* (1998) studied foliar attributes in coconut and reported maximum PCV for yield followed by number of leaf scars and stem circumference. It was minimum for leaflets per leaf. The values of GCV were smaller than PCV.

Muthulakshmi (1998) noticed high variability in *Garcinia cambogia*.

2.9.2 Correlation of traits :

Improvement in fruit yield is generally considered as one of the most prominent objectives set for breeding in fruit crops. Fruit yield is the complex trait largely influenced both by genetic potential of the crop as well as ecological condition of the particular agroclimatic zone. This most important genetic expression is also influenced by other related factors that is the uncontrollable periodic variations in different weather parameters within the agroclimatic zones. In view of this the expression of the genetic potential in terms of fruit yield in one agroclimatic zone is thus of paramount importance mainly with respect to correlation of different biotic as well as abiotic factors since the relationship between these factors is finally reflected in the yield.

Thamburaj and Shanmugasubramaniam (1977) noticed that in acid lime, fruit weight had a direct and significant correlation with volume of fruit, volume of juice per fruit and weight of juice.

In cinnamon fresh weight of bark and leaf oil with dry bark yield were positively and significantly associated whereas, bark oil was negatively associated with leaf oil (Krishnamoorthy, *et al.*, 1992).

In banana the studies on phenotypic correlations indicated high positive association between finger weight and bunch weight and also with most other yield components while number of hands per bunch and fingers per bunch had either insignificant positive correlation or high negative correlations with most of the yield components (Rekha and Prasad, 1993).

Patil *et al.* (1993 a) observed in coconut that size and weight of nut had inverse correlation with nuts per palm. The correlation studies revealed that the important characters like size, weight of copra and oil yield were mutually exclusive. The association studies between inflorescence characters and yield in coconut indicated a negative association of yield with length of spadix (Patil *et al.*, 1993 b).

Ranpise and Desai (1994 a) reported that in kagzi lime growth parameters (plant height, tree volume and stem girth) were positively correlated with each other. They were also positively correlated with number of fruits per plant and yield. The fruits per plant and yield had association with fruit quality attributes. Yield and rind thickness was positively associated.

In *Garcinia combogia* fruit weight and other fruit characters like length, volume, rind thickness, seed weight, rind weight, rind seed ratio and fruit rind ratio were observed to be highly correlated. Significant correlation was also observed for fruit weight with number of segments and segment width. The seed weight, rind weight, rind seed ratio and fruit rind ratio were significantly associated with segment width and rind thickness (Muthulakshmi, 1998).

Patil *et al.* (1998) reported positive correlation of circumference of stem and number of leaves per palm with yield in coconut. The length of leaf and length of leaf petiole had negative association with yield.

Jyothi (2000) studied association in pickled type mango and reported significant positive correlation between seed length and germination percentage. The plant height after three months was positively correlated with girth after 3 months. There was weak relation between root length and number of secondary roots.

2.9.3 Path analysis :

Correlation coefficients are helpful in measuring the association between two characters however they do not provide causal basis of such

an association. It is necessary to study and quantify the effects of these components on yield either directly or indirectly through some other components. The path analysis is therefore essential to pinpoint relatively more important traits affecting the yield.

In banana Rosamma and Narayana Namboodiri (1990) studied yield and yield contributing components and reported that characters like total number of fingers per bunch, number of hands per bunch, bunch length and girth at the base of pseudostem at shooting time have positive direct effect on bunch weight while girth of individual finger, total number of leaves per plant and leaf area contributed mainly through other characters.

In kagzi lime path analysis revealed that the average fruit weight had direct positive influences on yield (Ranpise and Desai, 1994 a).

Dwivedi and Mitra (1995) observed that in litchi fruit weight recorded the highest positive direct effect on aril weight and positive indirect effect via diameter of fruit and peel weight. Highest negative direct effect was recorded by length of fruit.

In *Garcinia cambogia* path analysis showed that fruit weight had a high influence on rind weight. The indirect positive effect of fruit weight via volume, rind thickness, seed weight and rind seed ratio was observed. The indirect effect of fruit weight and rind weight via fruit rind ratio was negative. Fruit length, volume, number of segments, segment width, rind thickness and seed weight did not influence the rind weight directly or indirectly (Muthulakshmi, 1998).

2.10 Plant growth models :

Plant growth model gives a simplified description of the real system under consideration. In nutmeg the attempts for developing growth model are seldom made. Flach (1966) found the relation of girth of stem with yield in nutmeg. He developed model for estimating of yield.

$$10 g (y+1) = 0.023x + 2.02$$

Where

y = Total production of trees over years from 1958 to 1961 in number.

x = The girth of tree in cm at 40 cm above ground level.

In mango Khan (1960) and Oppenheimer (1960) observed relationship between tree growth and fruit yield whereas Krishnamurthy *et al.* (1961) reported that there was no relationship between extension growth, number of nodes, internodal length and flowering in mango.

Teotia *et al.* (1970) studied tree vigour in Mango cv. Dashehari and noticed that spread, height and circumference of stock were all significantly related with yield when linear regression equation were computed for these characters. Multiple regression equations showed that yield was significantly related with spread alongwith either the height or the circumference of stock when included in the equation. The spread gave closer relationship with yield than either the height or the circumference of the stock.

In physical sciences, the term “model” is used to provide an explanation for certain phenomena and to postulate underlying processes which give rise to the observation under inspection (Yarranton, 1971).

According to Mead (1971) the use of high degree polynomials to represent biological situations should properly be defined as a mathematical representation rather than a model.

Haun (1974) proposed a wheat yield prediction system that is based on “cause and effect” relationship.

Parmeswaran (1979) studied yield of cashew in relation to growth parameters. Tree spread had positive correlation with yield. The following equation was computed.

$$Y = - 6.188 + 0.268 X_2$$

where X_2 = Spread

Y = Yield of cashew tree.

In chilli among the different yield traits, the regression co-efficients for fruit girth, ripe fruit yield, dry matter and ascorbic acid were found to be highly significant. For every additional unit increase in ripe fruit yield, dry matter and ascorbic acid there would be substantial increase in dry chilli yield whereas, with the increase in fruit girth there would be a decrease in dry chilli yield (Venkata Rao and Chhonkar, 1983).

Usha Rani (1995) reported in chilli that the estimation of regression of component characters on fruit yield were positive for all the characters studied but the number of primary branches per plant, root dry weight per plant, number of secondary branches per plant and root volume showed major contribution towards fruit yield.

2.10.1 Leaf area prediction :

Nazeem *et al.* (1989) estimated leaf area in clove using linear measurements with 0.98 R^2 .

Ramadasan and Jacob Mathew (1987) determined the area of leaflets in WCT coconut by using L-I Cor. Electronic leaf area meter model L-I-3000.

In large cardamom the regression equation of the product $L \times B$ at any stage of crop was found to be effective (Karibasappa and Dhiman, 1987)

In nutmeg also the product $L \times B$ was observed to be most effective for precision in leaf area estimation. (Sudhadevi *et al.*, 1990; Prasada Rao and Sebastian Siby, 1994; Balakrishnan *et al.*, 1998). Similar findings were also reported in cinnamon (Rema and Menon *et al.* 1993).

**MATERIAL
AND
METHODS**



CHAPTER III

MATERIALS AND METHODS

The investigation entitled "Phenological studies in nutmeg (*Myristica fragrans* houtt.) was carried out at Regional Coconut Research Station, Bhatye, Ratnagiri, Maharashtra State (India) from 1-1-1999 to 31-12-2000. The material used and methods followed during the course of this investigation are described in this chapter.

3.1 Climate and Weather conditions :

Bhatye, is situated at 17.00° North latitude and 73.40° East longitude. It is located on the coast of Arabian sea on the western outskirts of Ratnagiri city and linked with it by the creek bridge on the mouth of river Kajali. It has an elevation of 3 meter above MSL. The average rainfall at Bhatye is 2970 mm normally distributed from June to October while the average relative humidity is 73 per cent. The average minimum and maximum temperatures are 22.80°C and 31.10°C respectively.

The meteorological data recorded at the observatory of Agricultural Research Station, Ratnagiri for the period from January 1999 to December 2000 are presented in Appendix-1. The investigation was initiated in January 1999. In January and February the mean maximum temperatures were 31.91 to 32.30°C whereas the mean minimum temperatures were in the range of 18.20 to 19.78°C with an average of 25.55°C. The night temperatures started raising after February and remained between 21.04 to 22.05°C during March and April. During these two months the daily maximum temperature were in the range of 31.59 to 31.83°C. The relative humidity during these 2 months was in between 66.80 to 74.86 per cent. The relative humidity during these two months was 58.50 to 60.83 per cent. From September onwards the daily maximum temperature started raising gradually and reached maximum of 33.69°C in November whereas night temperatures were highest in May. The rainy season commenced from May. It reached peak in June and July thereafter it started receding with a complete cessation by November. The total rainfall during May to



Plate 1. A view of experimental nutmeg plantation under coconut

October 1999 was 2496 mm. From August onwards there was gradual decline in daily minimum temperature whereas the maximum temperature was stable between 24.58 to 24.78°C during May to July. The minimum temperature went below 20°C from January onwards and reached as low as 18.51°C during February 2000. It remained between 18 to 20°C during January to February 2000. Thus, the climate at experimental location was characterised by high rainfall during May to October, relative humidity of 76.35 to 89.43 per cent during rainy season and 47.85 to 75.38 per cent during post monsoon period with a modest temperature ranging between 18.20 to 34.20°C.

3.2 Experimental details :

The investigation was carried out for two consecutive years starting from January, 1999 to December, 2000. The seedling germplasm of nutmeg comprising of 39 genotypes planted as mixed crop under 20 year old WCT coconut plantation in 1979 constituted the experimental material.

The genotypes selected consisted of 22 female, 12 hermaphrodite and 5 male genotypes. These genotypes are as under.

Female genotypes :

1. N1	6. N29	11. N38	16. N49	21. N72
2. N5	7. N30	12. N41	17. N51	22. N74
3. N10	8. N34	13. N42	18. N57	
4. N11	9. N36	14. N43	19. N66	
5. N24	10. N37	15. N46	20. N70	

Hermaphrodite genotypes :

1. N4	4. N23	7. N32	10. N56
2. N7	5. N26	8. N33	11. N61
3. N22	6. N27	9. N55	12. N63

Male genotypes :

1. N15	2. N35	3. N60	4. N53	5. N69
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Plate 2. Female nutmeg genotype N1

3.3 Cultural practices :

The experimental trees were well maintained by following standard package of practices. The nutrients were applied @ 700 : 700 : 700 g NPK.

The irrigation was given through drip irrigation system and 50 L water was applied per day per tree. The mulching of fallen dried leaves of nutmeg was provided of 15 cm height under the canopy of each experimental nutmeg tree. 1 per cent Bordeaux mixture was drenched whenever the dieback symptoms were observed on experimental trees.

3.4 Observations :

The observations regarding plant growth characters, plant growth pattern, flowering, fruit growth, fruit characters, seedling ability (seed germination i.e. seed viability and seedling vigour) and grafting ability were recorded periodically to evaluate the phenological events of different genotypes.

3.4.1 Growth parameters of the genotype :

The observations on following growth parameters were recorded and used for developing the models of plant growth and architecture.

3.4.1.1 Plant height :

The height of experimental trees from the ground level to the apex was recorded in m with meter tape.

3.4.1.2 Canopy spread :

The spread of tree in the North South and the East West directions was measured in m with the help of meter tape. The average of both the sides was recorded as canopy spread.



Plate 3. Male nutmeg genotype N69

3.4.1.3 Canopy volume and canopy surface area :

In general the crown of the nutmeg trees was conical in shape hence the following formula was applied for deciding the crown volume and crown surface area.

The volume of tree was calculated based on canopy height and canopy radius and by using the following formula

$$\text{Tree volume} = \frac{1}{3} \pi r^2 h$$

Where canopy radius (r) was calculated by taking mean of North-South and East West spread. (Gautam J.N. 2000)

The canopy surface area of the tree was calculated based on canopy diameter (r) and slanting height of canopy (l) and by using the following formula.

$$\text{Canopy surface area} = \pi r (r + l)$$

Where canopy radius (r) is calculated as described in canopy volume. The slanting height of canopy was calculated based on canopy diameter (r) and tree height (h) by the following formula

$$l^2 = r^2 + h^2.$$

3.4.1.4 Girth of stem :

Girth of the tree trunk (stem) was recorded 1 m above the ground surface using meter tape in cm.

3.4.1.5 Number of crotches :

The number of crotches were counted and recorded.

3.4.1.6 Leaf characters :

The following leaf characters were recorded on all the types under study. For this ten fully mature leaves were randomly collected per tree from all the directions and from all the vertical levels of tree.



Plate 4. Hermaphrodite nutmeg genotype N61

3.4.1.6 a) Leaf length :

The length of leaf was measured with clear plastic scale from the petiole to the leaf tip and recorded in cm.

3.4.1.6 b) Leaf breadth :

The maximum distance between the two edges of lamina was measured with the help of measuring scale and was recorded in cm.

3.4.1.6 c) Fresh leaf weight :

The randomly selected leaves were weighted separately immediately after sampling on sensitive electronic balance Sansui model to record fresh weight in g.

3.4.1.6 d) Dry leaf weight :

The ten sampled leaves were dried at 52°C in an electric oven to constant dry weight in g.

3.4.1.6 e) Leaf area :

The ten leaves collected for measuring above parameters were used to determine the actual leaf area. The actual leaf area was measured by graph paper method.

3.4.1.7 Primary branches :

The primary branches were counted from top to bottom on each genotype and recorded in numbers.

3.4.1.8 Secondary branches :

Total eight primary branches were randomly selected from all direction and at all vertical levels of a tree. The secondary branches were counted on these primary branches. The average of the secondary branches was multiplied by the total number of primary branches to compute total number of secondary branches per tree.

3.4.1.9 Tertiary branches :

Sixteen secondary branches were randomly selected from all directions at all the vertical levels of each tree. The tertiary branches on these secondaries were counted and recorded. The average of these tertiary branches was multiplied by the total number of secondary branches to calculate total number of tertiary branches per tree.

3.4.2 Shoot growth :

This study was conducted on 34 genotypes. Among the remaining five, four genotypes did not produce any shoot during the investigation whereas one genotype was affected by die back and hence the shoot production was not satisfactory. Ten shoots were tagged randomly from all around the canopy at the stage of their emergence. Ten shoots were tagged in two replications. The observations were recorded at monthly interval starting from January to December 2000. The following observations of the developing shoot were recorded.

3.4.2.1 Length of the shoot :

The length of the growing shoot was measured in cm from the base to the tip of the shoot.

3.4.2.2 Number of leaves on shoot :

The leaves on the growing shoot were counted and recorded.

3.4.2.3 Appearance of flowers on shoot :

The appearance of flowers on the marked shoot was recorded when observed.

3.4.3 Flowering pattern :

To study the flowering pattern flower buds were tagged when they just appeared in the leaf axil. Fifty flower buds were tagged per replication in two replications. The following observations were recorded.

3.4.3.1 Days required for anthesis :

The period from appearance of flower bud in the leaf axil and the flower opening was counted in days and recorded as period required for anthesis.

3.4.3.2 Appearance of flower :

The flower appearance as solitary or in group was recorded at the bud stage itself.

3.4.3.3 Fruit set :

The number of fruits set from the marked flowers on the female and hermaphrodite genotypes were counted and recorded as percentage of the total flowers tagged.

3.4.4 Fruit development studies :

To study fruit development 50 fruits were tagged immediately after fruit set on 30 nutmeg genotypes under study. Among the remaining nine, four were female/ hermaphrodite genotypes but at the time of starting of the studies on fruit growth they did not produce adequate number of fruits required for intermittent sampling during the course of investigation. The remaining five genotypes were male. The following observations were recorded at an interval of 25 days upto harvesting. Four fruits were selected randomly each time per test plant to record the observations.

3.4.4.1 Colour of fruit :

At each observations colour of fruit was recorded by visual observations.

3.4.4.2 Dry pericarp weight :

The pericarp of nutmeg fruits at each stage was dried at 52°C to a constant weight and weight was recorded on sensitive electronic balance in g.

3.4.4.3 Dry mace weight :

The mace in the selected nutmeg fruits was extracted at each stage of fruit development and dried to constant weight at 52°C. The weight of dried mace was noted with the help of sensitive electronic balance in g.

3.4.4.4 Dry nut weight :

The nut in the selected fruits was separated at each stage of fruit development and dried at 52°C to a constant weight. The weight was recorded by using sensitive electronic balance in g.

3.4.4.5 Total dry fruit weight :

The weight of dry nut, mace and pericarp in total was considered as a total dry weight of fruit.

3.4.4.6 Change in the mace colour :

The change in the mace colour at each stage of fruit development was observed visually and recorded.

3.4.5 Fruit characters :

The fully mature fruits were randomly collected to record the following observations of individual fruit from female and hermaphrodite nutmeg genotypes under study. Ten fruits were selected per replication for two replications.

3.4.5.1 Fruit length :

The length of sampled fruits from stalk base to the apex of fruit was measured with the help of vernier calliper in cm.

3.4.5.2 Fruit breadth :

The maximum linear distance between two sides of the fruit was considered as the breadth and was measured with the help of vernier callipers in cm to workout mean breadth.

3.4.5.3 Weight of fruit :

Individual fruit was weighted on sensitive electronic balance in g and mean was worked out.

3.4.5.4 Length of nut :

The nuts from these fruits were separated and the length of nut from distal end to proximal end was recorded with the help of vernier callipers in cm.

3.4.5.5 Breadth of nut :

The maximum linear distance between two sides of nut was considered as the breadth and was measured with the help of vernier callipers in cm.

3.4.5.6 Fresh weight of nut :

The weight of above selected nuts was measured on sensitive electronic balance and mean weight was recorded.

3.4.5.7 Dry nut weight :

The nuts were dried to a constant weight at 52°C in thermostatic oven and the weight was recorded in g on a sensitive electronic balance.

3.4.5.8 Fresh mace weight :

The mace was separated from the ten fruits and weighed individually on a sensitive electronic balance in g.

3.4.5.9 Dry mace weight :

The mace of above selected fruits dried to a constant weight at 52°C and weighed separately on a sensitive electronic balance in g.

3.4.5.10 Weight of pericarp :

The weight of pericarp was computed by subtracting the weight of fresh nut and fresh mace from the weight of fruit for the respective fruits and recorded in g.

3.4.5.11 Weight of kernel :

The dried nuts were break opened and kernel was separated from it. The weight of individual kernel was recorded in g on a sensitive electronic balance.

3.4.5.12 Weight of shell :

The weight of kernel was subtracted from the weight of nut for respective nut to obtain the weight of shell and was recorded in g.

3.4.5.13 Recovery (%) :

The ratio of kernel weight in g to total nut weight was worked out and recorded as recovery percentage.

3.4.5.14 Nut and mace oil (%) :

For estimating the oil content of nut, the kernel was removed from dried nuts of the respective genotypes. It was made into fine powder with the help of grinder. Similarly, dry mace was also made into fine powder with the help of grinder. The oil content was determined by solvent extraction ~~by~~ using soxhlet apparatus.

3.4.5.15 Pericarp : Nut : Mace ratio :

The proportion of pericarp, nut and mace weight in total fruit weight both fresh and dried was calculated and recorded.

3.4.6 Yield :

Yield of individual nutmeg genotype was recorded separately for 1999 and 2000. For better assessment the yield data for 1995, 1996, 1997 and 1998 were also used.

3.4.6.1 Yield as number of fruits :

The yield as number of fruits was recorded by counting fruit number per genotype.

3.4.6.2 Yield of nuts :

The average values of dried nut weight per fruit of each genotype and nuts per tree were used to estimate the yield of nuts per genotype.

3.4.6.3 Yield of mace :

The average values of dried mace weight per fruit of each genotype and nuts per tree were used to compute yield of mace (kg) per tree.

3.4.6.4 Yield of kernel :

The average magnitude of kernel weight per fruit of each genotype and nuts per tree were considered to estimate yield of kernel for each nutmeg genotype.

3.4.7 Propagation studies :

3.4.7.1 Seed propagation :

The germination and seedling characters of female and hermaphrodite genotypes were studied to judge the germination ability. The freshly harvested fruits were randomly selected to extract nuts (seeds) from them. 50 seeds were selected per replication for two replications. These seed nuts were sown on sand raised beds of 150 cm width and 20 cm height under shade. The seeds were sown in horizontal position, 1 cm deep on bed surface. The beds were mulched with dry grass and watered regularly. The following observations were recorded.

3.4.7.1 a) Days required for germination :

The period from sowing of seed on bed to appearance of epicotyl above seed bed was counted in days as days required for germination.

3.4.7.1 b) Germination (%) :

The number of seedlings produced from the seeds sown was counted. The percentage of the germinated seeds to the total seeds sown was taken as germination percentage.

3.4.7.1 c) Growth observations :

After germination five seedlings were randomly marked per treatment to record growth observations. These observations were recorded 90 days after germination. The average of the selected five seedlings for particular growth character was recorded. The growth observations on seedling were as follows.

3.4.7.1 d) Total height :

The height of seedling was measured with measuring scale from the root tip to shoot tip in cm.

3.4.7.1 e) Shoot height :

The shoot height of seedling of respective genotype was recorded with the help of measuring scale from the shoot tip to the attachment point of shoot to the seed in cm.

3.4.7.1 f) Collar thickness :

The thickness of the stem at the bottom of seedling near the attached seed was recorded with the help of vernier callipers in cm on the selected seedlings.

3.4.7.1 g) Total leaves :

The number of total leaves on the sampled seedlings was counted and noted.

3.4.7.1 h) Length of the leaf :

The length of second leaf was measured from petiole end to the leaf tip with the help of measuring scale in cm.

3.4.7.1 i) Breadth of leaf :

The maximum distance between the two edges of lamina of the second leaf was measured with the help of measuring scale in cm.

3.4.7.1 j) Length of leaf petiole :

The length of petiole was measured by measuring scale from the petiole end to the starting point of leaf lamina in cm.

3.4.7.1 k) Root length :

The root length of the seedlings was noted with the help of measuring scale in cm from root tip to the root attachment to nut.

3.4.7.1 l) Number of secondary roots :

The number of secondary roots on the sampled seedling under observation of respective genotypes was counted and mean was recorded.

3.4.7.2 Vegetative propagation :

To study the grafting ability of nutmeg, softwood grafting was performed by using scion sticks of nutmeg genotypes. Ten grafts were prepared per replication for two replications. The scion sticks selected were terminal having medium maturity, plageotropic with one terminal leaf retained on them. The length of scion stick was 7.5 cm with thickness of 12 to 15 mm. The selected rootstock was one year old mixed vigorous seedling of *Myristica fragrans* with 25 to 30 cm height and 40 mm thickness at the bottom.

The selected rootstocks were headed back leaving about 6 to 7 cm softwood. This softwood was split vertically into cleft from the top to a length of about 4 cm below. The scion was prepared to wedge shape of 4 cm length at its lower end. Then by inserting the scion in the cleft of the rootstock, the union was secured tightly with polythene stripe of 200 gauge thickness and 1.5 cm width. After preparation of the graft the scion portion was covered from the top upto just below the graft union with a polythene

bag. The prepared grafts were transferred under shade and watered regularly. After 28 days the polythene bag over the scion stick was removed. The shoots appearing on rootstock below the graft union was removed as and when appeared.

The following observations were recorded.

3.4.7.2 a) Period required for sprouting :

The number of days required from date of graft preparation to sprouting was counted and recorded as period required for sprouting.

3.4.7.2 b) Sprouting (%) :

The number of grafts sprouted from the total grafts prepared per treatment was counted and percentage of sprouted grafts was calculated.

3.4.7.2 c) Survival (%) :

After 90 days from the graft sprouting the number of grafts survived was recorded and the percentage of these grafts was calculated over the total grafts per treatment as survival percentage.

3.4.7.2 d) Mortality (%) :

The survival percentage of grafts was subtracted from 100 for respective treatments to obtain the mortality percentage.

3.4.7.2 e) Growth observations of graft :

The following growth observations were recorded after final survival. For this purpose three grafts per treatment were randomly selected. The average magnitude of the growth characters for the three grafts was worked out.

3.4.7.2 f) Length of new shoot :

The length of new shoot was measured in cm from the leaf axil of mature leaf to the shoot end with the help of measuring scale in cm.

3.4.7.2 g) Total leaves:

The total number of leaves on the graft was counted and means recorded.

3.4.7.2 h) Length of leaf :

The length oldest new leaf was measured in cm from petiole end to the leaf tip with the help of measuring scale.

3.4.7.2 i) Breadth of leaf :

The maximum distance between the two edges of lamina of the selected old leaf was recorded with the help of measuring scale in cm.

3.4.7.2 j) Length of leaf petiole :

The length of leaf petiole on the selected old leaf was recorded from the petiole end to the starting point of leaf lamina in cm by measuring scale.

3.5 Statistical analysis and interpretation of data :

For quantitative estimation of variation in different characters of growth and yield the concepts of analysis of variance were employed. The experimental trees had only one replication however, the repetition of observations over time or lots of the specimen or different directions or different parts of the characters like branches, leaves, flowers, fruits, seeds etc. could be employed as replicated measurements for achieving the object of precision of the measurement. In perennial horticultural crops, it is difficult to apply the standard principles of experimental designs (Ramachander and Prasada Rao, 1986) however, the flexibility in using these principles for logical interpretation of data has been proposed by some workers [Muthulakshmi (1998), Jyothy (2000)]. On this background the ANOVA for the characters namely flowering, fruit characters, germination and grafting was carried out by taking multiple measurements over lots of adequate size. Randomized Block Design was used (Panse and Sukhatme, 1995). The details of ANOVA employed are as below.

ANOVA

Source	d. f.	M. S.	Expected M. S.
Replications	(r-1)	RMS	$\sigma n^2 + g \sigma^2 r$
Genotypes	(g-1)	GMS	$\sigma^2 e + r \sigma^2 g$
Error	(r-1) (g-1)	EMS	$\sigma^2 e$

Where,

r = Number of replications

g = Number of genotypes

MS = Mean squares

The genotype mean square (GMS) was tested against error mean sum of square by 'F' test for $n_1 = (g-1)$ and $n_2 = (r-1) (g-1)$ degrees of freedom.

3.5.1 Estimation of standard error, standard error of difference and critical difference :

- Standard error of mean (SEM) = $\sqrt{\frac{\sigma^2 e}{r}}$
- Standard error of difference between two means was calculated as S.E. of difference of means (SED) = SEM x $\sqrt{2}$
- The critical difference between any two means was calculated as :
C.D. = 't' error d.f. x SED.

3.5.2 Regression analysis :

Fitting a mathematical function to a set of data and analysis of fitted functions in statistical parlance is usually called as regressions. There are two broad categories of regression i) linear and ii) non-linear. Linear indicates the dependence of one factor over other independent factors. Causton and Venus (1981) have proposed the scope for use of regression models for deciding relationship between plant parts so as to develop a biologically meaningful mathematical model which can serve the purpose of explaining the functioning of whole plant. In linear regression theory the principles of maximum likelihood estimation and least square estimation are usually employed.

The functional form of linear relationship between dependent variable Y and independent variable X is represented by the equation

$$Y = a + \beta X$$

Where a = Intercept of line on Y axis

β the linear regression coefficient, is the slope of line or amount of change in Y for each unit change in X.

3.5.2.1 Multiple linear regression :

The simple linear regression is applicable only to the cases with one independent variable however there is an interdependence between the factors of production and hence for assessing the dependence of one particular factor on more than one independent variable the concept of multiple regression analysis is used. A multiple linear regression of the dependent variable Y on the independent variable $X_1, X_2, \dots, X_K$ is expressed as

$$Y = a + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k$$

The variable Y, X_1 , X_2 , X_K have to be measured simultaneously for each of the n units of observations. The validity of the model is tested by computing a significance of X value and the magnitude of coefficient of determination (R^2). It is preferable to have significant 'f' and R^2 more than 0.80.

This kind of regression analysis was done in current investigation by using the method outlined by Gomez and Gomez (1976). These concepts were principally utilized for developing the plant architecture model and the model for prediction of leaf area.

3.5.3 Polynomial Functions :

In a polynomial function the dependent variate is expressed as a function of two or more terms. The title is particularly applied to expressions involving sum of independent terms which are each different powers of the same primary variables (Hunt, 1982). If we have a variety y which is dependent upon another variate x which is independent then the

simplest case of regression of y on x is given by a linear equation $Y = a + bx$. Here Y is the value one would expect to obtain corresponding to any given x on the basis of observed linear relation in this equation. The two components 'a' and 'b' are so chosen that the quantity $\Sigma (y - Y)^2$ is minimum. This is known as the principle of least squares (Panse and Sukhatme, 1995). In this quantity y stands for the observed value of the dependent variate. Y for the value obtained by substituting in the equation the corresponding x value. This quantity therefore represents the sum of squares of deviations of observed values of y from those predicted from the regression equation and forms the residual variation after the regression line is fitted to the data. The regression equation is thus the relation between y and x which minimizes the residual variation in y . The calculation of 'a' and 'b' can be done by following formulae :

$$a = \bar{y} - b\bar{x}$$

and

$$b = \frac{\Sigma(y - \bar{y})(x - \bar{x})}{\Sigma(x - \bar{x})^2}$$

The quantity $\Sigma(y - \bar{y})(x - \bar{x})$ which is obviously sum of products of deviations of x and y from the respective means can also be expressed as :

$$\Sigma(y - \bar{y})(x - \bar{x}) = \Sigma y(x - \bar{x}) = \Sigma x(y - \bar{y})$$

The relation of y to x frequently may be better represented by lines of higher order. The equation may be quadratic eg. $Y = a + b_1X + b_2 X^2$ or cubic equation e.g. $Y = a + b_1X + b_2 X^2 + b_3 X^3$ or indeed any power of X i.e. $Y = a + b_1X + b_2 X^2 + b_3 X^3 + \dots$. The coefficient $a, b_1, b_2, b_3 \dots$ in the polynomial regression equation are established by minimising the quantity $(y - Y)^2$ representing the residual variation. This leads to the following normal equation.

$$\begin{aligned} (n)a + (\Sigma x)b_1 + (\Sigma x^2)b_2 + \dots &= \Sigma y \\ (\Sigma x)a + (\Sigma x^2)b_1 + (\Sigma x^3)b_2 + \dots &= \Sigma xy \\ (\Sigma x^2)a + (\Sigma x^3)b_1 + (\Sigma x^4)b_2 + \dots &= \Sigma x^2y \end{aligned}$$

Here we know the values of n , x and y . Hence, the calculations of these equations lead to estimation of polynomial constants viz. a , b_1 , b_2 , b_3 etc. The calculations can be done more conveniently either by following a systematic procedure by short cut method outlined by Little and Hills (1978), or by using orthogonal polynomials given by Fisher and Yates (1963). In present investigation the constants of polynomial were worked out on a programmable, calculator Casio PB 700.

A measure of usefulness of the polynomial fitted is given by the estimate of R^2 which is ratio of sum of squares due to regression to the total sum of squares. The central objective in fitting polynomial is to discover the simplest polynomial which accounts for a specified high proportion of the total variation in y . In present investigation the level of R^2 is fixed as 0.80 and fitting is done in such a way that lowest possible degree of polynomial is obtained with $R^2 > 0.80$. Polynomial functions were fitted to the data on fruit development during 1999-2000.

3.5.4 Genetic variability :

For assessing the variability in population due to the components viz. genotypic, phenotypic and environmental factors the biometrical analysis was done as per the methods given by Singh and Chaudhari (1995).

3.5.4.1 Estimation of components of variation :

The phenotypic, genotypic and environmental variance were calculated as :

$$\text{a) Environmental variance} = \sigma^2_e = \text{EMS}$$

$$\text{b) Genotypic variance} = \sigma^2_g = \frac{\text{GMS} - \text{EMS}}{r}$$

$$\text{c) Phenotypic variance} = \sigma^2_p = \sigma^2_g + \sigma^2_e$$

where,

G.M.S. = Genotypic mean sum of squares

E.M.S. – Error man sum of squares

r = Number of replications

3.5.4.2 Estimation of coefficient of variance :

The phenotypic and genotypic coefficient of variation were calculated by the formulae given by Burton and Devane (1953).

a) Phenotypic coefficient of variation (PCV)

$$P.C.V. = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

Where,

σ^2_p = Phenotypic variation

$\bar{X}$ = Mean of the character

b) Genotypic coefficient of variation :

$$G.C.V. = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

Where,

σ^2_g = Genotypic variation

$\bar{X}$ = Mean of the characters

3.5.4.3 Estimation of Heritability (H) :

Heritability in broad sense was estimated for various characters by the formulae suggested by Lush (1949) and Hanson *et al.* (1956).

$$H = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.5.4.4 Estimation of genetic advance (G.A.)

The genetic advance was calculated in per cent by the formula suggested by Johnson *et al.* (1955).

$$a) GA = \frac{\sigma^2_g}{\sigma^2_p} \times \sigma_p \times K$$

$$b) GA \text{ as percentage of mean (GAM)} = \frac{GA}{\bar{X}} \times 100$$

Where,

σ^2_p = Phenotypic variance

σ^2_g = Genotypic variance

σ_p = Phenotypic standard deviation

K = Selection differential at 5 per cent selection intensity (2.06)

X = Mean of the character

3.5.5 Correlation coefficient :

Analysis of co variance was carried out by taking two characters at a time. Plot error was used as environmental co-variance. Thus, phenotypic and genotypic co-variance were derived as detailed below.

Source	d. f.	Mean products
Replications	(r-1)	-
Varieties	(v-1)	GMP
Error	(r-1) (v-1)	EMP
Total	(rv-1)	-

Where,

r = number of replications.

v = number of varieties

GMP = Genotypes sum of products

EMP = Error sum of products.

The genotypic and phenotypic co-variances were worked out as per formulae given by Singh and Chaudhary (1995).

Environmental co-variance = (VOVe 1.2) = EMP

Genotypic co-variance (COVg 1.2) = $\frac{\text{GMP} - \text{EMP}}{r}$

Phenotypic co-variance (COVp 1.2) = (COVe 1.2) + (COVg 1.2)

The appropriate variances and co-variances were used for calculating phenotypic and genotypic correlation coefficient (Johnson *et al.* 1955).

Phenotypic correlation coefficients were derived as :

$$r_{pl.2} = \frac{\text{COVpl.2}}{\sqrt{(\sigma^2_{pl}) (\sigma^2_{p2})}}$$

Where,

$rp_{1.2}$ = Phenotypic correlation between characters 1 and 2.

$COVp_{1.2}$ = Phenotypic covariance between characters 1 and 2 respectively.

σ^2p_1 & σ^2p_2 = Phenotypic variance of characters 1 and 2 respectively.

Genotypic correlation coefficients were obtained by the formula

$$rg_{1.2} = \frac{COVg_{1.2}}{\sqrt{(\sigma^2g_1)(\sigma^2g_2)}}$$

$rg_{1.2}$ = Genotypic correlation between characters 1 and 2

$COVg_{1.2}$ = Genotypic co-variances between characters 1 and 2, respectively.

σ^2g_1 and σ^2g_2 = Genotypic variance of characters 1 and 2, respectively.

The significance of phenotypic and genotypic correlation coefficients was tested against 'r' values given by Fishers Table at (g-2) degree of freedom, respectively at $p = 0.05$ and $p = 0.01$ to test their significance.

The significance of phenotypic and genotypic correlation coefficients can also be tested by using 't' test.

$$t = r \sqrt{\frac{n-2}{1-r^2}}$$

Where,

r = Correlation coefficients

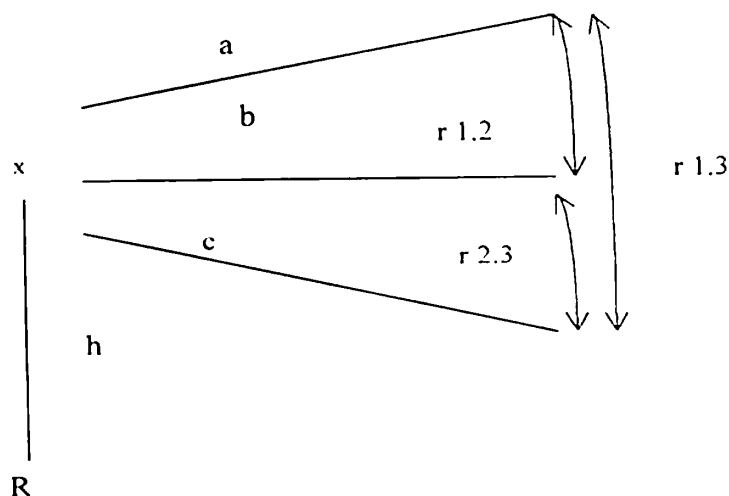
n = Total number of coefficients

The calculated 't' value is tested with table 't' value for respective (n-2) degrees of freedom for significance.

3.5.6 Path coefficient analysis :

To establish a cause and effect relationship, the genotypic and phenotypic correlation coefficients were partitioned in direct and indirect effects by path analysis as suggested by Dewey and Lu (1959). The first

step in path analysis is to prepare a path diagram based on cause and effect relationship.



The concept behind this is that yield is the function of various components like X_1 , X_2 , X_3 then components show following genotype of association with one another.

From the figure, it is obvious that yield is the result of X_1 , X_2 and X_3 and some other undefined factors designated by 'R'. The double arrowed lines indicates mutual association as measured by correlation coefficients and the single arrowed line represent direct influence as measured by path coefficients p_{ij} .

Path coefficients were obtained by solving a set of simultaneous equations of the form :

$$r_{ny} = P_{ny} + r_{n2} P_y + r_{n3} + \dots$$

Where,

r_{ny} = represented correlation between one component and yield

P_{ny} = represent path coefficient between character and the yield.

r_{n2} = represented correlation between that character and each of the other yield components in turn.

$$\begin{array}{cc}
 \text{Matrix A} & \text{Matrix B} \\
 \left(\begin{array}{c} r_{1y} \\ r_{2y} \\ \vdots \\ r_n \end{array} \right) & \left(\begin{array}{ccccccc} 1 & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & 1 & r_{23} & \dots & r_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \dots & 1 \end{array} \right)
 \end{array}$$

Where,

$r_{12} = r_{21}$ and so on and,

r_{1y} = correlation between one component character and yield.

The B-Matrix was inverted (B^{-1}) and path coefficients were obtained as : $(P_{ij}) = a \times (B^{-1})$

The indirect effect of a particular character through other characters was obtained by multiplication of direct path and particular correlation coefficients between the characters separately.

$$\text{Indirect effects} = r_{ij} \times P_{ij}$$

Where,

$$i = 1 \text{ to } 6$$

$$j = 1 \text{ to } 6$$

$$P_{ij} = P_{1y1}, P_{2y2}, \dots, P_{ny}$$

The residual factor i.e. variation in yield unaccounted for by these association was calculated from the following formula :

$$\text{Residual effect (X)} = 1 - R^2$$

Where,

$$R^2 = P_{1y}r_{1y} + P_{2y}r_{2y} + P_{3y}r_{3y} + \dots + P_{ny}r_{ny}$$

Where,

$$P_{1y}, P_{2y}, \dots, P_{ny} = \text{path values}$$

$$r_{1y}, r_{2y}, \dots, r_{ny} = \text{correlation coefficient}$$

The path coefficient analysis was performed for fruit characters.

3.5.7 Repeatability :

Lush (1937) proposed the concept of repeatability for assessing the performance of individuals over time (Jain, 1982). This concept was however principally used for assessing the lactation yield in dairy cows, fleece characteristics in sheep or egg production in poultry. In such cases the repeated records of the same individual over a time are available. In statistical terminology the repeatability signifies the intraclass correlation usually among the repeated expressions of a given trait of same individual. As such, it is a fraction of total variance among individual records due to permanent differences among individual, both genetic and environmental and $1-r$ is the fraction of variance caused by temporary circumstances, which vary from one record to another record of same individual. This concept is mostly applied in animal genetics. The perennial fruit crops also exhibit the repeated yields and hence there is a scope for assessing the individual trees for their performance over a long period. When more than one measurement of the characters like fruit yield are made on tree then the repeatability of the character is expressed as

$$r = \frac{\sigma^2G + \sigma^2EP}{\sigma^2p}$$

Where,

σ^2G = Genotypic variation

σ^2Ep = Variation due to environmental factors of nonvarying nature

σ^2p = The total phenotypic variation.

The repeatability, thus, represents the proportion of variance among individuals due to permanent differences, both genetic and environmental. The repeatability for number of nuts, nut yield (kg/tree) was estimated according to method given by Prem Narain *et al.* (1979). The yield records were subjected to Sanders conversion factor before estimating the repeatability.

3.5.8 Mahalanobis's generalized distance D^2 :

Mahalanobis (1936) D^2 – statistic was used for assessing the genetic divergence between populations. The generalized distance between any two population is defined as –

$$PD = \sqrt{\sum_{i=1}^p \sum_{j=1}^p \lambda_{ij} \delta_i \delta_j}$$

Where, λ_{ij} is the inverse of estimated variance, covariance matrix and δ_i and δ_j are the difference between the mean value of the two populations for i^{th} and j^{th} character and p is the number of characters available. This quantity is estimated by the D^2 statistic as,

$$D^2 = \sum_{i=1}^p \sum_{j=1}^p (\delta_{ij}) d_i d_j$$

Where, δ_{ij} is the sample estimate of λ_{ij} , d_i of δ_i and d_j of δ_j . Since the formula for computation requires the inversion of the matrix. Transformation of the original correlated, unstandardized characters means to standardized uncorrelated variable was done to simplify the computation procedure. This transformation was effected by pivotal condensation method (Rao, 1952). All the above computations were carried out for fruit characters of 34 genotypes under study on computer unit installed at Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

3.5.8.1 Testing the significance of D^2 values :

The D^2 values obtained for pair of population was taken as the calculated value of ' χ^2 ' and was tested against the tabulated value of ' χ^2 ' for ' p ' degrees of freedom, where p was the number of characters studied.

3.5.8.2 Determination of cluster constellations :

Usually a cluster is defined a group of populations such that any two populations belonging to the same cluster should on the average, show a smaller D^2 than those belonging to two different clusters. A simple device suggested by Tocher (Rao, 1952) was to start two closely associated

genotypes and find a third genotype which had the smallest D^2 from the first two. Similarly, fourth as chosen to have the smallest average D^2 from the first three and so on. If at any stage of D^2 of a genotype from those already listed appeared to be high, then this genotype did not fit with the former genotypes and was, therefore, taken to be outside the former group. The genotypes of the first group were then omitted and rest were treated in a similar way.

The cluster constellations were worked out for 34 genotypes individually. After the formation of clusters, inter and intra cluster distance were calculated. The square root of the average D square values obtained from above, represented the distance between and within clusters.

EXPERIMENTAL RESULTS



CHAPTER IV

EXPERIMENTAL RESULTS

A research project entitled “Phenological studies in nutmeg” was undertaken during the period January 1999 to December 2000 at the Regional Coconut Research Station, Ratnagiri. The 39 seedling genotypes of nutmeg planted in 1979 constituted the experimental material. The observations on occurrence of vegetative shoot and floral buds, plant architectural characters, foliage development and their relevance with variation in nut yield, fruit development, fruit yield and regeneration ability of the genotypes was assessed during the course of investigation. An attempt was made to assess the nature and extent of variability in growth and yield characters and which was used to group the genotypes into different clusters based on D^2 statistics. The concept of path coefficient analysis and repeatability was used to understand the cause and effect relationship for deciding the promising nutmeg genotypes. The results of the investigation are presented in this chapter.

4.1. Phenological studies :

4.1.1. Shoot growth :

The appearance of terminal tender shoot has a direct relevance with the yield performance of nutmeg tree. The data on the time of appearance of 34 nutmeg genotypes are given in Table 1. For this purpose it was planned to tag ten sprouting buds from January on each of the nutmeg genotype under study. Such bud sprouts were available from 1st fortnight of January onwards and continued up to second fortnight of February. Hence January-February could be regarded as period of first flush appearance in nutmeg in a calendar year. A critical perusal of data revealed that genotypes N1, N5, N23, N24, N26, N51, N56, N63 and N70 could exhibit almost all ten buds sprout in the first fortnight of January whereas in nutmeg genotypes N22, N27, N29, N55 and N15 the bud sprouts could be noticed in first fortnight of February. The nutmeg genotype N36 exhibited bud sprouts in the later period i.e. second fortnight of February of the

reference period. However, majority of the genotypes exhibited first vegetative flush during first and second fortnight of January.

Table 1. Period of emergence of new shoot, flowering initiation and fruit set in nutmeg genotypes

Genotype	Emergence of new shoot	Flowering initiation	Fruit set
N1	January (I), June (I)	May (II), August (I), July (I), September (I)	July (II), September (II)
N4	January (II), June (I)	May (II), June (I), July (I), October (I)	September (I)
N7	January (II) May (II), November (I)	May (II), June (I), July (I), September (I)	September (II), October (II)
N5	January (I), May (II), December (I)	June (I), July (II)	June (II)
N11	January (II), June (II)	May (II), June (I), July (I), September (I)	September (II), October (II)
N22	February (I), June (I)	June (I), October (I), November (I)	October (II)
N23	January (I), May (II)	May (II), September (I)	September (II)
N24	January (I), May (II)	May (II), June (I), September (I)	September (II), October (II)
N26	January (I), May (II)	May (II), June (I)	June (II)
N27	February (I), May (II)	May (II), June (I)	June (II)
N29	February (I), June (I), December (I)	May (II), June (I), September (I), November (I)	September (II)
N30	January (II), May (II)	June (I), July (II)	June (II)
N32	January (II), May (II)	May (II), June (I), September (II)	September (II)
N33	January (II), June (I)	May (II), August (I), September (I)	September (II)
N36	February (II), June (II)	May (II), June (I), September (I), October (I)	October (II)
N37	January (II), June (I), November (I)	August (I), July (II), September (I), December (I)	October (II)
N38	January (II), June (I)	May (II), June (I), July (II), September (I), October (I)	October (II)
N41	January (II), June (I)	May (II), June (I), October (I), November (I)	October (II)

Table 1 continued ...

Genotype	Emergence of new shoot	Flowering initiation	Fruit set
N42	January (II), June (I)	June (I)	June (II)
N43	January (II) June (I) November (I)	June (I)	June (II)
N46	January (II) May (II)	May (II), June (I), September (I)	September (II)
N49	January (II) May (II) December (I)	May (II), June (I), September (I) October (I)	September (II)
N51	January (I) June (II)	June (I), July (II)	June (II)
N55	February (I) May (II)	May (II), June (I), September (II), October (I) November (I)	October (II)
N56	January (I) June (I)	May (II), June (I), September (I), October (I), November (I)	October (II)
N63	January (I), May (II)	May (II), June (I), October (I) December (I)	October (II)
N66	January (II) May (II) December (I)	May (II), June (I)	June (II)
N70	January (I), June (I), December (I)	August (II), December (I)	August (II)
N72	January (II) May (II) December (I)	June (I), July (II)	June (II)
N74	January (II), June (I)	June (I), July (II)	June (II)
N15	February (I), May (II)	May (II), June (I), July (II), September (I), October (I), November (I)	-
N53	January (II) May (II)	May (II), June (I), September (I) October (I)	-
N60	January (II), June (II)	June (I), September (I)	-
I - First fortnight		II - Second fortnight	

These shoots continued growing and produced leaves as well as flowers and fruits in the subsequent period. In general the elongation of first shoot completed within the period from 30 to 90 days from its appearance and the leaves became dark and thick. The shoots remained in the quiescent state for a period of 60 to 90 days. At about 150 to 180 days from tagging the mature shoots exhibited production of new shoot

primordia at apex and simultaneously a floral bud appeared in the axil of the basal mature leaves. The period of the maturity phases of first shoot quiescent state (lag phase), appearance of new vegetative shoot and floral primordia varied among the genotypes under study. Majority of the genotypes showed a span of 60 days for cessation of elongation in first shoot followed by 90 days for lag period and 150 days for occurrence of flowering on basal leaves. However, the genotypes N36 and N72 showed shorter span of lag period (30 days). The genotype N36 had the shortest period for occurrence of flowering on basal leaves (90 days) followed by N27, N29, N55 and N15 (105 days). The longest period for initiation of flowering was observed in N70 (225 days) followed by N37 (210 days).

The new vegetative primordia developed into younger shoots which elongated for a period of 90 to 150 days and remained in quiescent stage for 60 to 90 days and produced new growth thereafter.

The flowering was recorded on the developing shoot from second fortnight of May. In the genotypes N5, N30, N42, N43, N51, N72, N74 it was observed only once. The developing shoots of N38, N55, N56, N15 produced flowers for five times. The earlier borne flowers exhibited fruitset in a period of about 20 days of flowering. The fruitset was observed from June to October.

The variation in the length of terminal shoots in nutmeg genotypes is given in Table 2. The mean shoot length produced by all the nutmeg genotypes was 11.78 cm. It was maximum in N56 (19.75 cm) followed by N5 (19.45 cm) and N53 (19.14 cm) whereas it was minimum in N32 (5.38 cm).

The variation in number of leaves produced on terminal shoots are presented in Table 3. The average leaves produced on a nutmeg shoot during a period of one year was 7.38. N72 (12.0) recorded maximum number of leaves followed by N55 (10.6) and N56 (10.5). The lowest leaves were noticed in N23 (3.5). From 150 to 270 days of bud appearance the leaf production was maximum (3.87).

Table 2. Temporal variation in the length of terminal shoots (cm) in nutmeg genotypes.

Geno- type	Days after bud appearance														Mean	SD	CV
	30	60	90	120	150	180	210	240	270	300	330	360					
N1	2.6	2.6	2.6	2.6	2.6	6.0	6.66	7.99	8.62	8.62	8.62	8.62	5.68	2.71	47.81		
N4	4.68	5.96	5.96	5.96	5.96	10.13	11.44	13.32	17.05	17.72	17.72	17.72	11.44	5.16	46.36		
N7	3.06	3.94	3.94	3.94	3.94	6.43	8.02	8.77	8.77	8.77	8.77	8.77	6.43	2.35	36.51		
N5	6.10	6.93	7.04	7.04	7.04	7.04	10.15	11.64	18.9	19.45	19.45	19.45	11.69	5.59	47.86		
N11	2.59	3.59	3.59	3.59	3.59	4.93	6.19	7.17	7.17	7.17	7.17	7.17	5.33	1.77	33.16		
N22	3.84	4.30	4.30	4.30	4.30	6.43	10.20	15.17	15.17	15.17	15.17	15.17	9.46	5.09	53.80		
N23	2.52	3.63	4.34	4.34	4.34	5.55	7.13	7.95	7.95	7.95	7.95	7.95	5.97	1.97	32.98		
N24	3.07	3.42	3.49	3.49	3.49	4.98	9.02	9.02	9.65	9.65	9.65	9.65	6.55	2.93	44.76		
N26	3.12	4.32	4.32	4.32	4.32	5.83	9.05	11.35	11.78	11.78	11.78	11.78	7.81	3.56	45.52		
N27	3.77	3.77	3.77	3.77	3.24	4.24	4.84	4.84	4.84	5.43	5.43	5.43	4.45	0.74	16.79		
N29	4.56	4.56	4.56	4.56	7.38	8.73	10.43	12.6	12.6	12.6	12.6	13.85	9.09	3.83	40.05		
N30	2.63	3.64	3.64	3.64	3.64	4.65	6.01	6.66	6.66	6.66	6.66	6.66	5.09	1.52	29.81		
N32	2.14	2.80	2.80	2.80	2.80	3.91	4.81	5.38	5.38	5.38	5.38	5.38	4.08	1.27	31.11		
N33	3.52	3.95	3.95	3.95	3.95	6.28	8.61	10.31	10.31	10.31	10.31	12.51	7.33	3.23	44.09		
N36	3.68	3.68	3.68	4.43	5.01	5.75	5.75	10.21	10.28	10.28	10.28	10.28	6.94	2.89	41.59		
N37	2.94	3.82	3.82	3.82	3.82	6.36	8.05	9.17	9.17	9.17	12.8	13.12	7.17	3.46	48.16		
N38	5.11	5.15	5.15	5.15	5.15	8.63	10.32	11.32	11.32	11.32	11.32	14.81	8.73	3.30	37.81		
N41	2.7	4.18	4.18	4.18	4.18	4.58	7.14	8.03	8.03	8.03	8.03	10.19	6.12	2.26	36.93		
N42	5.34	5.34	5.34	5.34	5.96	7.13	8.29	9.33	13.16	14.49	14.49	14.49	9.06	3.81	42.11		

Table 2 continued.....

Geno- type	Days after bud appearance												Mean	SD	CV
	30	60	90	120	150	180	210	240	270	300	330	360			
N43	3.37	4.35	4.35	4.35	4.35	6.23	8.39	9.29	9.29	9.29	9.29	9.29	6.82	2.41	35.32
N46	4.75	4.89	4.89	4.89	4.89	6.40	8.50	9.65	13.95	13.95	13.95	13.95	8.72	3.98	45.64
N49	3.02	3.74	3.74	3.74	3.74	5.61	6.73	7.15	7.15	7.15	7.15	10.20	5.76	2.09	36.22
N51	2.51	4.1	4.1	4.1	4.1	5.19	6.48	7.16	7.16	7.16	7.16	7.16	5.53	1.62	29.34
N55	3.72	3.77	3.77	3.77	3.77	6.43	10.28	13.47	14.25	14.25	14.25	14.25	8.83	4.79	54.25
N56	3.44	5.01	6.59	6.59	6.59	8.20	10.22	12.08	19.75	19.75	19.75	19.75	11.48	6.22	54.21
N60	3.18	5.32	6.43	6.43	6.43	6.43	8.44	11.2	11.2	11.2	11.2	11.2	8.22	2.75	33.51
N66	5.29	5.79	6.0	6.0	6.0	6.0	8.43	11.68	11.68	11.68	11.68	14.78	8.75	3.19	36.40
N15	2.04	2.84	3.38	3.38	3.38	5.94	6.93	13.3	13.3	13.3	13.3	15.9	8.08	5.05	62.50
N53	2.39	5.34	5.34	5.34	6.03	7.23	7.46	11.3	16.39	19.14	19.14	19.14	10.13	6.23	61.59
N63	4.4	5.8	5.8	5.8	5.8	7.97	10.52	11.58	16.7	16.7	16.7	16.7	10.37	4.88	47.12
N74	3.36	4.50	4.75	4.75	4.75	5.85	8.40	9.60	9.60	9.60	9.60	9.60	7.03	2.45	34.78
N72	4.55	5.52	5.52	5.52	5.52	7.22	8.89	9.71	9.71	9.71	9.71	13.7	7.94	2.61	32.93
N70	2.58	3.46	3.46	3.46	3.46	4.92	6.2	7.0	7.0	7.0	7.0	10.1	5.47	2.16	39.54
Range	2.04	2.80	2.80	2.80	2.80	3.91	4.81	4.84	4.84	5.38	5.38	5.38			
	to	to	to	to	to	to	to	to	to	to	to	to			
	6.10	6.93	7.04	7.04	7.38	10.13	11.44	13.47	19.75	19.75	19.75	19.75			
Mean	3.51	4.36	4.50	4.50	4.59	6.28	8.24	9.62	10.85	11.21	10.71	11.78			
SD	1.03	0.99	1.09	1.09	1.27	1.35	1.62	2.48	4.32	4.01	3.86	4.09			
CV	29.33	22.71	24.12	24.35	27.69	21.46	19.65	25.81	39.87	35.81	36.02	34.75			

Table 3. Temporal variation in the number of leaves on developing new shoots in nutmeg genotypes.

Geno- type	Days after bud appearance												Mean	SD	CV
	30	60	90	120	150	180	210	240	270	300	330	360			
N1	2	2	2	2	2	4	4.54	4.54	4.67	4.67	4.67	4.67	3.48	1.26	36.32
N4	2.9	2.9	2.9	2.9	2.9	6.0	6.0	6.2	8.13	8.13	8.13	8.13	5.44	2.28	41.96
N7	1.8	1.8	1.8	1.8	1.8	4.1	4.5	4.9	4.9	4.9	4.9	4.9	3.50	1.46	41.64
N5	3	3	3.1	3.1	3.1	3.1	5.9	5.9	8.9	9.2	9.2	9.2	5.56	2.71	48.84
N11	1.9	1.9	1.9	1.9	1.9	1.9	3.3	4.1	4.5	4.5	4.5	4.5	3.07	1.21	39.39
N22	2.5	2.5	2.5	2.5	2.5	3.5	5.0	7.5	7.5	7.5	7.5	7.5	4.88	2.32	47.58
N23	1.4	1.5	1.8	1.8	1.8	2.7	3.2	3.5	3.5	3.5	3.5	3.5	2.64	0.86	32.73
N24	2.1	2.1	2.1	2.1	2.1	2.1	3	5.3	6.0	6.0	6.0	6.0	3.74	1.82	48.52
N26	2.2	2.3	2.3	2.3	2.3	3.4	4.8	6.1	6.8	6.8	6.8	6.8	4.41	2.03	46.10
N27	1.9	1.9	1.9	1.9	2.6	3.0	3.3	3.3	3.3	4.0	4.0	4.0	2.93	0.83	28.27
N29	1.9	1.9	1.9	1.9	3.0	3.9	4.3	7.0	7.0	7.0	7.0	9.0	4.65	2.49	53.65
N30	1.8	1.8	1.8	1.8	1.8	2.9	3.4	3.8	3.8	7.0	7.0	7.0	3.66	2.07	56.60
N32	2.3	2.4	2.4	2.4	2.4	3.3	4.2	4.5	4.5	4.5	4.5	4.5	3.49	0.99	28.41
N33	2.3	2.3	2.3	2.3	2.3	4.2	5.4	5.6	5.6	5.6	5.6	7.6	4.26	1.80	42.25
N36	1.8	1.8	1.8	2.7	3.7	4.0	4.0	6.7	6.7	6.7	6.7	6.7	4.44	2.05	46.14
N37	2.1	2.2	2.2	2.2	2.2	3.8	4.7	5.4	8.0	8.0	9.0	9.0	4.90	2.76	56.30
N38	2.7	2.7	2.7	2.7	2.7	5.5	6.4	6.4	6.4	6.4	6.4	8.4	4.95	2.00	40.42
N41	2.0	2.0	2.0	2.0	2.0	3.0	4.3	4.4	7.0	7.0	7.0	9.0	4.30	2.45	56.90
N42	2.7	2.7	2.7	2.7	3.6	4.3	5.2	5.7	7.8	7.9	7.9	7.9	5.09	2.18	42.85

Table 3 continued.....

Table 3 continued.....															
Geno- types	Days after bud appearance												Mean	SD	CV
	30	60	90	120	150	180	210	240	270	300	330	360			
N43	2.8	2.8	2.8	2.8	2.8	3.9	4.6	5.3	5.3	5.3	5.3	5.3	4.08	1.15	28.22
N46	2.6	2.6	2.6	2.6	2.6	3.9	5.1	5.9	5.9	5.9	5.9	5.9	4.29	1.53	35.62
N49	2.1	2.3	2.3	2.3	2.3	3.5	4.4	4.7	4.7	4.7	4.7	6.7	3.73	1.41	37.90
N51	1.7	3.1	3.1	3.1	3.1	4.2	4.8	5.4	5.4	5.4	5.4	5.4	4.18	1.25	29.85
N55	2.1	2.4	2.4	2.4	2.4	4.6	7.3	10.6	10.6	10.6	10.6	10.6	6.38	3.82	59.78
N56	2.3	2.8	3.9	3.9	3.9	4.8	6.1	7.4	10.5	10.5	10.5	10.5	6.43	3.15	49.10
N60	2.7	2.7	3.5	3.5	3.5	3.5	5.1	6.2	7.0	7.0	7.0	7.0	4.89	1.75	35.84
N66	3.1	3.4	3.5	3.5	3.5	3.5	4.8	6.5	6.5	6.5	6.5	8.5	4.98	1.74	34.98
N15	1.0	2.1	2.1	2.1	2.1	3.8	4.0	6.9	8.7	9.0	9.0	10.0	5.07	3.24	64.04
N53	2.7	3.1	3.1	3.1	4.3	4.9	5.7	6.5	9.8	9.8	9.8	9.8	6.05	2.86	47.31
N63	3.0	3.0	3.0	3.0	3.0	4.5	5.5	5.7	8.0	8.5	8.5	8.5	5.35	2.33	43.59
N74	2.0	2.6	4.3	4.3	4.3	4.3	6.5	8.0	8.0	8.0	8.0	8.0	5.69	2.20	38.70
N72	3.1	3.7	3.7	3.7	5.2	6.2	6.8	9.0	10.0	10.0	10.0	12.0	6.95	3.0	43.12
N70	1.9	1.9	1.9	1.9	1.9	3.2	4.6	5.0	5.0	5.0	5.0	7.0	3.69	1.71	46.20
Range	1.4 to 3.1	1.5 to 3.7	1.8 to 4.3	1.8 to 4.3	1.8 to 5.2	1.9 to 6.2	3.0 to 7.3	3.3 to 10.6	3.3 to 10.6	3.5 to 10.6	3.5 to 10.6	3.5 to 12.0			
Mean	2.25	2.62	2.58	2.58	2.76	3.85	4.87	5.88	6.71	6.83	6.86	7.38			
SD	0.51	0.08	0.67	0.65	0.83	0.92	1.05	1.52	1.96	1.91	1.93	2.07			
CV	22.54	41.10	25.98	25.31	29.84	23.82	21.66	25.79	29.19	27.88	28.14	27.99			



Plate 5. One year old shoot in nutmeg genotypes N1, N30 and N51



Plate 6. Flowering habit in female (N10), hermaphrodite (N61) and male (N69) genotypes

4.2 Plant architecture :

The growth attributes like height, spread, number of branches, crown volume, girth of stem etc. are the important determinants of the plant architecture in nutmeg. The data on such growth attributes of the 34 genotypes are given in Table 4 and illustrated with Fig. 1. It is evident that the 20 year old female and hermaphrodite nutmeg plants had on an average 7.87 m height with 4.30 m spread. An average plants produced 34 crotches, 119 primary branches, 2932 secondary branches and 18576 tertiary branches. The tree had crown with an average volume of 42.19 m³ having a crown surface of 72.50 m². The mean girth of the trunk at the base was 45.5 cm. It could be noted that there was great amount of variation for all these characters in the population under study. Among these characters crown volume showed the largest variation (53.49%) followed by secondary branches (38.60%), tertiary branches (37.36%) and crown surface (35.64%). The variation for number of crotches (17.26%), girth of the trunk (14.33%) and spread (22.77%) was relatively less. The smallest magnitude of coefficient of variation was noticed for plant height (14.27%). For yield in terms of number of fruits per tree for 6 years the magnitude of variation was maximum (64.68%). The variation for all the characters except yield was significant.

Table 4. Yield (no. of fruits/tree) and related plant architecture components of female and hermaphrodite nutmeg genotypes

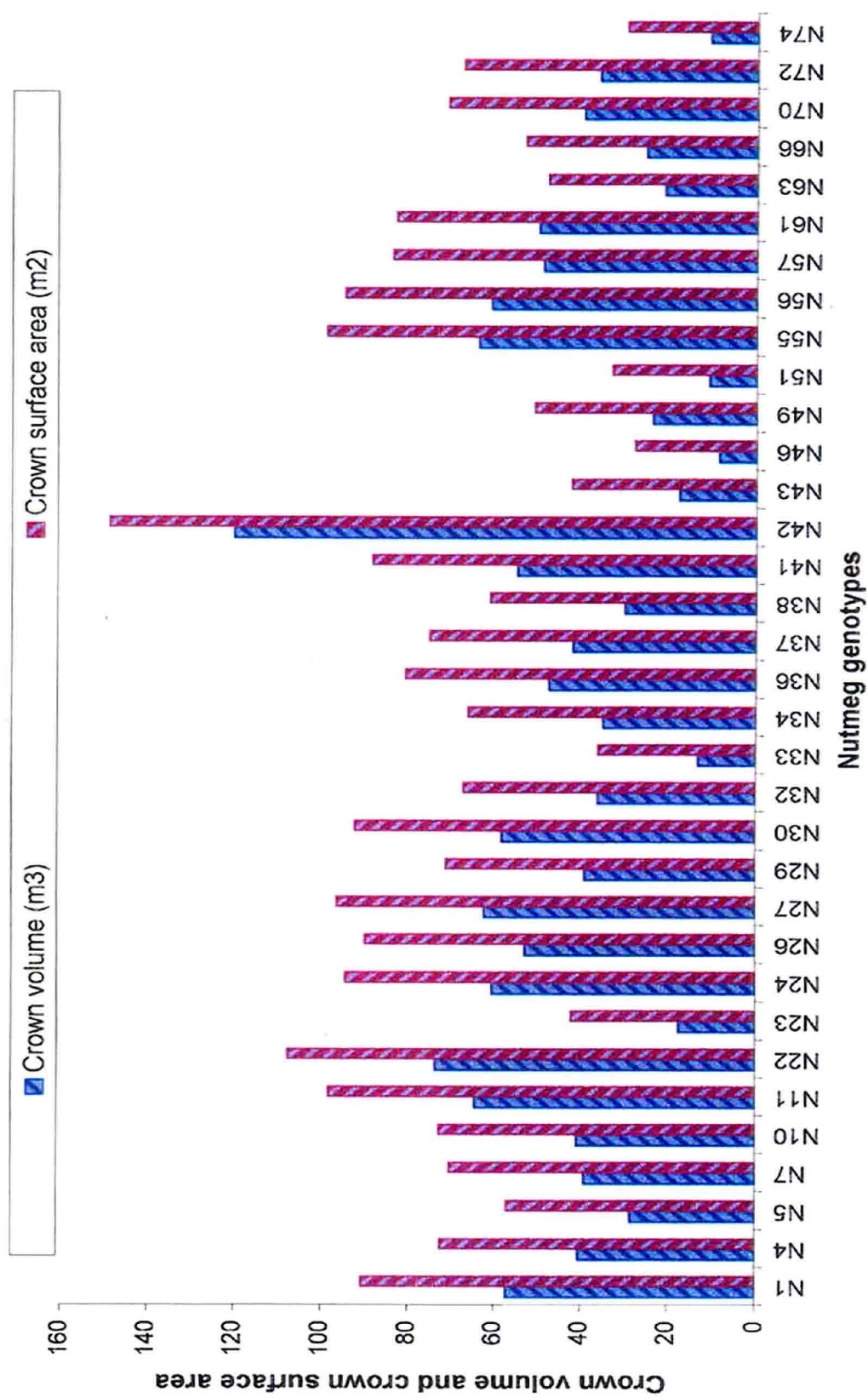
Geno- type	Height (m)	Spread (m)	Girth at bottom (cm)	No. of crot- ches	No. of primaries	No. of second- aries	No. of tertiaries	Crown volume (m ³)	Crown surface (m ²)	Ave- rage yield of 2 years	Average yield of 6 years
N1	7.67	5.38	46.5	38	129	2878	22483	57.34	90.72	434	314
N4	7.75	4.50	42.5	30	114	2047	9210	40.61	72.52	114	86
N5	5.61	4.41	42.5	28	100	1924	15514	28.55	57.19	144	195
N7	6.80	4.70	47.5	31	110	1962	11527	39.30	70.43	398	264
N10	7.63	4.58	44.0	38	134	2249	16724	41.04	72.87	491	341
N11	8.10	5.55	58.0	41	124	2518	25649	64.66	98.37	544	409
N22	8.92	5.64	54.0	34	86	1892	12248	73.82	107.71	422	293
N23	6.72	3.17	38.5	25	75	1645	9042	17.56	42.21	65	47

Table 4 continued ...

Geno- type	Height (m)	Spread (m)	Girth at bottom (cm)	No. of cro- ches	No. of prim- aries	No. of second- aries	No. of tertiaries	Crown volume (m ³)	Crown surface (m ²)	Average yield of 2 years	Ave- rage yield of 6 years
N24	8.33	5.28	43.5	32	121	3473	26251	60.65	94.45	299	266
N26	10.84	4.33	53.5	33	114	3296	22657	53.06	89.93	106	207
N27	8.54	5.30	49.0	34	242	7448	40217	62.54	96.53	92	113
N29	8.52	4.22	43.5	31	109	2918	18348	39.33	71.42	358	339
N30	8.38	5.19	53.5	37	138	3420	25228	58.58	92.40	418	267
N32	7.77	4.23	38.5	31	138	4098	35079	36.38	67.40	125	98
N33	7.45	2.60	36.5	30	113	2411	12660	13.17	36.29	236	215
N34	7.66	4.19	40.5	36	112	2893	15215	35.20	66.33	555	450
N36	8.34	4.69	38	40	212	5782	28017	47.70	80.69	575	448
N37	8.75	4.29	51	36	126	3450	20700	42.04	75.12	816	571
N38	8.71	3.64	45	41	143	3051	17543	30.12	61.22	254	220
N41	7.05	5.49	52	31	104	3473	20404	54.89	88.32	651	559
N42	9.18	5.59	50	42	125	3494	23805	120.17	148.96	937	789
N43	6.90	3.13	35	34	92	2232	11297	17.63	42.38	252	151
N46	7.00	2.16	39	30	93	2223	15404	8.55	27.68	168	98
N49	7.00	3.60	42.5	32	119	3316	18446	23.74	51.03	352	185
N51	8.05	2.27	34	41	119	3072	25150	10.81	32.96	366	224
N55	9.70	5.05	52.5	44	111	2195	14811	63.99	98.88	149	111
N56	8.23	5.34	54	49	143	3442	24518	61.02	94.77	209	115
N57	9.65	4.41	53	36	105	2566	19883	49.00	83.79	398	231
N61	7.75	4.97	52	34	90	2178	12251	50.10	83.06	91	124
N63	7.50	3.27	46	33	99	2367	15089	20.99	47.94	137	96
N66	7.05	3.70	45	28	92	2475	16081	25.26	53.19	236	216
N70	7.05	4.64	46	31	126	2747	13046	39.72	71.12	455	304
N72	7.90	4.18	46	31	110	2728	14663	36.12	67.46	787	711
N74	5.10	2.83	34	18	73	1840	12421	10.65	29.74	342	303
Mean	7.87	4.30	45.5	34.11	119	2932	18576	42.19	72.50	352	275
Range	5.10 to 10.84	2.16 to 5.64	34 to 58	18 to 49	73 to 242	1645 to 7448	9042 to 40217	8.55 to 120.17	27.68 to 148.96	65 to 937	47 to 789
S.D.	1.12	0.98	6.52	5.89	32.98	131.96	6940.2	22.57	25.84	222.62	178.1
C.V.	14.27	22.77	14.33	17.26	27.75	38.60	37.36	53.49	35.64	63.20	64.68
SE ±	0.03	0.01	0.38	0.27	1.03	3.11	0.14	0.22	5.38	220.61	-
C.D. at 5%	0.08	0.03	1.09	0.79	2.98	8.98	0.39	0.64	15.53	N.S.	-

The data on growth attributes of male genotypes are presented in Table 5. The 20 years old male nutmeg plant recorded 8.76 m average height with

Fig. 1. Crown volume and crown surface area of female
and hermaphrodite genotypes



4.87 m spread. It produced on an average 35.8 crotches with 116.20 primary branches, 3143 secondary branches, and 20649 tertiary branches. The average male tree had a crown volume of 65.66 m³ with 99.56 m² crown surface area. The girth of stem at the base was 52.0 cm. The variation recorded in male trees was relatively less as compared with female and hermaphrodite trees. The variation revealed from coefficient of variation recorded was maximum in number of secondaries (31.37%) followed by number of tertiaries (21.81%). The lowest variation was noticed for girth at bottom (5.30%) followed by height (5.66) and crown surface area (6.63%).

Table 5. Plant architecture components of male nutmeg genotypes.

Male genotype	Height (m)	Spread (m)	Girth at bottom (cm)	No. of crotches	No. of primaries	No. of secondaries	No. of tertiaries	Crown volume (m ³)	Crown surface area (m ²)
N15	8.40	5.66	55	28	94	2891	19872	70.16	103.78
N35	8.15	5.24	48	29	89	2235	22346	58.22	91.70
N69	8.75	4.94	50	34	108	2607	15459	55.53	89.33
N60	9.60	3.29	55	48	156	5051	28346	81.32	115.96
N53	8.90	5.22	52	40	134	2931	17221	63.09	97.04
Range	8.15 to 9.60	3.29 to 5.66	48 to 55	28 to 48	89 to 156	2235 to 5051	17221 to 28346	55.53 to 81.32	89.33 to 115.96
Mean	8.76	4.87	52.0	35.8	116.20	3143	20649	65.66	99.56
SD	0.49	0.82	2.76	7.44	25.30	985.96	4503.66	9.27	9.59
CV	5.66	16.89	5.30	20.78	21.77	31.37	21.81	14.12	6.63

The variable data provided a scope for ascertaining the potential traits responsible for the ultimate yield potential of the tree. For this it is necessary to trace out whether there exists any kind of mutual association among these different characters. This was assessed by estimating the linear correlation coefficients. The magnitudes of correlation coefficient (r) among all such characters are given in Table 6. It is revealed that the tree height had significant positive correlation with spread, number of crotches, girth at bottom, number of tertiaries, crown volume and crown surface area. The spread of the tree had significant correlation with number of crotches, girth at bottom, number of primaries, number of tertiaries, crown volume and crown surface area. Further, the number of crotches showed

Table 6. Correlation coefficients for the yield of nutmeg (number of fruits).

Sr. No.	Particulars	Height	Spread	Number of crotches	Girth at bottom	No. of primaries	No. of secondaries	No. of tertiaries	Crown volume	Crown surface area	Yield
1.	Height (X1)	1.000	0.398*	0.613**	0.565**	0.328	0.329	0.375*	0.585**	0.625**	0.139
2.	Spread (X2)		1.000	0.421*	0.755**	0.352*	0.299	0.346*	0.874**	0.912**	0.330
3.	Number of crotches (X3)			1.000	0.451**	0.444**	0.287	0.354*	0.527**	0.542**	0.152
4.	Girth at bottom (X4)				1.000	0.105	0.076	0.244	0.708**	0.751**	0.199
5.	Number of primaries (X5)					1.000	0.912**	0.659**	0.321	0.350*	0.081
6.	Number of secondaries (X6)						1.000	0.762**	0.315	0.334	0.137
7.	Number of tertiaries (X7)							1.000	0.392*	0.401*	0.056
8.	Crown volume (X8)								1.000	0.992**	0.443*
9.	Crown surface area (X9)									1.000	0.420*
11.	Yield of six years (Y)										1.000

*. ** significant at 5 and 1 % level of significance respectively.

positive association with girth at bottom, number of primary branches, number of tertiary branches, crown volume and crown surface area. The three characters namely, number of secondaries, number of tertiaries and crown surface area showed significant positive correlation with number of primaries. The number of secondaries however, had significant correlation with tertiaries. The crown volume and crown surface area also showed significant positive correlation with number of tertiaries. Further, the crown volume had almost perfect correlation with crown surface area. It must be noted that none of the characters except crown volume and crown surface area had close association with yield (number of fruits/ tree). Thus, the crown volume and crown surface area appeared to be the immediate determinants of yield in nutmeg. It must, however, be noted that the volume and surface area of the crown have a very strong association with other architectural characters like height, spread, crotches, girth at bottom, number of primaries and number of tertiaries. Hence, while deciding any ideal architecture of nutmeg tree a simultaneous consideration of all these characters with a greater weightage on crown volume and crown surface area is essential.

The dependence of yield in terms of number of fruits per tree on all these individual characters was assessed by the regression technique. From the regression equations given in Table 7 it is revealed that the yield in terms of number of fruits per tree significantly depended upon crown volume and crown surface area. The dependence of yield on remaining characters of plant architecture when taken individually was not justified as the regression was not significant. This suggested a need for ascertaining the dependence of yield simultaneously on two or more characters of growth of the tree. Under such situation the multiple regression equation gives a clear idea for deciding which of the components are responsible for determining the ultimate yield.

Table 7. Regression equation for the yield of nutmeg (number of fruits) on the basis of related plant architecture characters.

Sr. No.	Character	Regression equation	R ²
1.	Height (X1)	$\hat{Y} = 101.28 + 22.11 (X1)$	0.018
2.	Spread (X2)	$\hat{Y} = 17.57 + 59.80 (X2)$	0.109
3.	Number of crotches (X3)	$\hat{Y} = 118.43 + 4.60 (X3)$	0.023
4.	Girth at bottom (X4)	$\hat{Y} = 27.84 + 5.44 (X5)$	0.040
5.	Number of primaries (X5)	$\hat{Y} = 223.39 + 0.44 (X5)$	0.006
6.	Number of secondaries (X6)	$\hat{Y} = 212.32 + 0.02 (X6)$	0.016
7.	Number of tertiaries (X7)	$\hat{Y} = 230.18 + 0.002 (X7)$	0.009
8.	Crown volume (X8)	$\hat{Y} = 127.70 + 3.50 (X8)$	0.196**
9.	Crown surface Area (X9)	$\hat{Y} = 65.29 + 2.90 (X9)$	0.175*

** , * significant at 1% and 5% level of significance respectively.

The multiple regressions for yield over a 6 years as a dependent character and growth characters as independent characters are given in Table 8. It is revealed that a simultaneous consideration of height, spread, number of secondaries, crown volume and crown surface can explain the variability in nut yield significantly. This was represented by a multiple regression.

$$\hat{Y} = 1215.65 - 213.27 (X1) - 505.64 (X2) + 0.01 (X6) - 46.67 (X8) + 68.23 (X9).$$

An attempt was further made to isolate still more important characters for deciding the nutmeg yield. In this connection the following regression equation gave a condensed summary of the degree of dependence of yield of nutmeg on the component characters like height, spread, crown volume and crown surface area.

$$\hat{Y} = 1213.44 - 210.98 (X1) - 503.01 (X2) - 48.61 (X8) + 68.14 (X9)$$

Table 8. Multiple regression equations for yield of nutmeg (number of fruits) on the basis of various related characters.

Sr. No.	Regression equation	R ²
1.	$\hat{Y} = 1155.77 - 205.69 (X1) - 454.76 (X2) + 5.33 (X3) - 1.12 (X4) - 2.53 (X5) + 0.10 (X6) - 0.01 (X7) - 46.02 (X8) + 64.04 (X9)$	0.36
2.	$\hat{Y} = 1147.09 - 208.43 (X1) - 461.73 (X2) + 5.22(X3) - 2.46 (X5) + 0.09 (X6) - 0.01 (X7) + 33.54 (X8) + 64.11 (X9)$	0.36
3.	$\hat{Y} = 1152.26 - 186.21 (X1) - 438.80 (X2) - 1.47 (X5) + 0.07 (X6) - 0.01 (X7) - 41.71 (X8) + 59.52 (X9)$	0.35
4.	$\hat{Y} = 1162.63 - 195.13 (X1) - 465.30 (X2) + 0.04 (X6) - 0.004 (X7) - 43.17 (X8) + 61.81 (X9)$	0.34
5.	$\hat{Y} = 1215.65 - 213.27 (X1) - 505.64 (X2) + 0.01 (X6) - 46.67 (X8) + 68.23 (X9)$	0.33*
6.	$\hat{Y} = 1213.44 - 210.98 (X1) - 503.01 (X2) - 48.61 (X8) + 68.14 (X9)$	0.33*
7.	$\hat{Y} = 687.37 - 64.85 (X1) - 133.11 (X2) + 9.27 (X9)$	0.27*
8.	$\hat{Y} = 254.28 - 32.02 (X1) + 3.77 (X9)$	0.20*
9.	$\hat{Y} = 65.29 + 2.90 (X9)$	0.18*

* Significant at 5% level of significance.

The technique of step down regression provides a scope for identification of most important characters on which the ultimate yield is dependent. Among the 9 characters height, spread and crown surface area explained the variability in nutmeg more satisfactorily. In a further attempt to identify still more important character, plant height and crown surface were found to be the most important characters associated with the yield and among these two crown surface was the immediate determinant of yield of nutmeg.

The results, thus, suggested that while making selections for high yield, the tree having good height, good spread, more number of tertiaries, greater crown volume and more crown surface are ideal and need critical assessment.

4.3 Leaf area prediction :

Leaf growth is pivotal to plant growth and development. The rate, at which plant produces and expands the leaves, is an important factor in determining their ability to capture solar energy, grow, transpire, absorb minerals and water and fix nitrogen. Nutmeg is a shade-loving tree and the production potential of this crop is related with sprouting of new vegetative buds and their development into newer shoots. The leaves arising from such new shoot are generally 3 to 4 in number. Their integrated performance under the shade of host orchard of coconut or arecanut or any horticultural forest species is a result of interaction with various environmental factors namely solar radiation, temperature, relative humidity, water supply and mineral nutrition. The axils of these three leaves are the specific sites of production of fruits and the corresponding leaf is an immediate and important source of assimilates for development of the fruit units of the axially fruits. Assessment of the expansion of leaf is therefore, a basic aspect in the investigations related with the phenology of nutmeg crop.

The data on linear measurement on individual leaves namely length, breadth, length x breadth, fresh weight, dry weight and actual leaf area of 39 nutmeg genotypes are given in Table 9 and illustrated with Fig. 2. On an average the nutmeg leaf was 10.09 cm long, 4.16 cm broad, weighing 0.87 g as fresh and 0.29 g as dry. The actual average leaf area was 30.00 cm² and the product of length and breadth was 42.49 cm². The coefficient of variation for all these characters ranged from 8.12 (breadth) to 14.84 (dry weight of leaf). Among the 39 genotypes N53 (12.15 cm) had maximum leaf length followed by N41 (11.80 cm). Minimum leaf length was observed in N33 (8.23 cm) followed by N32 (8.59 cm). The leaf breadth was maximum in N24 (4.96 cm) followed by N55 (4.78 cm) whereas it was minimum in N33 (3.65 cm) followed by N30 (3.67 cm). The nutmeg genotypes

N24, N63 and N70 had the heaviest individual leaf (1.08 g) whereas the genotype N15 recorded the lightest leaf (0.71 g) followed by N43 (0.73 g). The weight of dry leaf in N63 was the maximum (0.38 g) followed by N57 (0.36 g). The genotype N43 recorded the minimum dry leaf weight (0.22 g) followed by N32 (0.23 g). The area of individual leaf was the highest in N57 (39.49 cm²) followed by N24 (38.30 cm²) which was minimum in N33 (23.85 cm²) followed by N51 (24.45 cm²). The product length x Breadth was maximum in N57 (56.47 cm²) followed by N24 (56.38 cm²), whereas it was minimum in N74 (33.86 cm²) followed by N33 (34.65 cm²). It can be noticed from these observations that the genotype N33 had the smaller leaves as compared to the other nutmeg genotypes. The genotype N24, N57 produced the big sized leaves.

Table 9. Leaf characters of nutmeg genotypes.

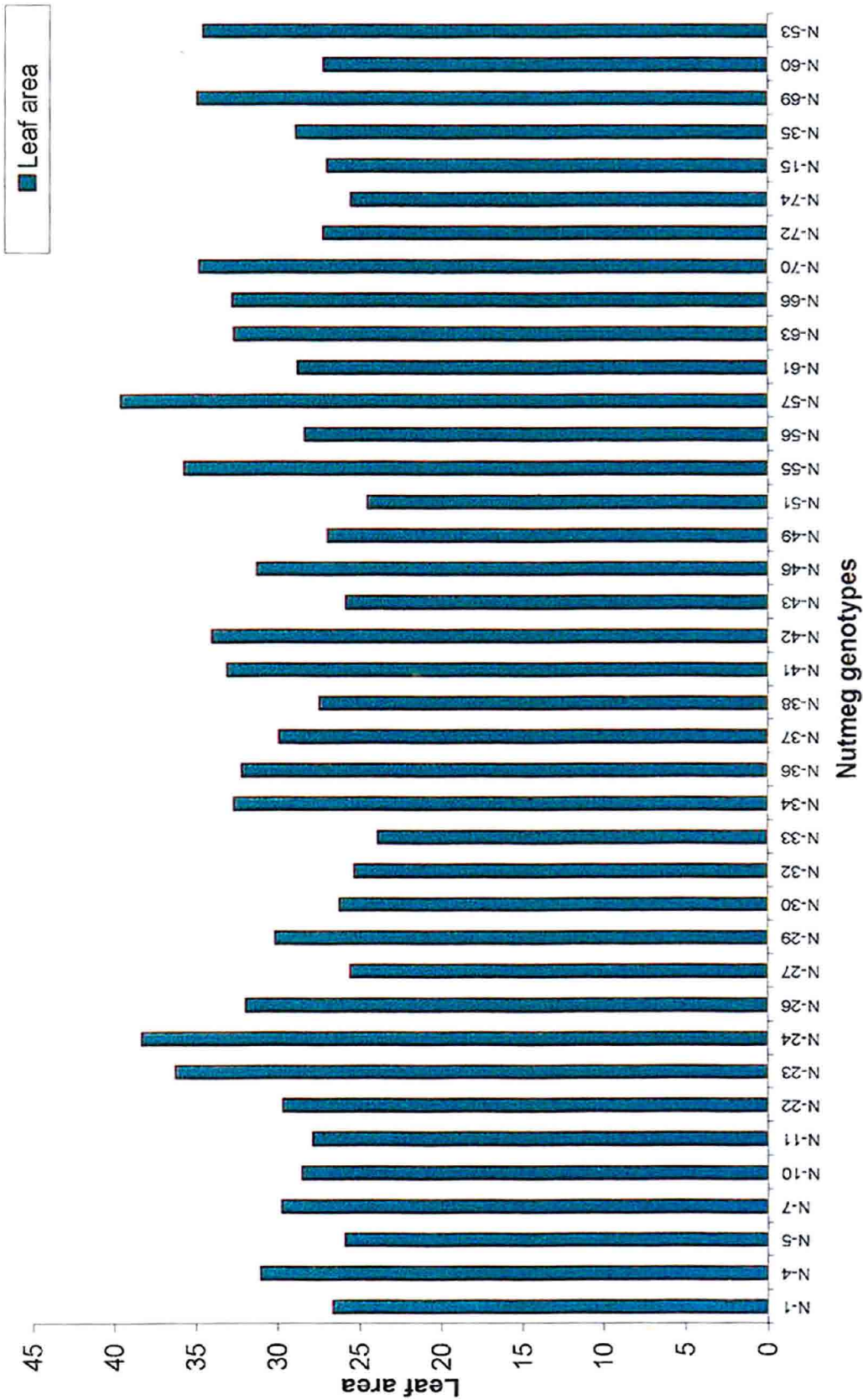
Genotype	Length (cm)	Breadth (cm)	Leaf area (cm ²)	Fresh weight (g)	Dry weight (g)	Length x Breadth (cm ²)
N-1	9.37	3.99	26.60	0.78	0.28	38.27
N-4	10.45	4.27	31.00	0.88	0.31	46.33
N-5	9.89	3.72	25.85	0.69	0.25	38.17
N-7	9.93	4.29	29.70	0.99	0.33	43.61
N-10	10.40	3.93	28.50	0.86	0.29	41.05
N-11	9.59	3.92	27.81	0.77	0.24	38.60
N-22	10.11	4.04	29.63	0.78	0.26	42.18
N-23	11.31	4.76	36.20	0.94	0.33	54.46
N-24	11.25	4.96	38.30	1.08	0.35	56.38
N-26	10.64	4.20	31.90	0.85	0.29	45.14
N-27	9.80	3.72	25.54	0.85	0.26	36.99
N-29	9.82	4.36	30.10	0.85	0.25	44.26
N-30	9.61	3.67	26.20	0.80	0.26	36.29
N-32	8.59	4.39	25.30	0.69	0.23	38.15
N-33	8.23	3.65	23.85	0.77	0.24	34.65
N-34	10.69	4.40	32.60	0.94	0.29	47.22
N-36	10.91	4.26	32.13	0.86	0.31	46.82

Table 9 continued ...

Genotype	Length (cm)	Breadth (cm)	Leaf area (cm ²)	Fresh weight (g)	Dry weight (g)	Length x Breadth (cm ²)
N-37	11.40	3.75	29.85	0.88	0.29	43.16
N-38	9.59	4.03	27.38	0.79	0.24	39.34
N-41	11.80	4.20	33.00	1.06	0.33	50.34
N-42	11.10	4.41	33.93	0.90	0.30	49.57
N-43	9.73	3.80	25.78	0.73	0.22	37.75
N-46	10.40	4.19	31.18	0.92	0.31	45.47
N-49	10.01	3.88	26.85	0.82	0.28	39.80
N-51	8.62	3.89	24.45	0.83	0.26	34.37
N-55	10.72	4.78	35.63	0.97	0.34	45.57
N-56	9.51	4.08	28.25	0.75	0.26	39.64
N-57	11.63	4.77	39.49	1.01	0.36	56.47
N-61	9.52	4.41	28.69	0.89	0.27	42.80
N-63	10.22	4.48	32.58	1.08	0.38	46.36
N-66	10.33	4.48	32.68	1.05	0.34	46.67
N-70	11.11	4.28	34.68	1.08	0.35	47.94
N-72	9.88	4.00	27.13	0.81	0.26	39.94
N-74	8.86	3.78	25.44	0.81	0.27	33.86
N-15	9.14	4.19	26.90	0.71	0.24	39.14
N-35	10.55	3.95	28.80	0.85	0.29	42.88
N-69	10.12	4.65	34.78	0.95	0.34	47.86
N-60	10.4	3.71	27.10	0.87	0.29	38.85
N-53	12.15	4.18	34.43	0.94	0.32	50.92
Range	8.23 to 12.15	3.65 to 4.96	23.85 to 39.49	0.71 to 1.08	0.22 to 0.38	33.86 to 56.47
Mean	10.09	4.16	30.00	0.87	0.29	42.49
S. D.	0.14	0.34	3.92	0.11	0.04	6.19
C.V.	11.31	8.12	13.06	12.35	14.84	14.57

Considering leaf area as a factor dependent, the regressions were worked out on each of the independent variables, namely, length, breadth, length x breadth, fresh weight and dry weight. The regression equations

Fig. 2. Leaf area of nutmeg genotypes



given in Table 10 revealed that the equation $Y = -16.96 + 4.62 (L)$ explains almost 90 per cent variation in the actual leaf area on the basis of linear length. This clearly suggested that it is possible to estimate the actual leaf area even by employing simple linear measurements without detaching leaf from plant. The regression equation constructed by using leaf breadth explained more than 86 per cent variations whereas a product of length and breadth was found to be the most reliable as it was responsible for more than 96 per cent variation in actual leaf area. It was also revealed that the fresh weight of the leaves could be employed for predicting the leaf area with fairly good precision as it explained 80 per cent variation. The dry weight of the leaves was not at all reliable as it contributed only 12 per cent variation in leaf area.

Table 10. Regression equations for predicting area of individual leaf (cm²) on the basis of ancillary characters.

Sr. No.	Ancillary character	Regression equation	R ²
1.	Length (L)	$\hat{Y} = -16.96 + 4.62 (L)$	0.90
2.	Breadth (B)	$\hat{Y} = -16.51 + 11.32 (B)$	0.86
3.	Fresh weight (FW)	$\hat{Y} = 2.16 + 32.50 (FW)$	0.80
4.	Dry weight (DW)	$\hat{Y} = 27.93 + 12.50 (DW)$	0.12
5.	Length x Breadth (L x B)	$\hat{Y} = 1.78 + 0.65 (L \times B)$	0.96

From the above results, it can be inferred that the area of individual leaf of nutmeg can be predicted at any stage of its growth in an attached state by taking simple linear measurements and constructing regression model by employing these linear measurements which can serve as an useful heuristic tool for phenological studies in nutmeg. The fresh weight of leaves would not serve meaningful tool, as it requires destructive sampling. The foregoing results thus, revealed that it is possible to develop an empirical formula for prediction of leaf area by simple linear measurements without destructive sampling.

4.4 Flowering and fruitset :

Flowering in nutmeg usually occurs in 3 to 5 flushes throughout the year. The major flush occurs with onset of monsoon in Konkan. The flowering occurs on physiologically mature shoots. The vegetative shoots as discussed previously usually appears in three flushes every year. However the genetic variability for number of flowers at each axil and duration of anthesis from flower bud appearance in 39 genotypes of nutmeg was studied in the current investigation. Further, the extent of setting of fruits on the flowered shoots was also recorded. The data are given in Table 11 and illustrated with Fig. 3.

Table 11. Period for anthesis and fruit set in nutmeg genotypes.

Genotype	Number of flowers per leaf axil	Period for anthesis			Fruit set (%)		
		1999	2000	Pooled	1999	2000	Pooled
1.	2.	3.	4.	5.	6.	7.	8.
N1	1	42	43	42.5	20 (26.56)	13 (21.13)	16.5 (23.97)
N4	1 to 3	36	43	39.5	12 (20.27)	6 (14.18)	9 (17.46)
N5	1	42	43	42.5	6 (14.18)	4 (11.54)	5 (12.92)
N7	1 to 3	38	36.5	37.25	8 (16.53)	4 (11.54)	6 (14.18)
N10	1	36	37	36.5	32 (34.45)	8 (16.43)	20 (26.56)
N11	1	35	37	36	4 (11.54)	8 (16.43)	6 (14.18)
N22	1 to 3	35	43	39	8 (16.53)	9 (17.46)	8.5 (16.95)
N23	1 to 3	49	55	51	16 (23.58)	15 (22.79)	15.5 (23.19)
N24	1	29	43	36	8 (16.53)	8 (16.43)	8 (16.43)
N26	1 to 3	36	37	36.5	4 (11.54)	12 (20.27)	8 (16.43)
N27	1 to 3	49	55	52	1 (5.74)	3 (9.98)	2 (8.13)

Table 11 continued ...

1.	2.	3.	4.	5.	6.	7.	8.
N29	1	36.5	36.5	36.5	40 (39.23)	17 (24.35)	28.5 (32.27)
N30	1	33.5	43	38.25	28 (31.95)	8 (16.43)	18 (25.10)
N32	1 to 3	37	41.5	39.25	4 (11.54)	1 (5.74)	2.5 (9.10)
N33	1 to 3	36.5	37	36.75	36 (36.87)	12 (20.27)	24 (29.33)
N34	1	32	37	34.5	21 (27.28)	17 (24.35)	19 (25.84)
N36	1	37.5	37	37.25	8 (16.53)	34 (35.67)	21 (27.28)
N37	1	31.5	37	34.25	9 (17.46)	33 (35.06)	21 (27.28)
N38	1	40	43	41.5	14 (21.97)	17 (24.35)	15.5 (23.19)
N41	1	35	43	39	4 (11.54)	4 (11.54)	4 (11.54)
N42	1	46.5	48	47.25	16 (23.58)	17 (24.35)	16.5 (23.97)
N43	1	37	43	40	28 (31.95)	9 (17.46)	18.5 (25.48)
N46	1	35.5	43	39.25	24 (29.33)	4 (11.54)	14 (21.97)
N49	1	37.5	38	37.75	52 (46.15)	4 (11.54)	28 (31.95)
N51	1	43.5	46	44.75	36 (36.87)	17 (24.35)	21.5 (27.63)
N55	1 to 3	36	35	35.5	4 (11.54)	4 (11.54)	4 (11.54)
N56	1 to 3	36	39.5	37.75	4 (11.54)	8 (16.43)	6 (14.18)
N57	1	38.5	43	40.75	20 (26.56)	19 (25.84)	19.5 (26.21)
N61	1 to 3	43.5	48	45.75	1 (5.74)	6 (14.18)	3.5 (10.78)
N63	1 to 3	47.5	55	51.25	20 (26.56)	4 (11.54)	12 (20.27)
N66	1	35.5	36.5	36	16 (23.58)	15 (22.79)	15.5 (23.19)

Table 11 continued ...

1.	2.	3.	4.	5.	6.	7.	8.
N70	1	33.5	37	35.25	36 (36.87)	20 (26.56)	28 (31.95)
N72	1	41	46	43.5	44 (41.55)	38 (38.06)	41 (39.82)
N74	1	42	41	41.5	32 (34.45)	16 (23.58)	24 (29.33)
N15	1 to 5	47.5	46	46.75	-		
N35	1 to 4	47.5	46	46.75	-		
N53	1 to 3	43.5	43	43.25	-		
N60	1 to 3	45.5	44	44.75	-		
N69	1 to 5	49.0	48.5	48.75	-		
Mean		39.31	42.41	40.83	18.11	12.18	15.00
SE m $\pm$		1.79	2.62	1.75	2.23	1.54	1.33
C.D. at 5%		5.15	7.57	5.04	6.42	4.44	3.83

Figures in the parenthesis indicate arcsin transformed values

The duration for flowering from the day of appearance of floral bud ranged between 35.25 to 52 days. The average period from appearance of floral bud to anthesis was 40.83 days. The duration was maximum in N27 (52 days) followed by N63 (51.25 days) and N23 (51 days). The genotype N 37 exhibited flowering in a shortest period i.e. 34.25 days. Two other genotypes namely N34 and N55 also exhibited flowering in equally short period (34.5 and 35.5 days respectively).

Table 12. Magnitudes of variance for days required for flowering and fruit set (%) in nutmeg genotypes.

Particulars	Mean sum of squares for treatments	Mean sum of squares for error	Genotypic variance	Phenotypic variance	Environmental variance
Days required for flowering	49.29**	6.12	21.59	27.71	6.12
Fruit set	123.36**	3.52	59.92	63.44	3.52

* Significant at 1% level of significance.

Fig. 3. Period for anthesis and fruit set (%) in nutmeg genotypes

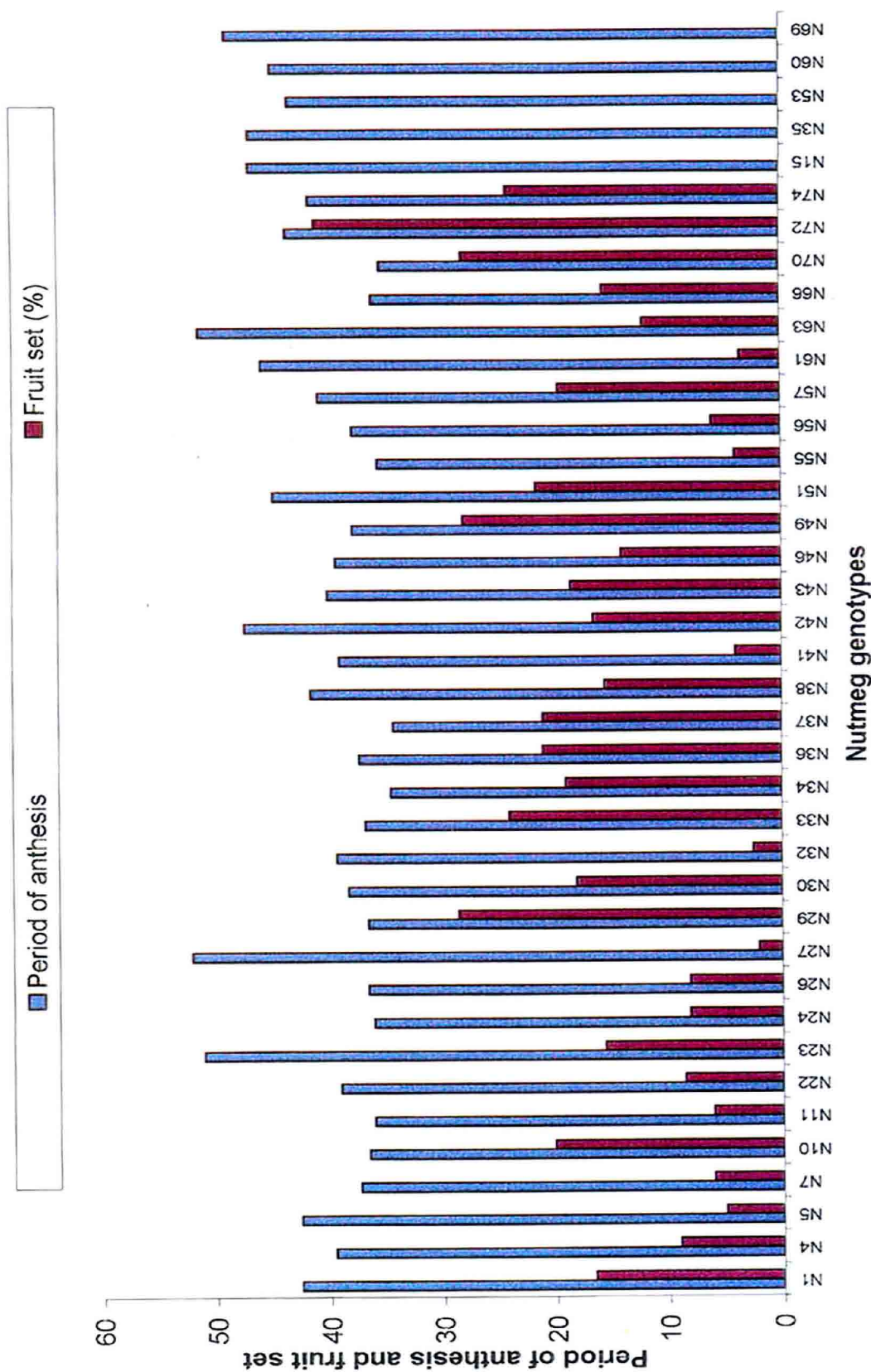




Plate 7. Fruitset in nutmeg genotypes N66, N38 and N30



Plate 8. Fruit set in nutmeg genotypes N11, N33 and N74

The variation among genotypes for the period from bud appearance to flowering was statistically significant (Table 12). The magnitudes of variance at genotypic and phenotypic level were 21.59 and 27.71, respectively. The PCV and GCV values for this duration were 11.24 and 9.32 respectively (Table 13). The period for flowering showed high heritability in broad sense (77.93) and also had noticeably high genetic advance on percent mean basis (20.71%). Thus, the character appeared to be under the control of additive gene effects.

Table 13. Genetic parameters for days required for flowering and fruitset (%) in nutmeg genotypes.

Particulars	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Environmental coefficient of variation (ECV)	Heritability (n ² δ)	Genetic advance (GA)	Genetic advance on % Mean basis (GAM)
Days required for flowering	11.24	9.92	1.32	77.93	8.45	20.71
Fruit set	36.50	35.47	1.02	94.44	15.49	103.30

The average fruit set from the flowers was 15 per cent. It was maximum in N72 (41%). Three other genotypes namely N 29, N70 and N 49 also showed reasonably high fruit set (28 to 28.5%). The lowest fruit set was noticed in N27 (2%). The genotypes N32 and N61 also showed very low fruit set (2.5 and 3.5% respectively).

The variability among the genotypes for fruit set was statistically significant. The magnitude of PCV and GCV for this character were higher than those for duration of flowering. They were 36.50 and 35.47 per cent respectively. Importantly, the environmental component of variation was very low which indicated that the fruit set in this crop is genetically governed and the environment has very low effect on it. The heritability in the broad sense, for fruit set was very high (94.44) and the genetic advance on percent mean basis was also very high (103.3%). This suggested that the fruitset in nutmeg is also governed by additive gene action and there is

good scope for selecting genotype with higher fruit set on per se performance basis.

4.5 Fruit Development :

Developing fruit is a potential sink for assimilates from the leaves which act as source of photosynthates. In nutmeg the fruit growth is essentially supported by the leaf in the axil of which it is borne. The setting of fruits in current investigation occurred from September to October in 39 genotypes under study for fruit development. The growth of these fruits further occurred in a sigmoid fashion over a period of about 250 to 300 days depending upon the genotype. The nutmeg fruit has three major components, namely fleshy pericarp, feathery colourful mace and the hard stony nut. The changes in the weight of these three components showed a peculiar pattern. This was assessed by fitting the polynomials of suitable degree by regressing the weight of individual fruit component on the time in days from fruit set. The results are presented in this section in Table 14 to 19.

4.5.1 Ontogenetic changes in weight of pericarp :

The population mean for dry weight of pericarp at 25 days after fruit set was 0.16 g as against 0.006 g for nut and 0.001 g for mace (Table 14). Thus more than 96 per cent portion in the initial stage of growth was comprised of fleshy pericarp. The pericarp grew rapidly upto 100 days from fruit setting to reach a magnitude of 2.18 g and thereafter it grew steadily to reach a value of 4.33 g by 225 days. At this time the contribution of dry pericarp in total weight of fruit was 49 per cent. A second degree polynomial explained more than 91 per cent variation in dry weight of fleshy pericarp (Table 15). The following equation described the phenomenon of the growth of fleshy pericarp during the ontogeny of nutmeg fruit.

$$Y (\text{pericarp}) = - 1.788 + 0.0592 (X) - 0.000157 (X^2)$$

A small value of intercept was followed by a remarkably high magnitude of 'b₁' indicating a rapid increase in dry weight of pericarp during

Table 14. Dry pericarp weight (g) at various stages of fruit development in nutmeg.

Geno- type	Dry pericarp weight (g) / Days after fruit set														Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300					
N1	0.18	0.74	2.40	2.98	3.46	4.01	4.55	4.71	4.75	4.17	0	0	3.20	1.55	48.52		
N4	0.13	0.33	1.64	1.85	1.99	4.27	4.94	6.13	5.65	5.09	5.73	5.83	3.63	2.17	59.90		
N7	0.28	0.84	2.01	2.22	3.12	3.13	3.30	3.92	3.81	0.0	0	0	2.51	1.21	48.00		
N10	0.11	0.57	1.64	2.01	2.27	2.33	2.52	2.81	2.94	2.41	0	0	1.96	0.88	45.30		
N11	0.16	0.63	1.86	2.15	3.23	3.33	3.39	3.52	3.46	0.0	0	0	2.41	1.22	50.56		
N22	0.08	0.46	0.93	1.41	3.42	3.62	3.94	4.19	4.35	4.29	3.96	4.0	2.89	1.58	54.67		
N23	0.17	0.50	1.96	2.23	3.49	3.87	6.26	7.19	7.02	7.14	7.57	7.58	4.58	2.74	59.86		
N24	0.13	0.54	1.03	1.39	3.03	4.63	5.34	5.37	4.99	6.10	0	0	3.26	2.18	66.91		
N26	0.12	0.55	0.89	1.72	2.09	2.70	4.47	4.58	5.91	5.93	5.93	6.23	3.43	2.23	65.17		
N29	0.15	0.71	2.22	2.77	3.81	3.50	3.60	4.03	4.14	0.0	0	0	2.77	1.38	49.88		
N30	0.18	0.78	2.33	2.75	3.23	3.17	3.56	3.78	4.14	4.06	4.28	0	2.98	1.35	45.31		
N33	0.11	0.48	1.42	2.20	2.28	2.72	3.10	2.99	2.86	3.16	3.18	0	2.23	1.04	46.81		
N34	0.15	0.95	1.13	2.13	2.92	2.98	2.97	3.42	3.99	4.14	3.90	3.94	2.72	1.28	47.24		
N36	0.15	0.72	1.25	2.32	2.57	4.21	4.38	4.70	5.34	5.05	4.72	4.10	3.28	1.72	52.51		
N37	0.14	0.36	1.01	1.34	1.80	2.81	3.59	3.36	4.22	4.12	0	0	2.28	1.46	64.16		
N41	0.16	0.94	1.59	2.49	3.45	3.90	3.98	5.03	4.26	3.95	3.68	0	3.04	1.46	48.18		
N42	0.18	0.56	0.84	1.73	1.91	2.24	2.93	3.54	3.24	0.0	0	0	1.91	1.13	59.43		

Table 14 continued.....

Geno- type	Dry pericarp weight (g) / Days after fruit set												Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300			
N43	0.13	0.58	1.35	1.72	1.79	1.85	2.03	2.27	2.32	0.0	0	0	1.56	0.71	45.40
N46	0.12	0.65	1.56	1.88	2.47	3.09	3.03	3.27	3.60	3.80	0	0	2.34	1.19	51.85
N49	0.15	0.67	2.08	2.29	2.91	2.99	3.12	2.82	2.82	3.15	3.49	0	2.41	1.02	42.27
N51	0.14	0.64	1.63	1.79	2.50	2.49	2.53	2.67	3.16	2.51	0	0	2.01	0.91	45.46
N55	0.19	0.83	1.23	2.00	3.36	3.78	3.76	4.82	5.86	5.57	5.12	0	3.30	1.87	56.77
N56	0.21	0.80	1.32	2.22	2.71	3.61	4.70	5.24	5.39	5.19	5.03	4.70	3.43	1.82	53.11
N57	0.32	0.93	2.44	3.25	4.25	4.75	5.32	6.15	5.91	6.15	5.60	6.71	4.32	2.04	47.28
N61	0.12	0.05	0.76	1.05	1.57	2.37	3.78	3.58	3.74	3.51	4.25	3.96	2.41	1.50	62.36
N63	0.19	0.72	2.47	3.09	3.73	4.40	4.93	5.67	5.59	5.62	0	0	3.64	1.90	52.25
N66	0.22	0.56	1.41	3.69	3.82	5.27	4.95	5.84	6.55	6.07	0	0	3.84	2.22	57.90
N70	0.22	0.50	1.69	2.43	2.83	3.01	3.34	3.67	3.58	0.0	0	0	2.36	1.22	51.43
N72	0.09	0.41	0.72	2.02	2.59	2.45	3.20	3.13	3.28	3.02	0	0	2.09	1.17	55.93
N74	0.18	0.85	1.53	2.39	2.42	2.43	3.06	2.65	3.01	0.0	0	0	2.06	0.94	45.54
Mean	0.16	0.63	1.54	2.18	2.83	3.33	3.82	4.17	4.33	3.47	2.21	1.56			
S.D.	0.05	0.20	0.51	0.58	0.69	0.83	0.96	1.22	1.21	2.21	2.49	2.50			
C.V.	31.88	31.38	33.37	26.58	24.26	25.03	25.24	29.19	27.99	63.68	12.56	159.44			

early phase of fruit growth. A diminutive and negative value of 'b₂' suggested that towards maturity the rate of pericarp growth declined steadily.

Table 15. The polynomial equations explaining changes in dry weight of fleshy pericarp during fruit growth of some nutmeg genotypes

Genotype	Polynomial equation	R ²
N4	$Y = -0.176 + 0.023 (X)$	0.86
N36	$Y = -1.623 + 0.052 (X) - 0.000106 (X^2)$	0.95
N26	$Y = -0.681 + 0.025 (X)$	0.96
N7	$Y = 0.277 + 0.018 (X)$	0.91
N42	$Y = -0.248 + 0.017 (X)$	0.96
N72	$Y = 0.027 + 0.015 (X)$	0.85
N37	$Y = -0.470 + 0.0149 (X)$	0.96
Population mean	$Y = -1.788 + 0.0592(X) - 0.000157 (X^2)$	0.92

The genotype N4 was characterised by longest duration of fruit growth (300 days). On the day of first record (25 days) the magnitude of dry pericarp weight was 0.13 g (Table 14). In comparison with population mean for dry pericarp weight the magnitude of pericarp weight in N4 was lower upto 125 days. But thereafter, it remained higher than the population mean and reached the maximum of 5.83 g after 300 days from setting. The growth of dry fleshy pericarp in this culture was explained very satisfactorily even by the first degree polynomial (Table 15). The magnitude of R² for this first degree polynomial was 0.86. The following equation summarized the process of pericarp development during fruit ontogeny of N4.

$$Y (\text{pericarp}) = 0.176 + 0.023 (X)$$

The genotype N7 required shortest period for fruit development (218 days). The magnitudes of dry pericarp weight at all the stages of fruit growth in this genotype were higher than those of the population mean. The initial value of dry pericarp weight was 0.28 g as against 0.16 g of a population mean. It grew very rapidly to reach 3.12 g by 125 days and

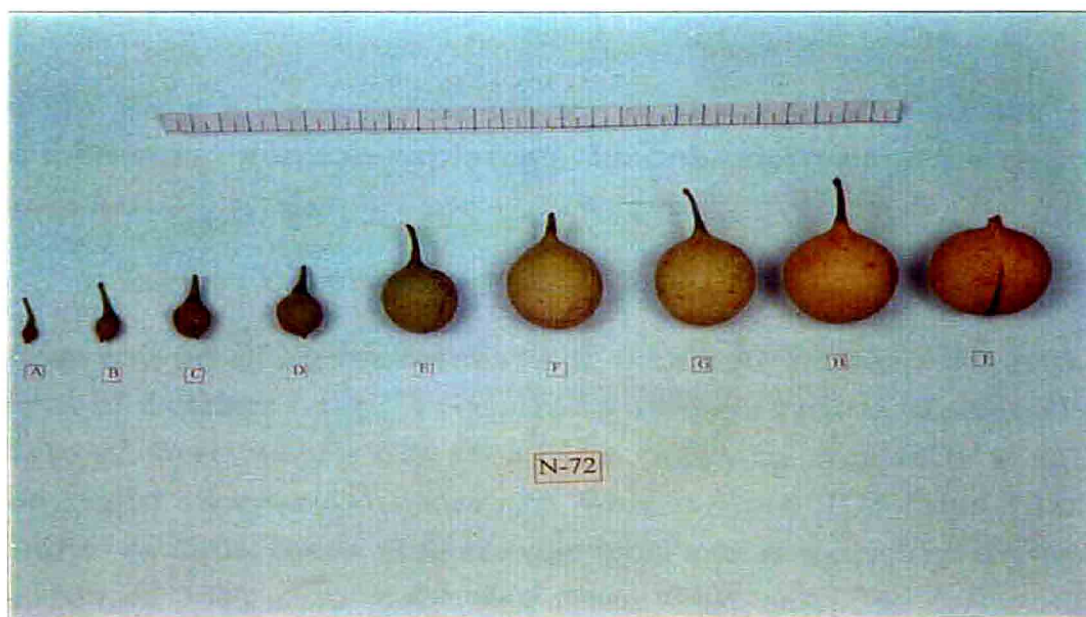


Plate 9. Fruit development in nutmeg genotype N72

A - Fruit set	B - 25 days	C - 50 days
D - 75 days	E - 100 days	F - 125 days
G - 225 days	H - At harvest	

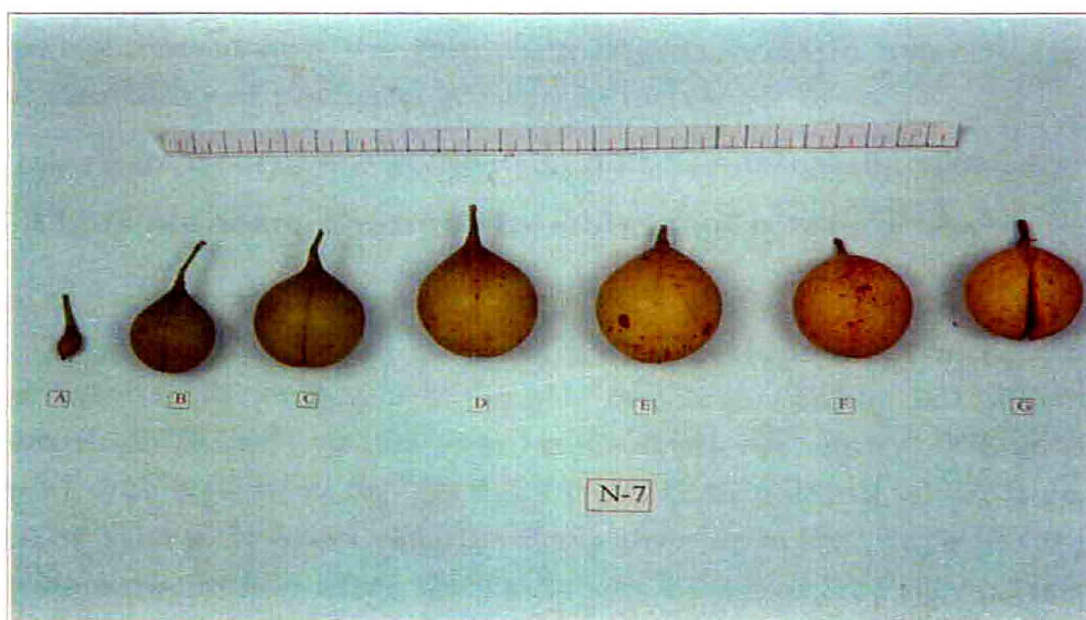


Plate 10. Fruit development in nutmeg genotype N7

A - Fruit set	B - 75 days	C - 100 days
D - 125 days	E - 150 days	F - 200 days
G - At harvest		

thereafter the growth was very steady to reach a maximum of 3.81 g by 212 days. The following equation explained the behaviour of pericarp growth of genotype N7 satisfactorily.

$$Y (\text{pericarp}) = 0.277 + 0.018 (X)$$

The genotype N72 represented a common pattern of growth and development of nutmeg fruit. It required 246 days period of overall growth. On the date of first record (25 days) the pericarp was 0.09 g in weight. There was rapid increase in pericarp weight upto 100 days (2.02 g). In further course of time there was steady increase in pericarp dry weight to reach a value of 3.28 g on 225th day from fruit set. The following linear regression was found to be the best fit as it explained 85 per cent variation in weight of pericarp during fruit ontogeny.

$$Y (\text{pericarp}) = 0.027 + 0.015(X)$$

From the foregoing results it can be concluded that the dry weight of fleshy pericarp follows either linear or quadratic pattern of variation during the growth of fruit. But the quadratic growth can be takes as a common phenomenon and the following equation could be considered as a condensed summary of pericarp growth in nutmeg.

$$Y (\text{pericarp}) = - 1.788 + 0.0592(X) - 0.000157(X^2)$$

4.5.2 Ontogenetic changes in weight of nut :

The nut development in nutmeg fruit showed different trend than that of pericarp. In the initial stage of fruit development the proportion of nut in the total fruit weight was only 3 per cent (Table 16). The average weight of nut produced at 25 days after fruit set was 0.006 g. The nut development was steady upto 150 days from fruit setting when it reached a magnitude of 1.16 g. It grew rapidly thereafter upto 200 days (3.06 g) when its growth became steady after that to reach 4.02 g at 225 days. Its share in total weight of fruit was 46 per cent.

Table 16. Dry nut weight at various stages of development of nutmeg fruit

Geno- type	Dry nut weight (g) / Days after fruit set												Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300			
N1	0.005	0.56	0.32	0.64	1.40	1.84	2.59	3.67	4.58	3.81	0.0	0.0	1.91	1.59	83.19
N4	0.004	0.005	0.07	0.10	0.16	0.55	0.64	1.39	2.73	3.53	3.70	3.98	1.40	1.54	109.58
N7	0.005	0.06	0.33	0.71	1.30	1.52	2.61	4.09	4.37	0.0	0.0	0.0	1.66	1.57	94.41
N10	0.004	0.04	0.37	0.72	1.33	1.63	2.27	2.46	4.48	3.67	0.0	0.0	1.69	1.44	85.20
N11	0.004	0.03	0.24	0.66	1.07	1.37	1.99	2.68	4.37	0.0	0.0	0.0	1.38	1.35	98.56
N22	0.004	0.02	0.04	0.10	0.68	0.65	1.78	2.54	3.96	4.62	5.46	5.40	2.11	2.11	100.01
N23	0.009	0.01	0.12	0.13	0.44	0.72	1.53	3.76	3.65	4.71	6.11	6.41	2.30	2.38	103.29
N24	0.004	0.01	0.13	0.13	0.46	2.60	4.10	5.68	5.10	4.90	0.0	0.0	2.31	2.29	99.25
N26	0.004	0.01	0.06	0.09	0.22	1.52	1.52	2.02	5.26	5.35	5.09	5.20	2.19	2.24	101.99
N29	0.004	0.04	0.23	0.71	1.01	1.89	2.16	4.86	5.10	0.0	0.0	0.0	1.78	1.86	104.35
N30	0.004	0.06	0.23	0.51	1.04	0.96	1.77	4.06	4.88	4.59	4.49	0.0	2.05	1.92	93.50
N33	0.004	0.02	0.10	0.40	0.48	1.00	1.65	2.01	2.92	2.95	2.94	0.0	1.32	1.17	88.72
N34	0.004	0.06	0.06	0.32	0.66	0.66	0.95	1.93	3.78	4.90	4.45	4.45	1.85	1.88	101.44
N36	0.004	0.03	0.07	0.22	0.36	0.78	1.41	2.62	3.20	3.54	3.62	4.10	1.67	1.56	93.75
N37	0.004	0.01	0.08	0.13	0.25	0.74	1.66	3.91	3.92	4.44	0.0	0.0	1.51	1.76	115.93
N41	0.004	0.02	0.24	0.46	1.48	1.57	2.25	2.63	3.30	3.61	3.80	0.0	1.76	1.39	78.82
N42	0.004	0.03	0.06	0.22	0.44	0.66	2.08	4.24	4.31	0.0	0.0	0.0	1.34	1.68	125.65

Table 16 continued.....

Geno type	Dry nut weight (g) / Days after fruit set												Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300			
N43	0.003	0.05	0.12	0.45	0.88	1.07	1.80	2.65	3.20	0.0	0.0	0.0	1.14	1.11	97.46
N46	0.004	0.03	0.17	0.18	0.57	1.05	1.18	3.52	3.70	3.78	0.0	0.0	1.44	1.55	107.88
N49	0.004	0.06	0.34	0.57	1.02	1.42	2.36	2.96	3.77	4.28	4.82	0.0	1.96	1.68	85.70
N51	0.004	0.04	0.16	0.28	1.12	1.40	1.64	1.97	3.70	3.73	0.0	0.0	1.40	1.33	94.92
N55	0.004	0.02	0.07	0.13	0.48	0.58	1.00	1.97	3.92	3.96	4.28	0.0	1.49	1.66	111.31
N56	0.004	0.02	0.06	0.15	0.29	0.66	1.15	1.96	2.71	3.96	4.92	5.46	1.78	1.93	108.62
N57	0.004	0.03	0.20	0.50	0.78	1.23	2.42	3.58	3.58	3.63	4.56	5.06	2.13	1.80	84.57
N61	0.004	0.03	0.05	0.06	0.18	0.36	0.62	1.46	2.37	3.97	4.49	4.31	1.49	1.73	116.11
N63	0.004	0.04	0.05	0.08	0.77	1.68	2.59	3.47	4.62	5.10	0.0	0.0	1.84	1.89	102.71
N66	0.009	0.02	0.07	0.49	0.91	1.89	2.22	4.14	6.35	5.66	0.0	0.0	2.18	2.27	104.52
N70	0.004	0.02	0.18	0.49	0.65	0.93	2.19	3.18	3.65	0.0	0.0	0.0	1.25	1.32	104.98
N72	0.007	0.02	0.08	0.55	1.21	1.40	2.75	3.50	3.50	4.75	0.0	0.0	1.78	1.64	92.13
N74	0.004	0.07	0.22	0.76	0.92	1.51	2.02	2.91	3.93	00	0.0	0.0	1.37	1.28	93.56
Mean	0.006	0.03	0.15	0.35	0.75	1.16	1.90	3.06	4.02	3.19	2.09	1.48			
S.D.	0.007	0.02	0.10	0.23	0.38	0.52	0.70	1.02	0.87	1.87	2.30	2.30			
C.V.	108.63	60.20	65.34	67.12	50.99	44.98	37.08	33.19	21.56	58.65	109.90	155.22			

The variation of 93 per cent in dry weight of nut was explained by a third degree polynomial equation (Table 17). This following equation explained the pattern of nut development during the ontogeny of nutmeg fruit.

$$Y(\text{nut}) = 1.353 - 0.057(X) + 0.000593(X^2) - 0.00000134(X^3)$$

The genotype N4 required maximum period for fruit development (300 days). The nut weight recorded in this genotype at 25 days after fruit set was 0.004 g which was less than population mean (Table 16). Its magnitude for nut weight remained lower than the population mean upto 225 days after fruit set. Thereafter, it remained higher than the population average and reached 3.98 g at 300 days from fruit set. The first degree polynomial explained 86 per cent variation in nut development in this genotype (Table 17). The following equation summerized the process of nut development in N4.

$$Y(\text{nut}) = -1.280 + 0.016(X)$$

Similar trend of nut development was also noticed in N26 and N36 where the fruit development required longer period. In these genotypes relatively rapid nut growth was recorded in the later stages of fruit development.

Table 17. The polynomial equations explaining changes in dry weight of nut during fruit growth of some nutmeg genotypes.

Genotype	Polynomial equation	R ²
N4	$Y = -1.280 + 0.016(X)$	0.86
N36	$Y = -1.154 + 0.017(X)$	0.92
N26	$Y = -1.800 + 0.024(X)$	0.83
N7	$Y = -1.243 + 0.023(X)$	0.91
N42	$Y = 0.656 - 0.025(X) + 0.00019(X^2)$	0.94
N72	$Y = -1.254 + 0.022(X)$	0.94
N37	$Y = -1.536 + 0.022(X)$	0.82
Population mean	$Y = 1.353 - 0.057(X) + 0.000593(X^2) - 0.00000134(X^3)$	0.93

In N7 the fruit development was quicker than the other genotypes under study (212 days). Except for the very first state of observation (25 days) its nut weight was always higher than the population mean. The nut

weight was 0.005 g at 25 days of fruit set as against 0.006 g population mean. The nut growth was steady upto 150 days (1.52 g) of fruit set there after it grew rapidly upto 200 days (4.09 g) and became steady again to record 4.37 g at the time of harvest. The following equation explained the nut growth pattern in N7 satisfactorily.

$$Y (\text{nut}) = 1.243 + 0.023(X)$$

In another early genotype namely N42 the nut development in the initial stages upto 175 days was slow. The magnitudes of nut weight recorded upto 175 days for N42 was lower than that for population mean. In this genotype the nut weight increased rapidly after 150 days (0.66 g) upto 200 days (4.24 g) and became steady thereafter to attain 4.31 g at the time of harvest. The equation below sufficiently explained the nut development behaviour of N42.

$$Y (\text{nut}) = 0.656 - 0.025(X) + 0.0019(X^2)$$

The second degree polynomial explained 94 per cent variation in nut weight during fruit ontogeny.

In N72 it took 246 days for fruit development. This period can be treated as average period of fruit development. In this genotype the nut weight was 0.007 g at 25 days from fruit set and increased steadily upto 150 days (1.40 g). The nut development became fast afterwards upto 200 days (3.50 g) and became steady to reach 4.75 g at the time of harvest (246 days). The first degree polynomial was observed to be the best for this genotype as it explained 94 per cent variation in nut weight during fruit ontogeny. The following regression equation was found to be fit for nut development in N72.

$$Y (\text{nut}) = -1.254 + 0.022(X)$$

Similar trend of nut development was observed in the genotype N37.

Thus from the above study on nut development during fruit ontogeny it can be concluded that the quadratic or cubic pattern of variation could be

considered as the common phenomena. The following equation offers condensed summary of nut growth in nutmeg.

$$Y(\text{nut}) = 1.353 - 0.057(X) + 0.000593(X^2) - 0.00000134(X^3)$$

4.5.3 Ontogenetic changes in weight of mace :

The mace development pattern showed different trend than that of pericarp and mace. The average mace produced by the 30 genotypes under study was 0.001 g at 25 days after fruit set which was 1 per cent in the total fruit weight (Table 18). Its proportion was the lowest among the components viz. nut and pericarp. It steadily increased upto 175 days and thereafter it grew rapidly upto 225 days (0.46 g) and remained afterwards steady to reach 0.51 g at 250 days after fruit set. Its proportion in total fruit at 225 days was 5 per cent. A third degree polynomial explained 91 per cent variation in dry weight of mace (Table 19). The equation below explained the mace development during ontogeny of fruit.

$$Y(\text{mace}) = 0.157 - 0.006(X) + 0.0000607(X^2) - 0.00000012(X^3)$$

Among the genotypes under study N4 required longest period for fruit development. The mace weight recorded in this genotype was 0.001 g at 25 days of fruit set, which was similar to that of population mean (Table 18). Thereafter it slowed down and remained below population mean upto 125 days. The rate of mace growth in this genotype increased rapidly towards 175 days (0.16 g) to 200 days (0.33 g) from fruit set. In further course of time again it rapidly peaked up during 275 days to 300 days and reached to a peak weight of 0.74 g. The first degree polynomial in this genotype explained 86 per cent variation (Table 19). The following regression equation explained the behaviour of mace growth of N4 satisfactorily.

$$Y(\text{mace}) = -0.168 + 0.002(X)$$

Table 18. Dry mace weight at various stages of fruit development in nutmeg

Geno- type	Days after fruit set														Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300					
N1	0.001	0.06	0.06	0.09	0.15	0.18	0.26	0.43	0.70	0.73	0.0	0.0	0.27	0.25	94.89		
N4	0.001	0.005	0.02	0.04	0.04	0.13	0.16	0.33	0.34	0.33	0.48	0.74	0.22	0.22	100.00		
N7	0.001	0.01	0.03	0.07	0.12	0.14	0.20	0.32	0.51	0.0	0.0	0.0	0.15	0.16	101.42		
N10	0.001	0.04	0.04	0.06	0.10	0.13	0.16	0.18	0.47	0.38	0.0	0.0	0.16	0.14	93.47		
N11	0.001	0.03	0.03	0.04	0.04	0.07	0.10	0.11	0.34	0.0	0.0	0.0	0.08	0.10	113.75		
N22	0.001	0.02	0.01	0.03	0.12	0.14	0.24	0.35	0.43	0.60	0.85	0.82	0.30	0.29	98.63		
N23	0.001	0.01	0.03	0.05	0.09	0.15	0.25	0.34	0.38	0.53	1.71	1.78	0.44	0.60	136.10		
N24	0.002	0.01	0.05	0.05	0.11	0.22	0.38	0.51	0.86	1.01	0.0	0.0	0.32	0.35	108.38		
N26	0.001	0.01	0.02	0.05	0.06	0.10	0.27	0.30	0.86	1.16	1.16	1.15	0.43	0.48	111.34		
N29	0.001	0.04	0.03	0.06	0.08	0.09	0.11	0.23	0.40	0.0	0.0	0.0	0.12	0.12	101.96		
N30	0.001	0.06	0.06	0.06	0.11	0.12	0.17	0.35	0.40	0.48	0.71	0.0	0.23	0.21	93.53		
N33	0.001	0.02	0.03	0.06	0.07	0.11	0.15	0.18	0.27	0.45	0.50	0.0	0.17	0.16	97.69		
N34	0.001	0.006	0.02	0.04	0.10	0.10	0.12	0.26	0.34	0.55	0.55	0.60	0.22	0.22	98.43		
N36	0.001	0.005	0.01	0.04	0.04	0.11	0.19	0.22	0.24	0.42	0.73	0.81	0.23	0.26	114.22		
N37	0.001	0.001	0.005	0.01	0.03	0.06	0.11	0.22	0.35	0.48	0.0	0.0	0.13	0.16	125.22		
N41	0.001	0.02	0.04	0.07	0.17	0.18	0.24	0.45	0.45	0.51	0.66	0.0	0.25	0.22	85.56		
N42	0.001	0.03	0.01	0.04	0.05	0.09	0.16	0.51	0.49	0.0	0.0	0.0	0.15	0.19	124.24		

Table 18 continued.....

Geno- type	Days after fruit set												Mean	S.D.	C.V.
	25	50	75	100	125	150	175	200	225	250	275	300			
N43	0.001	0.05	0.03	0.06	0.10	0.10	0.15	0.22	0.45	0.0	0.0	0.0	0.13	0.13	100.29
N46	0.001	0.03	0.03	0.04	0.08	0.14	0.16	0.35	0.60	0.73	0.0	0.0	0.22	0.25	113.67
N49	0.001	0.02	0.03	0.05	0.08	0.11	0.18	0.25	0.32	0.43	0.63	0.0	0.19	0.19	99.98
N51	0.001	0.03	0.04	0.04	0.10	0.13	0.15	0.17	0.46	0.50	0.0	0.0	0.16	0.17	110.95
N55	0.001	0.02	0.02	0.04	0.08	0.12	0.20	0.23	0.50	0.70	0.84	0.0	0.25	0.28	112.69
N56	0.001	0.02	0.02	0.04	0.07	0.11	0.24	0.34	0.41	0.87	0.94	1.11	0.35	0.39	110.92
N57	0.001	0.03	0.05	0.13	0.16	0.22	0.35	0.41	0.52	0.90	0.94	0.99	0.39	0.35	89.87
N61	0.001	0.03	0.03	0.03	0.03	0.04	0.09	0.14	0.19	0.22	0.65	0.61	0.18	0.22	119.57
N63	0.001	0.04	0.07	0.09	0.11	0.16	0.24	0.37	0.70	0.77	0.0	0.0	0.26	0.26	102.14
N66	0.002	0.02	0.05	0.06	0.09	0.14	0.17	0.36	0.53	0.83	0.0	0.0	0.23	0.26	113.68
N70	0.001	0.02	0.02	0.06	0.10	0.10	0.21	0.26	0.50	0.0	0.0	0.0	0.14	0.15	107.28
N72	0.002	0.005	0.01	0.07	0.12	0.12	0.23	0.31	0.41	0.57	0.0	0.0	0.18	0.18	99.05
N74	0.001	0.01	0.03	0.08	0.09	0.12	0.19	0.22	0.49	0.0	0.0	0.0	0.13	0.14	105.14
Mean	0.001	0.03	0.04	0.08	0.09	0.12	0.19	0.31	0.46	0.51	0.37	0.29			
S.D.	0.003	0.02	0.05	0.09	0.04	0.04	0.07	0.11	0.16	0.41	0.44	0.48			
C.V.	30.00	60.20	114.83	113.66	44.44	31.10	34.31	36.45	33.46	80.55	120.02	166.38			

Table 19. The polynomial equations explaining changes in dry weight of mace during fruit growth of some nutmeg genotypes.

Genotype	Polynomial equation	R ²
N4	$Y = -0.168 + 0.0002(X)$	0.86
N36	$Y = -0.217 + 0.003(X)$	0.80
N26	$Y = -0.363 + 0.004(X)$	0.82
N7	$Y = -0.126 + 0.002(X)$	0.85
N42	$Y = 0.085 - 0.003(X) + 0.000022(X^2)$	0.90
N72	$Y = -0.146 + 0.002(X)$	0.89
N37	$Y = 0.075 - 0.002(X) + 0.00001(X^2)$	0.99
Population mean	$Y = 0.157 - 0.006(X) + 0.0000607(X^2) - 0.00000012(X^3)$	0.91

In the late maturing genotype N36 the mace development was slow upto 225 days. It was 0.001 g at 25 days of fruit set and was lower than the population mean upto 250 days from fruit set. The increase was steady in mace growth in this genotype upto 250 days (0.42g) thereafter it was rapid upto 275 days of fruit set (0.73 g) and was steady afterwards to reach a peak at 300 days (0.81 g). The following linear regression was found to be best fit as it explained 80 per cent variation in weight of mace in N36 during fruit ontogeny.

$$Y (\text{mace}) = -0.217 + 0.003(X)$$

In early developing nutmeg fruit of N7 the magnitudes of dry mace weight were higher than those of population mean from 125th day of fruit set upto harvesting. The initial value at 25th day was 0.001g which increased steadily upto 150 days (0.14 g) and thereafter grew very rapidly to 0.51 g at harvest (212 days). The following regression equation described the phenomenon of mace growth in N7 during the ontogeny of fruit.

$$Y (\text{mace}) = -0.126 + 0.002(X)$$

This first degree polynomial explained 85 per cent variation in mace growth.

In N72 where the fruit development took average period of 246 days the mace development steadily occurred upto 200 days of fruit set there after it developed rapidly upto harvest (246 days) and reached to 0.57 g. The linear regression equation below summarised the process of mace development in N72.

$$Y (\text{mace}) = -0.146 + 0.002(X)$$

In N37 also the period required for fruit development was moderate (246 days). The mace growth in this genotype remarkably increased from 175 days (0.11g) upto harvest (246 days) which was 0.48 g. A second degree polynomial explained more than 99 per cent variation in dry weight of mace in N37. The following quadratic equation was found to be the best.

$$Y (\text{mace wt.}) = 0.075 - 0.002(X) + 0.00001(X^2)$$

From the results it can be observed that the mace development was rapid during the later stages of fruit development. In genotypes namely N72 & N36 it followed linear trend whereas, in genotypes N42 and N37 it followed quadratic trend. However, for the values averaged over population the cubic equation was the best fit and took the form as given below

$$Y (\text{mace wt.}) = 0.157 - 0.006(X) + 0.0000607(X^2) - 0.00000012(X^3)$$

4.6 Fruit characters :

4.6.1 Fruit length, breadth and weight :

The data on length, breadth and weight of fruit of 34 nutmeg genotypes recorded during 1999 and 2000 are given in Table 20 and illustrated with Fig. 4. On an average the nutmeg fruit had 5.16 cm length, 4.03 cm breadth and 43.80 g weight when averaged over 2 years. The variation in all these three dimensions was statistically significant in both the years. Among the 34 genotypes N23 had maximum fruit length (6.29 cm) followed by N66 (6.03 cm) and N57 (5.85 cm). The minimum average fruit length was noticed in N32 (4.01 cm). The maximum fruit breadth was noticed in N57 (5.10 cm) followed by N56 (4.69 cm) whereas minimum fruit length was observed in N72 (3.45 cm) followed by N10 (3.47

cm). The maximum pooled average weight was noticed in N23 (68.74 g) followed by N66 (63.28 g) whereas a minimum fruit weight was noticed in N43 (26.98 g) followed by N 72 (29.80 g). A critical perusal indicated that the genotypes possessing highest fruit weight had the longest fruit size. In this connection N23, N66 and N57 are the distinct genotypes which had very high fruit weight (68.74, 63.28 and 60.13g respectively) as well as long fruit dimensions and maximum fruit width. Further the genotypes having lowest fruit weight also had smaller dimensions in terms of length and breadth of fruit. The genotypes N43 and N72 had minimum fruit weight and were characterized by smaller length and breadth. In other words it can be stated that length and breadth are two important determinants of ultimate fruit weight in nutmeg.

Table 20. Length, breadth and weight of fruits of different nutmeg genotypes

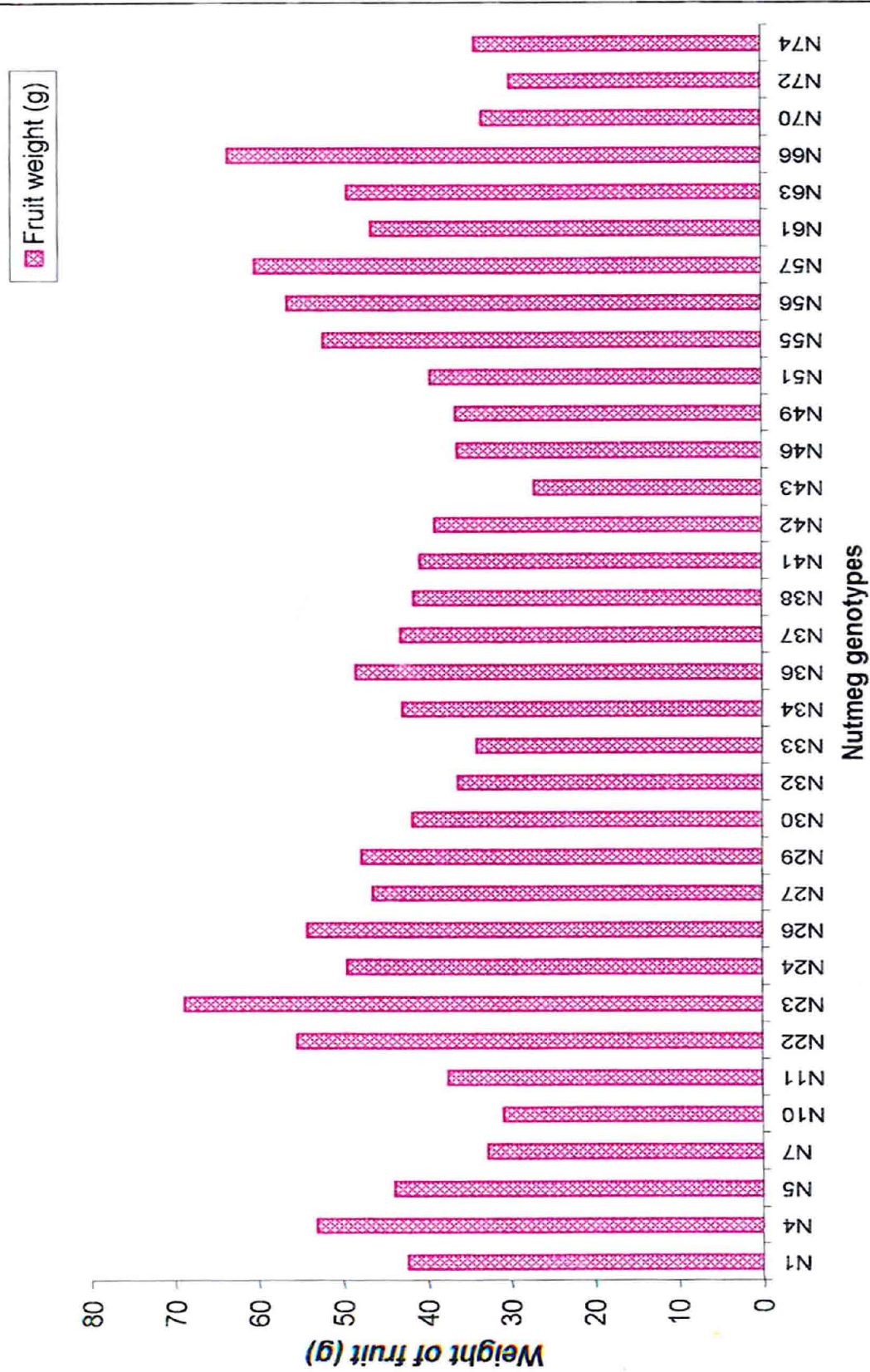
Genotype	Length of fruit (cm)			Breadth of fruit (cm)			Weight of fruit (g)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	5.46	5.04	5.25	4.05	3.92	3.99	44.49	40.05	42.27
N-4	5.10	5.07	5.08	4.14	4.23	4.19	52.76	53.50	53.14
N-5	5.54	5.03	5.28	4.28	3.91	4.09	47.94	39.69	43.82
N-7	5.20	4.16	4.81	3.71	3.52	3.62	35.86	29.55	32.71
N-10	5.53	4.72	5.13	3.60	3.32	3.47	35.94	25.69	30.82
N-11	5.01	4.25	4.62	4.11	3.84	3.97	41.83	33.06	37.45
N-22	5.57	5.50	5.53	4.39	4.22	4.31	53.07	52.76	55.41
N-23	5.92	6.65	6.29	4.32	4.93	4.62	58.47	79.31	68.74
N-24	5.52	5.76	5.65	4.27	4.34	4.31	43.57	55.31	49.44
N-26	5.84	5.80	5.82	4.73	4.04	4.38	55.83	52.42	54.12
N-27	5.51	4.97	5.24	4.54	3.74	4.14	53.40	39.30	46.35
N-29	5.66	4.90	5.29	4.32	3.99	4.16	51.86	43.43	47.65
N-30	5.62	5.18	5.40	3.95	3.92	3.94	42.46	40.73	41.60
N-32	3.99	4.03	4.01	3.87	3.81	3.84	38.92	33.50	36.21
N-33	4.87	4.51	4.69	3.84	3.46	3.66	37.88	29.99	33.94
N-34	5.23	5.05	5.14	4.09	4.08	4.09	45.61	39.84	42.73
N-36	5.07	4.64	4.86	4.08	4.04	4.06	51.09	45.55	48.32

Table 20 continued ...

Genotype	Length of fruit (cm)			Breadth of fruit (cm)			Weight of fruit (g)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-37	5.15	4.95	5.05	4.07	3.88	3.98	45.19	40.69	42.94
N-38	5.29	4.79	5.04	4.02	3.88	3.92	44.08	38.76	41.43
N-41	4.96	4.75	4.86	4.03	3.82	3.93	42.93	38.37	40.65
N-42	5.36	5.16	5.26	3.99	3.68	3.84	42.48	35.23	38.86
N-43	5.06	4.04	4.55	4.19	3.14	3.67	31.83	22.11	26.98
N-46	5.22	4.86	5.04	3.75	3.65	3.71	38.06	34.21	36.13
N-49	5.68	4.92	5.30	3.79	3.34	3.51	39.46	33.28	36.37
N-51	5.10	4.57	4.84	3.99	3.77	3.88	42.29	36.34	39.32
N-55	5.33	5.06	5.20	4.35	4.77	4.56	54.69	59.36	52.03
N-56	6.16	5.42	5.79	5.39	3.98	4.69	62.24	50.43	56.33
N-57	5.99	5.71	5.85	4.50	5.71	5.10	63.79	56.47	60.13
N-61	5.68	4.68	5.19	4.47	3.94	4.21	53.05	39.57	46.31
N-63	6.06	5.35	5.71	4.18	3.84	4.01	50.85	47.49	49.17
N-66	6.20	5.86	6.03	5.54	4.45	4.50	64.66	61.89	63.28
N-70	5.16	4.63	4.90	3.55	3.59	3.57	33.96	32.38	33.17
N-72	4.43	4.44	4.44	3.53	3.35	3.45	30.95	28.66	29.80
N-74	4.83	4.17	4.49	3.95	3.55	3.76	37.93	29.95	33.94
Mean	5.36	4.99	5.16	4.13	3.93	4.03	46.16	41.70	43.80
SEM $\pm$	0.16	0.16	0.09	0.12	0.09	0.08	2.66	1.47	1.75
C.D. at 5%	0.46	0.46	0.26	0.35	0.26	0.23	7.67	4.24	5.05

The population under study thus apparently showed the significant variation for length, breadth and weight of fruit. This variation could be further partitioned into three different components namely genotypic, phenotypic and environmental variation. From the data in Table 21 it is revealed that the genotypic as well as phenotypic coefficient of variation for fruit length and fruit breadth was almost similar in magnitudes and the environmental coefficient of variation was very low (0.40). This suggested that these two characters are not influenced by environment and the selection on the basis of phenotypic observation can be reliable. Further the magnitudes of PCV (23.19) and GCV (22.49) for total fruit weight were higher than those for length and breadth. This suggested that there was a

Fig. 4. Weight of fruit (g) of nutmeg genotypes



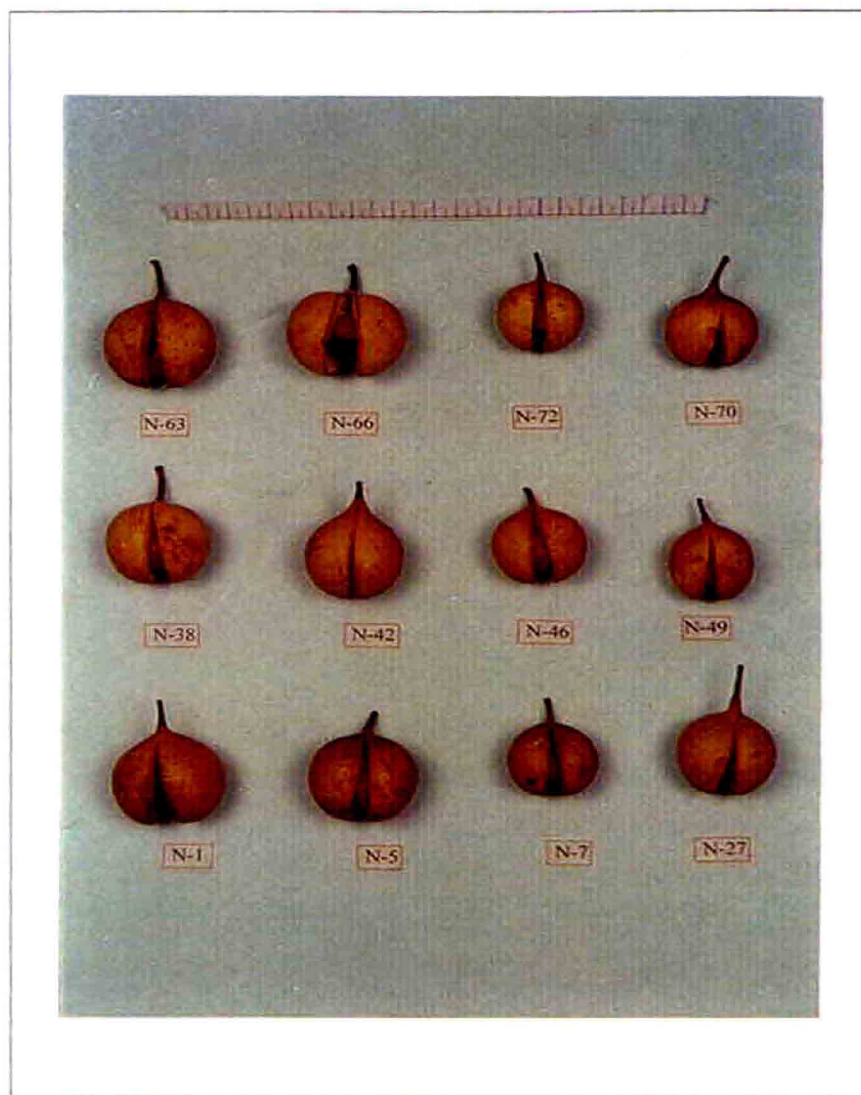


Plate 11. Fruits at harvest of various nutmeg genotypes

good amount of variation in total fruit weight at genotypic as well as phenotypic level. The magnitude of heritability for fruit length, breadth and weight very high which suggested a scope for selection of the better genotypes for these three characters. The Genetic advance on per cent mean basis was lowest for fruit length, higher for fruit breadth and highest for fruit breadths. This again suggested that there is a good scope for exploiting variation by selection on per se performance basis for total fruit weight which is the character of ultimate interest.

Table 21. Genetic parameters for fruit length, fruit breadth and fruit weight in nutmeg.

Sr. No.	Particulars	Fruit length	Fruit breadth	Fruit weight
1.	Mean sum of squares for treatments	0.476**	0.285**	200.20**
2.	Mean sum of squares for Error	0.019	0.013	6.104
3.	Phenotypic variance	0.25	0.15	103.16
4.	Genotypic variance	0.23	0.14	97.05
5.	Environmental variance	0.02	0.01	6.11
6.	Phenotypic coefficient of variation (PCV)	9.64	9.58	23.19
7.	Genotypic coefficient of variation (GCV)	9.24	9.18	22.49
8.	Environmental coefficient of variation (ECV)	0.40	0.40	0.70
9.	Heritability (h^2b)	92.20	91.60	94.10
10.	Genetic advance (GA)	0.47	0.73	19.69
11.	Genetic Advance on % mean basis (GAM)	9.12	18.07	44.95

** Significant at 1 per cent level of significance.

From the foregoing results it can be inferred that there is a good amount of variability for length, breadth and weight in the nutmeg population under study. These characters are highly heritable and among them fruit weight has high value of GA on per cent mean basis. The selection of genotypes therefore constitutes the next step in the improvement programme. Using the population mean as truncation value

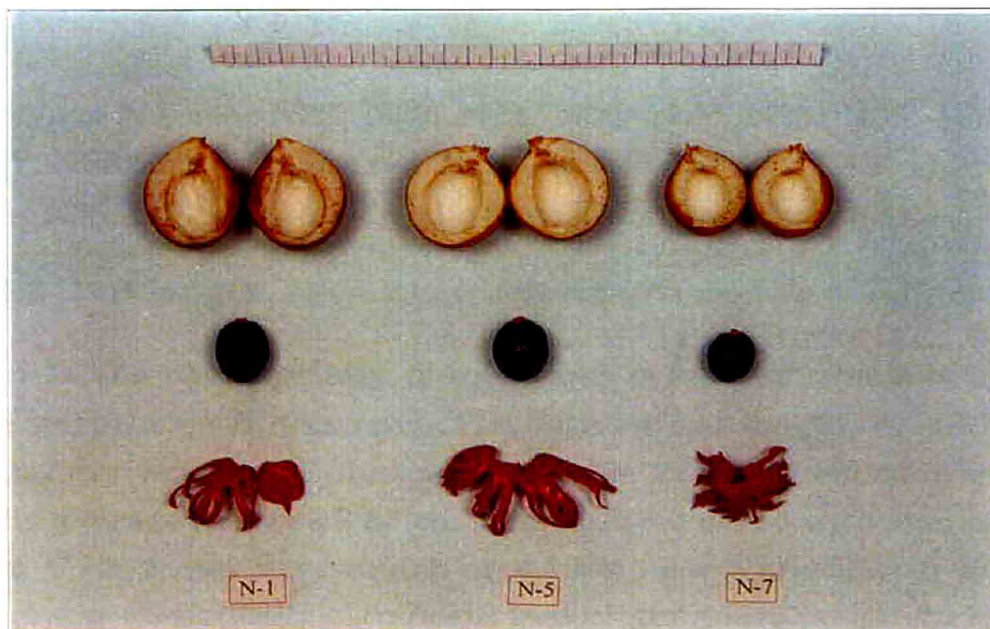


Plate 12. Pericarp, nut and mace in fruit of nutmeg genotypes N1, N5, N7



Plate 13. Pericarp, nut and mace in fruit of nutmeg genotypes N27, N30 and N38

the genotypes N4, N5, N22, N23, N24, N26, N27, N29, N36, N55, N56, N57, N61, N63 and N66 deserve due attention for further study whereas genotypes N23, N57 and N66 are the most promising genotypes.

4.6.2 Nut length, breadth, fresh weight and dry weight :

Nut is the commercially nutmeg and hence nut characters are of immense importance in this crop. The data on nut length, breadth, fresh weight and dry weight are presented in Table 22 and illustrated in Fig. 5 and 6. The average nut was 2.83 cm long, 2.05 cm broad with average fresh weight of 6.79 g and dry weight of 4.58 g. The variation in all these characters was statistically significant in both the years under study except nut length during 2000. The genotype N66 recorded the maximum nut length (3.20 cm) followed by N 57 and N23 (3.12 cm) whereas it was minimum in N11 (2.26 cm) followed by N 43 (2.28 cm) and N32 (2.36 cm). The maximum breadth of nut was in N55 (2.32 cm) followed by N22 and N57 (2.31 cm) whereas it was minimum in N49 (1.79 cm) followed by N7 (1.84 cm). The pooled mean fresh weight of nut was the highest in N22 (9.73 g) followed by N57 (9.17 g) and N23 (9.04 g). The genotype N43 produced the lightest nuts (4.73g) followed by N32 (4.85 g) and N70 (4.90g). The maximum pooled dry weight of nut was noticed in N22 (6.51 g) followed by N23 (6.42 g) and N57 (6.06 g), whereas the genotype N43 recorded the minimum weight of dried nut (3.28 g) followed by N32 (3.38 g) and N33 (3.53 g). Thus the data showed that the genotypes producing bold nuts with maximum length and breadth recorded heavy nuts with respect to fresh and dry weight. In this connection N22, N23 and N57 are the genotypes, which deserve attention. On the other hand, the genotypes having smaller length and breadth of nut recorded lowest nut weight. The genotypes N43 and N32 produced small nuts and were also characterized by shorter length and breadth. It is thus evident that length and breadth of nut are the two important determinants of fresh and dry weight in nutmeg.

Fig. 5. Weight of pericarp, nut and mace (g) of nutmeg genotypes

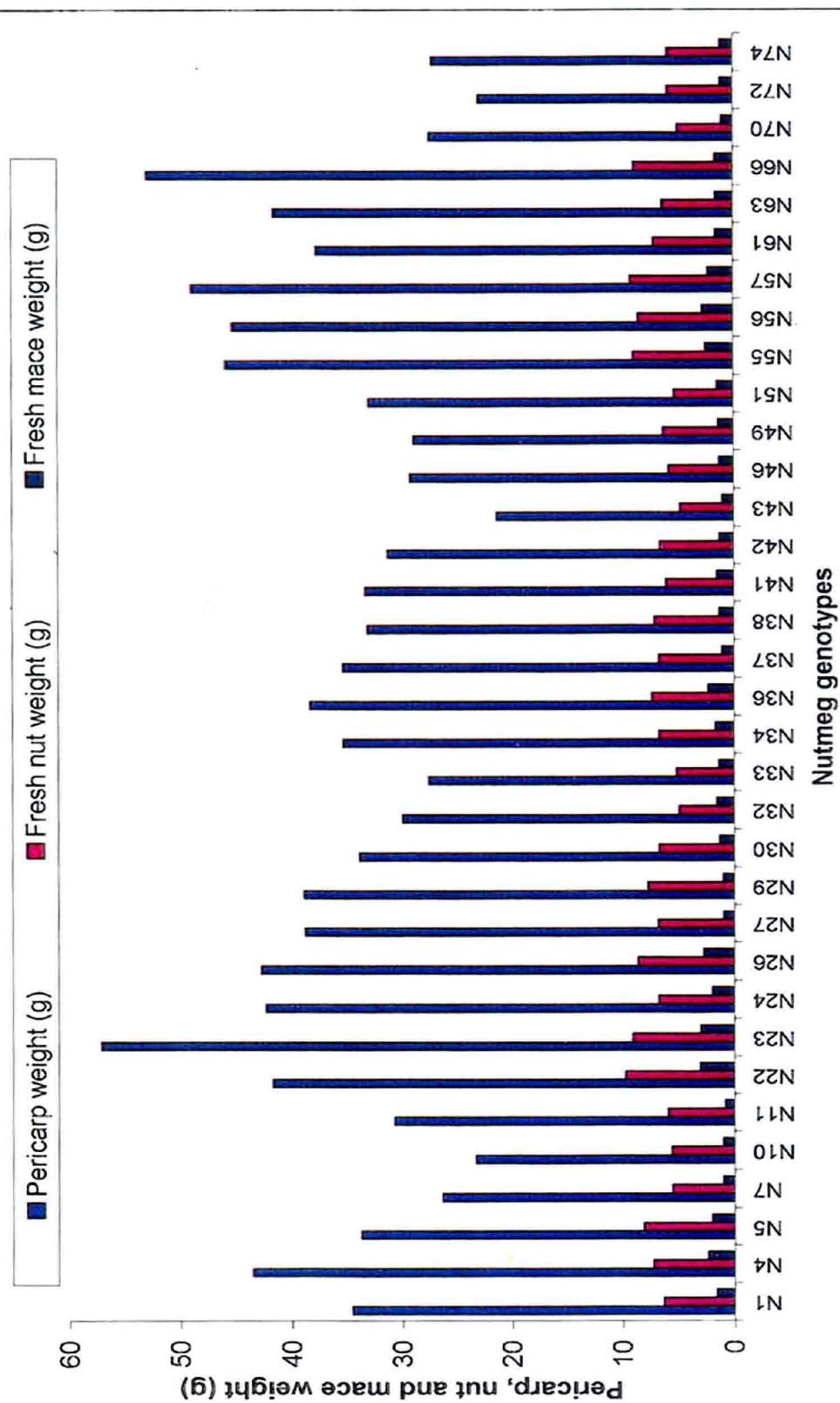
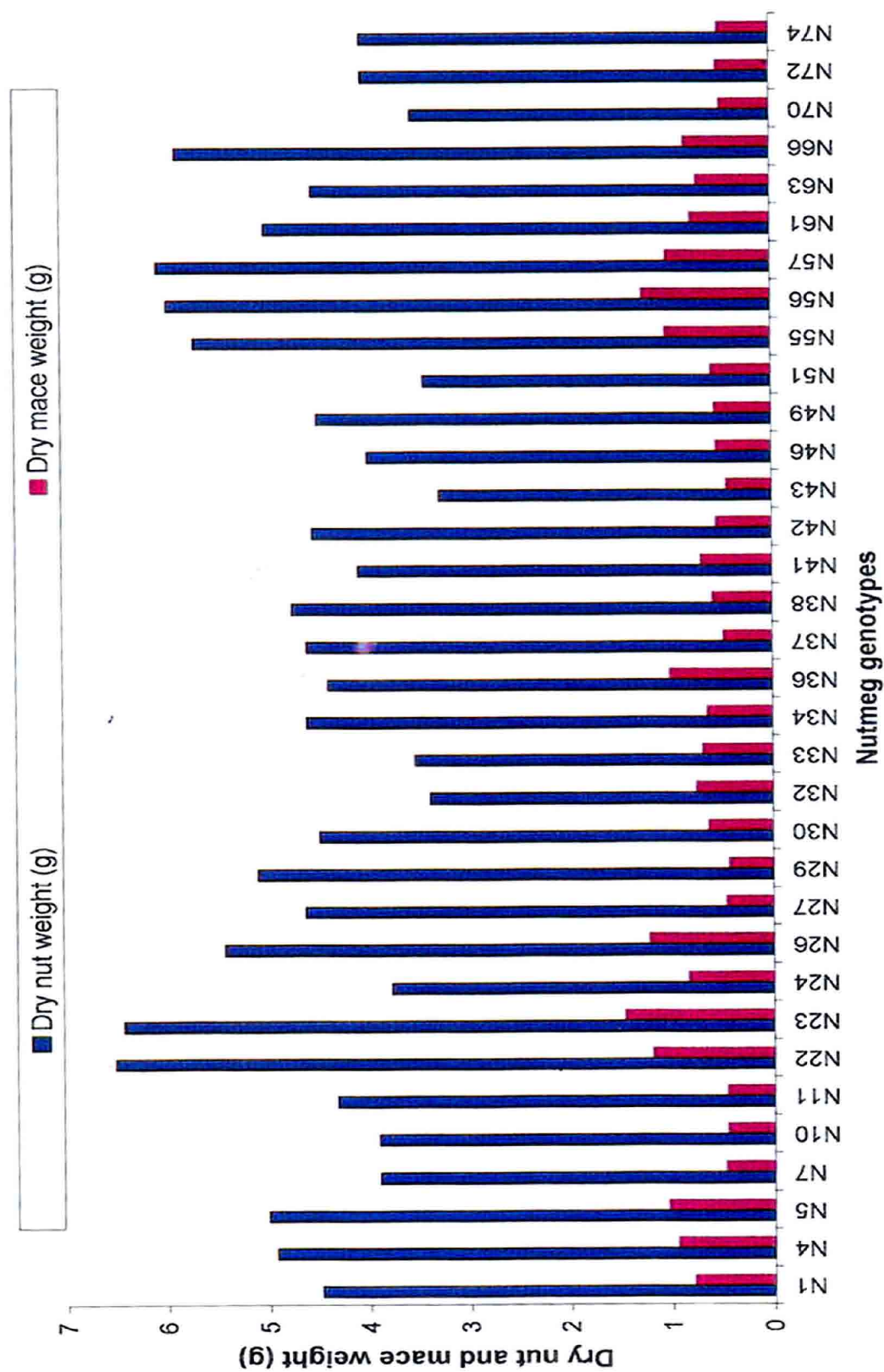


Table 22. Length, breadth, fresh weight and dry weight of nut of different nutmeg genotypes

Geno- type	Length of nut (cm)			Breadth wt. of nut (cm)			Fresh wt. of nut (g)			Dry weight of nut (g)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	2.98	2.68	2.83	2.15	1.84	2.00	7.23	5.31	6.28	5.06	3.88	4.47
N-4	2.47	2.73	2.60	2.04	2.17	2.11	7.56	6.82	7.19	5.82	4.02	4.92
N-5	3.04	3.05	3.05	2.21	2.10	2.15	8.99	7.13	8.06	5.57	4.43	5.00
N-7	2.73	2.42	2.57	1.84	1.83	1.84	6.20	4.79	5.49	4.40	3.36	3.89
N-10	3.35	2.80	3.08	1.99	1.91	1.95	6.20	4.85	5.57	4.34	3.46	3.90
N-11	2.57	2.31	2.26	2.09	1.88	1.99	6.52	5.14	5.83	4.84	3.78	4.31
N-22	3.04	2.98	3.01	2.49	2.13	2.31	10.50	8.95	9.73	7.01	6.00	6.51
N-23	3.11	3.12	3.12	2.26	2.25	2.26	8.16	9.92	9.04	5.80	7.04	6.42
N-24	2.66	3.05	2.86	1.87	2.26	2.07	5.37	8.06	6.72	3.02	4.52	3.77
N-26	3.20	3.00	3.10	2.46	2.04	2.25	10.13	7.02	8.58	6.52	4.31	5.42
N-27	2.93	2.86	2.90	2.09	1.98	2.04	7.22	6.28	6.75	4.91	4.33	4.62
N-29	3.31	2.86	3.09	2.27	1.88	2.08	8.59	6.74	7.67	5.70	4.39	5.09
N-30	2.67	2.83	2.75	2.13	2.03	2.08	6.96	6.31	6.64	4.73	4.23	4.48
N-32	2.51	2.20	2.36	1.98	1.92	1.95	5.55	4.16	4.85	3.85	2.91	3.38
N-33	2.64	2.63	2.64	2.06	1.70	1.88	5.84	4.39	5.12	4.03	3.03	3.53
N-34	2.68	2.48	2.58	2.31	2.07	2.19	7.51	5.70	6.65	5.20	3.99	4.60
N-36	2.89	2.68	2.79	2.40	2.14	2.27	8.35	6.30	7.33	5.00	3.78	4.39
N-37	2.87	2.81	2.85	2.13	1.87	2.00	7.08	6.23	6.66	4.88	4.31	4.60
N-38	2.89	2.77	2.83	2.10	1.99	2.05	7.41	6.72	7.07	4.86	4.61	4.74
N-41	2.92	2.59	2.76	2.10	1.79	1.95	6.88	5.13	6.01	4.67	3.50	4.09
N-42	2.79	2.60	2.70	2.15	1.97	2.09	7.01	6.14	6.58	4.88	4.20	4.54
N-43	2.34	2.21	2.28	1.73	2.21	1.97	5.64	3.82	4.73	3.83	2.71	3.28
N-46	2.79	2.83	2.81	1.99	1.83	1.91	5.99	5.53	5.76	4.10	3.89	3.99
N-49	3.24	2.87	3.05	1.78	1.81	1.79	6.87	5.69	6.28	4.85	4.13	4.49
N-51	2.58	2.53	2.56	2.01	1.91	1.97	5.52	4.97	5.25	3.61	3.24	3.43
N-55	3.08	2.85	2.97	2.38	2.25	2.32	8.82	9.00	8.91	5.57	5.83	5.70
N-56	3.29	2.93	3.11	2.11	2.16	2.13	9.78	7.17	8.48	7.04	4.89	5.97
N-57	3.23	3.00	3.12	2.39	2.23	2.31	10.03	8.30	9.17	6.63	5.49	6.06
N-61	3.04	2.71	2.88	2.24	2.05	2.15	8.28	6.25	7.06	5.62	4.39	5.00
N-63	3.17	2.88	3.03	1.97	1.96	1.97	6.72	5.88	6.30	4.94	4.12	4.53
N-66	3.29	3.12	3.20	2.31	2.10	2.14	9.78	7.81	8.80	6.27	5.46	5.87
N-70	2.64	2.45	2.55	1.85	1.86	1.96	5.07	4.72	4.90	3.72	3.36	3.54
N-72	2.43	2.54	2.49	2.07	1.96	2.11	5.86	5.78	5.82	3.98	4.07	4.03
N-74	2.66	2.47	2.57	2.15	1.81	1.98	6.50	5.08	5.79	4.50	3.57	4.04
Mean	2.91	2.77	2.83	2.10	1.99	2.05	7.35	6.24	6.79	4.99	4.21	4.58
SEM±	0.25	0.27	0.14	0.14	0.07	0.07	0.51	0.30	0.29	0.35	0.20	0.22
C.D. at 5%	0.72	N.S.	0.40	0.40	0.20	0.20	1.47	0.87	0.84	1.01	0.58	0.63

Fig. 6. Dry nut and mace weight (g) of nutmeg genotypes



Significant variation was noticed in nutmeg genotypes for nut with respect to length, breadth, fresh weight and dry weight. This variation was further partitioned into genotypic, phenotypic and environmental variation and is presented in Table 23. Among the nut parameters the genotypic coefficient of variation (GCV) and the phenotypic coefficient of variation (PCV) was minimum in nut breadth (6.72 and 8.44, respectively). The GCV and PCV noticed in fresh nut weight was the maximum (19.76 and 20.65 respectively). The environmental coefficient of variation (ECV) for all the characters was very low indicating that these characters are under little influence of the environment and reliable selection on the basis of phenotypic observations for these traits can be made. Further, the magnitudes of PCV and GCV for fresh nut weight (20.65 and 19.76, respectively) and dry nut weight (19.65 and 18.39, respectively) showed that there was a good amount of variation at genotypic as well as phenotypic level for these characters. The magnitudes of heritability was

Table 23. Genetic parameters for length, breadth, fresh weight and dry weight of nut in nutmeg.

Sr. No.	Particulars	Nut length	Nut breadth	Fresh weight	Dry weight
1.	Mean sum of squares for treatments	0.191**	0.048**	3.771**	1.518**
2.	Mean sum of squares for Error	0.041	0.011	0.167	0.100
3.	Phenotypic variance	0.12	0.03	1.97	0.81
4.	Genotypic variance	0.08	0.02	1.80	0.71
5.	Environmental variance	0.04	0.01	0.17	0.10
6.	Phenotypic coefficient of variation (PCV)	12.06	8.44	20.65	19.65
7.	Genotypic coefficient of variation (GCV)	9.69	6.72	19.76	18.39
8.	Environmental coefficient of variation (ECV)	2.37	1.72	0.89	1.26
9.	Heritability (h^2b)	64.9	62.3	91.50	87.60
10.	Genetic advance (GA)	0.46	0.22	2.64	1.62
11.	Genetic Advance on % mean basis (GAM)	16.12	10.84	38.93	35.46

** Significant at 1 per cent level of significance

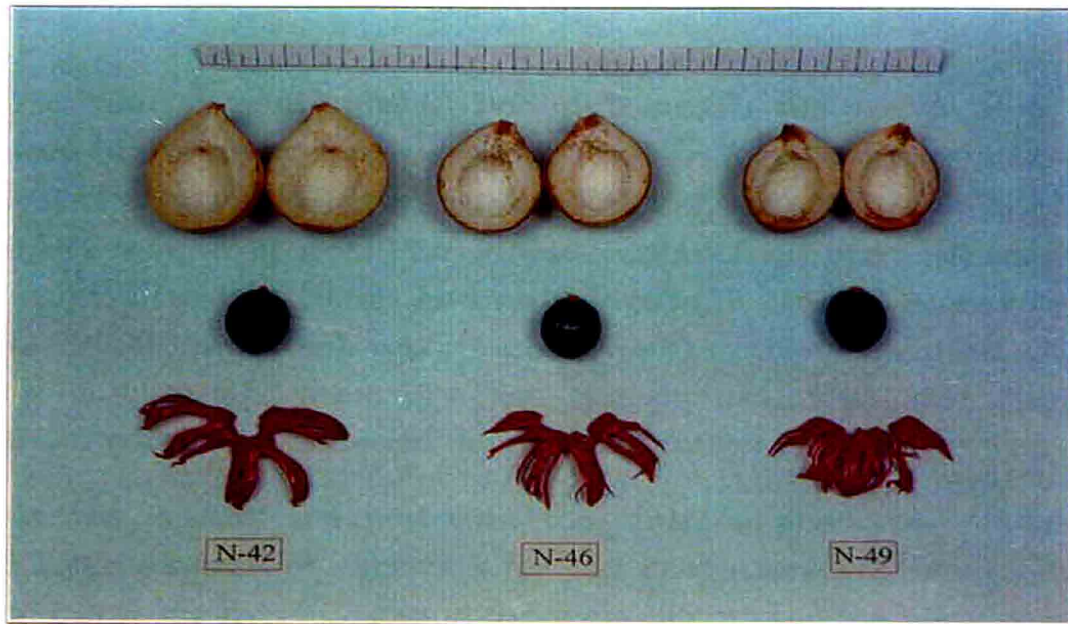


Plate 14. Pericarp, nut and mace in fruit of nutmeg genotypes N42, N46 and N49

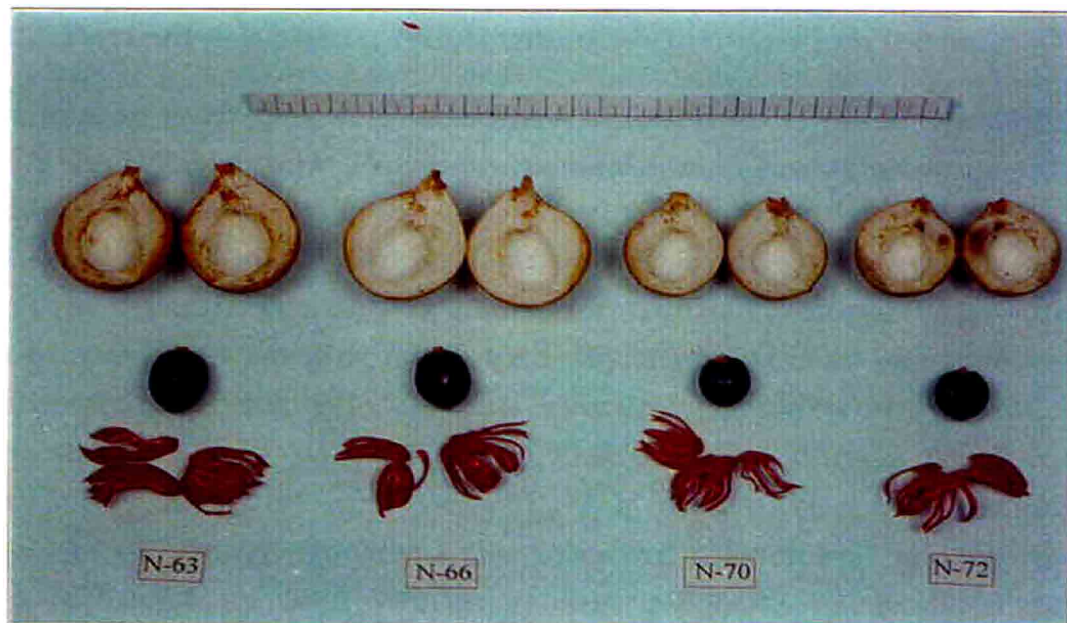


Plate 15. Pericarp, nut and mace in fruit of nutmeg genotypes N63, N66, N70 and N72

moderate for nut breadth (62.3) and nut length (64.9), whereas it was considerably high for dry nut weight (87.60) and fresh nut weight (91.50). This indicated a vast scope of selection of nutmeg genotypes on the basis of fresh and dry weight of nut. The genetic advance on per cent mean basis was low in nut breadth (10.84) and nut length (16.12) and moderate in dry nut weight (35.46) and fresh nut weight (38.93). This again is an indication that fresh nut weight and dry nut weight are the most important characters on which selection can be made in nutmeg.

Thus the results indicate that the nutmeg genotypes under study possessed large amount of variation for nut characters viz. length, breadth, fresh weight and dry weight. Among these characters the fresh and dry weight of nut are highly heritable and have high values of GAM. These characters are useful in selection of nutmeg genotypes. Using the population mean as a base value the nutmeg genotypes N4, N5, N22, N23, N27, N29, N34, N38, N55, N56, N57, N61, N66 can be treated as better genotypes and among them N57, N22 and N23 are the most promising ones.

4.6.3 Pericarp weight, fresh mace weight and dry mace weight :

In nutmeg fruit nut and mace are embedded in pericarp which splits open when the fruit ripens. Pericarp has economic importance as number of value added products such as chutney, jam, jelly, candy etc. can be prepared from it. Mace is the aril surrounding the nut and is a spice in demand. The nutmeg genotypes differ for quantity of pericarp and mace. The data on pericarp weight, fresh and dry mace weight are given in Table 24 and illustrated with Fig. 5. The average pericarp weight of nutmeg genotypes under study was 35.62 g. The average values for fresh mace weight and dry mace weight were 1.56 g and 0.74 g respectively. The genotype N23 (57.03 g) produced the maximum pericarp among all the 34 genotypes followed by N66 (52.78 g) and N55 (45.73 g). The minimum pericarp was noticed in N43 (21.31 g) followed by N72 (22.92 g) and N10 (23.29 g). The highest fresh weight of mace was recorded in N22 (2.98 g) followed by N23 (2.96 g) and it was minimum in N11 (0.74 g) followed by N27 (0.91 g) and N43 (0.93 g). The pooled average weight of dry mace

recorded in N23 (1.46 g) was the highest followed by N56 (1.26 g) and N26 (1.22 g); whereas it was minimum in N29 (0.44 g) followed by N43 (0.45 g).

Table 24. Pericarp weight, fresh and dry mace weight of different nutmeg genotypes

Genotype	Pericarp weight (g)			Fresh mace weight (g)			Dry mace weight (g)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	35.53	33.35	34.44	1.69	1.39	1.54	0.87	0.72	0.79
N-4	42.41	44.34	43.38	2.21	2.34	2.28	0.93	0.96	0.95
N-5	36.34	30.93	33.64	2.06	1.64	1.94	1.20	0.87	1.04
N-7	28.65	23.92	26.29	1.00	0.86	0.94	0.49	0.45	0.48
N-10	28.53	18.04	23.29	1.15	0.74	0.95	0.59	0.38	0.46
N-11	33.99	27.26	30.63	0.83	0.64	0.74	0.61	0.29	0.46
N-22	41.84	41.28	41.56	3.45	2.50	2.98	1.35	1.02	1.19
N-23	47.82	66.24	57.03	2.76	3.16	2.96	1.19	1.72	1.46
N-24	36.53	45.64	42.21	1.68	2.11	1.90	0.75	0.94	0.84
N-26	42.33	42.95	42.64	3.37	2.03	2.70	1.58	0.86	1.22
N-27	42.30	32.10	38.70	0.90	0.91	0.91	0.46	0.47	0.46
N-29	41.65	35.90	38.78	1.10	0.78	0.94	0.51	0.37	0.44
N-30	34.24	33.32	33.78	1.26	1.39	1.26	0.60	0.66	0.63
N-32	31.95	27.79	29.87	1.43	1.54	1.49	0.72	0.78	0.75
N-33	30.44	24.58	27.51	1.61	1.02	1.32	0.84	0.53	0.69
N-34	37.35	33.10	35.23	1.86	1.30	1.58	0.69	0.58	0.64
N-36	39.99	37.55	38.23	2.76	1.69	2.23	1.26	0.77	1.01
N-37	37.07	33.48	35.28	1.04	0.97	1.01	0.51	0.44	0.48
N-38	35.62	30.48	33.05	1.36	1.17	1.27	0.63	0.54	0.59
N-41	34.47	31.94	33.21	1.59	1.31	1.45	0.77	0.62	0.70
N-42	33.99	28.39	31.20	1.48	0.89	1.19	0.68	0.43	0.55
N-43	25.18	17.45	21.31	1.02	0.85	0.93	0.49	0.39	0.45
N-46	30.73	27.59	29.16	1.35	1.08	1.22	0.59	0.48	0.54
N-49	31.27	26.35	28.82	1.32	1.24	1.28	0.58	0.53	0.56
N-51	35.12	30.20	32.87	1.66	1.15	1.41	0.71	0.47	0.59
N-55	43.51	47.94	45.73	2.36	2.41	2.39	1.03	1.03	1.03
N-56	49.53	40.78	45.16	2.93	2.47	2.70	1.34	1.17	1.26
N-57	51.28	46.25	48.77	2.48	1.90	2.19	1.15	0.88	1.02

Table 24 continued.....

Genotype	Pericarp weight (g)			Fresh mace weight (g)			Dry mace weight (g)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-61	43.04	32.20	37.60	1.73	1.22	1.48	0.91	0.64	0.78
N-63	42.69	40.17	41.43	1.44	1.52	1.49	0.71	0.72	0.72
N-66	53.00	52.56	52.78	1.60	1.51	1.56	0.87	0.82	0.84
N-70	27.98	26.76	27.37	1.01	0.91	0.96	0.50	0.46	0.49
N-72	24.09	21.75	22.92	1.09	1.01	1.05	0.54	0.50	0.52
N-74	30.24	24.01	27.12	1.19	0.86	1.03	0.59	0.43	0.51
Mean	37.17	34.16	35.62	1.70	1.42	1.56	0.79	0.67	0.74
SEM $\pm$	2.22	1.53	1.29	0.14	0.08	0.09	0.08	0.04	0.04
C.D. at 5%	6.40	4.41	3.72	0.40	0.23	0.26	0.23	0.11	0.11

Importantly the genotypes under study recorded significant variation for pericarp weight, fresh weight of mace and dry weight of mace. This variation partitioned in the components viz. phenotypic, genotypic and environmental is presented in Table 25. The perusal of data indicate that the GCV and PCV for all the three characters were fairly high. The maximum GCV was recorded in fresh weight of mace (40.33) followed by dry mace weight (36.66) and pericarp weight (23.56). The PCV showed similar trend. It is interesting to note that the ECV recorded in all the three components was very low suggesting that all these three characters are not under the influence of environment and the selection on the basis of phenotypic observations for these characters can be effective. The higher magnitudes of PCV and GCV indicated a good amount of variation in all the three characters at genotypic as well as phenotypic level. The heritability recorded in all these three components was very high. It indicated a scope for selection of nutmeg genotypes for these characters. The value for GAM was the highest for fresh mace weight (81.49) followed by dry mace weight (73.53) and was moderate in flesh weight (47.44). This indicated that there is possibility of better selection made on the basis of mace weight which is a character of economical interest.

Table 25. Genetic parameters for pericarp weight, fresh and dry mace weight in nutmeg.

Sr. No.	Particulars	Pericarp weight	Fresh mace weight	Dry mace weight
1.	Mean sum of squares for treatments	144.20**	0.810**	0.151**
2.	Mean sum of squares for Error	3.333	0.015	0.004
3.	Phenotypic variance	73.79	0.41	0.08
4.	Genotypic variance	70.46	0.40	0.07
5.	Environmental variance	3.33	0.01	0.01
6.	Phenotypic coefficient of variation (PCV)	24.11	41.04	37.65
7.	Genotypic coefficient of variation (GCV)	23.56	40.33	36.66
8.	Environmental coefficient of variation (ECV)	0.55	0.71	0.99
9.	Heritability (h^2b)	95.50	96.40	94.80
10.	Genetic advance (GA)	16.89	1.27	0.54
11.	Genetic Advance on % mean basis (GAM)	47.44	81.49	73.53

** Significant at 1 per cent level of significance.

The results, thus, clearly indicate that the pericarp weight, fresh weight of mace and dry weight of mace had fairly high amount of variability in the nutmeg genotypes under study. Among these the weight of mace both as fresh and dry is highly heritable and had high GAM. The selection on the basis of mace weight can be effectively made in the genotypes under study using the population mean as partitioning value. The genotypes N1, N4, N5, N22, N23, N26, N27, N32, N36, N55, N56, N57, N61 and N66 can be rated as promising genotypes on mace weight basis and N23, N26 and N56 are the most distinct among them in this regard.

4.6.4 Kernel weight, shell weight and recovery :

Kernel and shell are the two components of nut and the former is the core nutmeg of commerce. Kernel is the actual part used as spice. Kernel and its recovery per cent have therefore prime importance. Eventually the nutmeg genotype possessing high amount of kernel and recovery (%) can be treated as the most promising. Shell has least economical value and its proportion in nut should be least in a good nutmeg genotype. The data on

kernel weight (g), shell weight (g) and recovery (%) of 34 nutmeg genotypes recorded during 1999 and 2000 are presented in Table 26 and illustrated with Fig. 7. In an average the nutmeg genotypes under study recorded 3.17 g Kernel, 1.47 g shell and 68.42 per cent recovery. The kernel weight in genotype N22 (4.63 g) was the maximum followed by N57 (4.43 g) and N23 (4.36 g) whereas it was minimum in N51(2.28 g) followed by N43 (2.30 g) and N70 (2.45 g). The minimum average shell weight was recorded in N43 (0.98 g) followed by N70 (1.10 g) and N51 (1.15 g) whereas it was maximum in N23 (2.07 g) followed by N55 (2.04 g) and N66 (1.94 g). The maximum pooled recovery was observed in N24 (74.27%) followed by N57 (72.81%) and N56 (72.56%). In N63 (61.91%) the recovery recorded was the minimum followed by N4 (62.85%) and N55 (64.36%). The data also revealed that the genotypes possessing lowest kernel weight had the minimum shell weight. The genotypes N43, N51 and N70 are noteworthy in this connection. The recovery percentage did not indicate clear relationship with kernel weight. Further it was also noticed that as the nut weight increased the proportional weight of kernel and shell were also increased.

Table 26. Kernel weight, shell weight and recovery (%) of different nutmeg genotypes

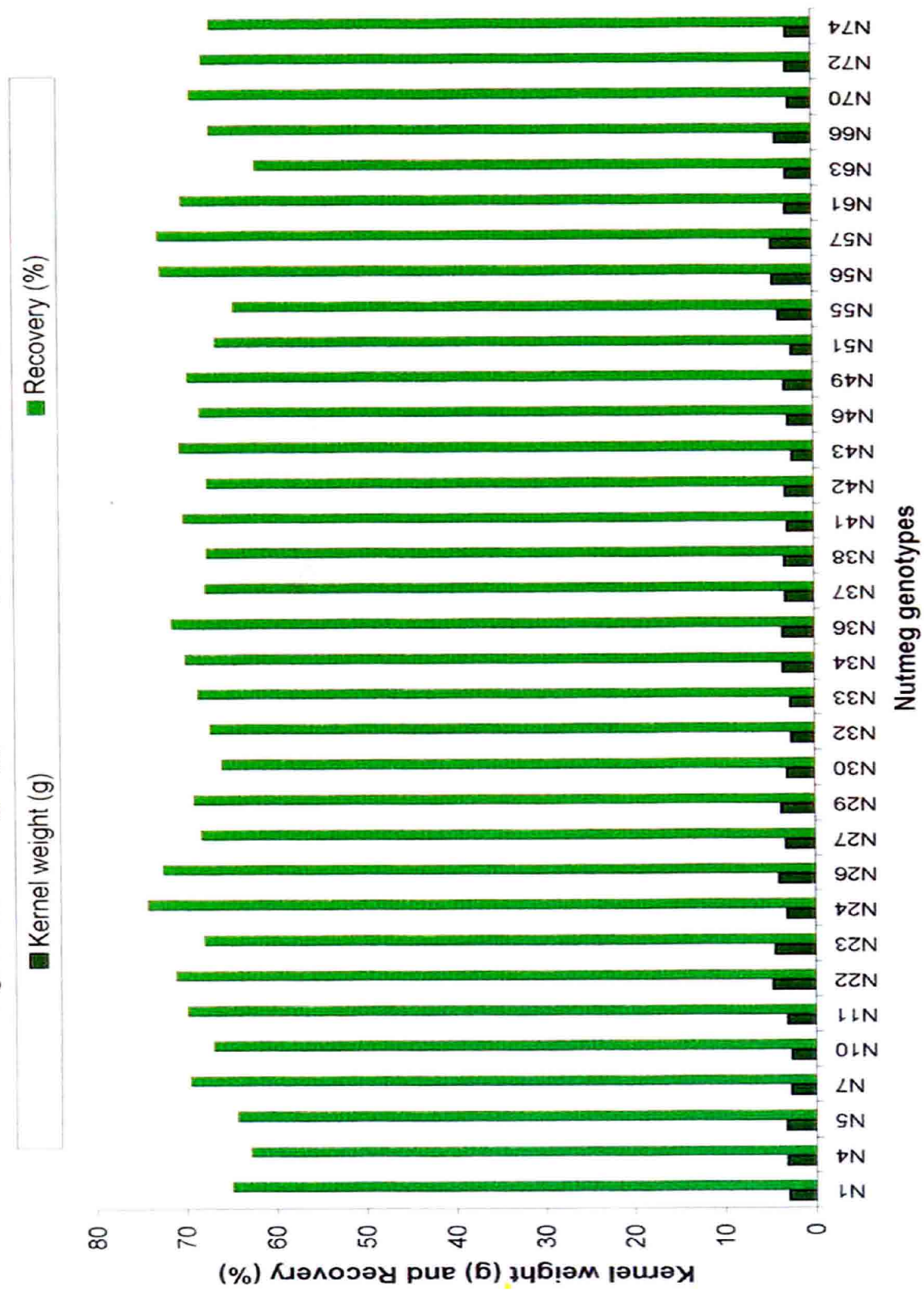
Genotype	Kernel weight (g)			Shell weight (g)			Recovery (%)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	3.38	2.27	2.92	1.68	1.43	1.55	66.80	63.11	64.96
N-4	3.81	2.43	3.12	2.01	1.60	1.81	65.38	60.31	62.85
N-5	3.53	2.77	3.15	1.81	1.66	1.73	66.19	62.59	64.39
N-7	2.95	2.43	2.69	1.45	0.94	1.20	67.00	72.14	69.57
N-10	2.91	2.32	2.61	1.43	1.14	1.29	66.95	67.03	66.99
N-11	3.36	2.67	3.02	1.66	1.12	1.39	69.34	70.48	69.91
N-22	4.95	4.31	4.63	2.07	1.70	1.89	70.53	71.79	71.16
N-23	4.02	4.69	4.36	1.78	2.35	2.07	69.36	66.65	68.01
N-24	2.83	3.28	3.06	1.36	1.24	1.31	75.96	72.58	74.27
N-26	4.93	2.99	3.97	1.59	1.32	1.46	75.66	69.43	72.54

Table 26 continued.....

Genotype	Kernel weight (g)			Shell weight (g)			Recovery (%)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-27	3.47	2.85	3.16	1.44	1.48	1.47	70.67	65.87	68.27
N-29	4.10	3.11	3.61	1.87	1.37	1.63	68.70	69.42	69.06
N-30	3.20	2.72	2.96	1.53	1.51	1.53	67.64	64.27	65.96
N-32	3.05	1.93	2.49	1.43	0.98	1.21	68.04	66.36	67.20
N-33	4.63	2.06	2.59	1.38	0.97	1.18	69.22	67.94	68.59
N-34	3.65	2.79	3.42	1.56	1.21	1.38	70.09	69.77	69.93
N-36	4.38	2.53	3.46	1.38	1.26	1.32	76.10	66.87	71.49
N-37	3.45	2.99	3.11	1.66	1.33	1.50	66.01	69.28	67.65
N-38	3.24	3.16	3.20	1.63	1.46	1.55	66.55	68.39	67.47
N-41	3.41	2.35	2.88	1.26	1.16	1.21	73.15	67.02	70.09
N-42	3.41	2.73	3.07	1.48	1.47	1.48	69.71	65.07	67.39
N-43	2.63	1.97	2.30	1.21	0.75	0.98	68.56	72.35	70.46
N-46	2.76	2.68	2.73	1.34	1.20	1.27	67.33	69.08	68.21
N-49	3.37	2.87	3.13	1.48	1.26	1.37	69.35	69.63	69.49
N-51	2.36	2.19	2.28	1.26	1.05	1.15	65.25	67.60	66.42
N-55	3.62	3.73	3.68	1.96	2.11	2.04	64.78	63.93	64.36
N-56	5.22	3.47	4.35	1.82	1.42	1.62	74.13	70.99	72.56
N-57	4.99	3.86	4.43	1.64	1.63	1.64	75.33	70.29	72.81
N-61	4.14	1.54	2.84	1.48	1.54	1.51	73.59	66.64	70.12
N-63	3.06	2.55	2.81	1.88	1.58	1.73	62.03	61.78	61.91
N-66	4.28	3.59	3.94	1.99	1.88	1.94	68.31	65.69	66.99
N-70	2.52	2.37	2.45	1.21	0.99	1.10	67.64	70.61	69.13
N-72	2.66	2.81	2.74	1.32	1.28	1.30	66.80	68.80	67.80
N-74	3.03	2.37	2.70	1.48	1.20	1.34	67.22	66.48	66.86
Mean	3.51	2.81	3.17	1.57	1.41	1.47	69.14	67.65	68.42
SEM $\pm$	0.22	0.14	0.13	0.11	0.25	0.06	0.30	0.08	0.43
C.D. at 5%	0.63	0.40	0.38	0.32	0.72	0.17	0.87	0.23	1.24

The genetic parameters for kernel weight, shell weight and recovery are presented in Table 27. The variation recorded for all these components was significant. The GCV and PCV was low for recovery (4.03 and 4.12 respectively) and moderate for shell weight (19.24 and 20.13) respectively). ECV was very low for all the three characters which suggested that the variation in these characters is not influenced by the environment. The higher magnitudes of PCV and GCV for kernel and shell weight indicated that there was good amount of variation at genotypic as well as phenotypic level for these characters. The magnitudes of heritability for all the three

Fig. 7. Kernel weight (g) and recovery (%) of nutmeg genotypes



characters were very high. It was 91.40 for kernel weight and 95.40 for recovery. This again suggested that these three characters are useful for making selections in nutmeg. The GAM was lowest in recovery (8.10), medium in shell (34.66) and highest in kernel (37.89).

Table 27. Genetic parameters for kernel weight, shell weight and recovery (%) in nutmeg.

Sr. No.	Particulars	Kernel weight	Shell weight	Recovery (%)
1.	Mean sum of squares for treatments	0.778**	0.144**	15.55**
2.	Mean sum of squares for Error	0.035	0.007	0.365
3.	Phenotypic variance	0.41	0.08	7.96
4.	Genotypic variance	0.37	0.07	7.60
5.	Environmental variance	0.04	0.01	0.36
6.	Phenotypic Coefficient of Variation (PCV)	20.13	18.59	4.12
7.	Genotypic Coefficient of Variation (GCV)	19.24	17.70	4.03
8.	Environmental Coefficient of Variation (ECV)	0.89	0.89	0.18
9.	Heritability (h^2b)	91.40	90.50	95.40
10.	Genetic advance (GA)	1.20	0.51	5.54
11.	Genetic Advance on % mean basis (GAM)	37.89	34.66	8.10

** Significant at 1 per cent level of significance.

The results obtained revealed that there was good amount of variability for kernel weight in nutmeg among the nutmeg genotypes under study. The kernel weight and can be used to make selection among these genotypes. On the basis of population mean for three characters the genotypes N22, N26, N29, N34, N36, N56, N57 could be considered as promising genotypes whereas N22 and N57 are the most promising genotypes among them.

4.6.5 Nutmeg butter and mace oil :

Concrete oil of nutmeg is known as nutmeg butter. It is rather firm in texture and has a pleasant odour of nutmeg and a greasy and aromatic flavour. It consists of myristin and has commercial use in soap and pharmaceutical industry. Mace oil is a thick red liquid giving characteristic

flavour of the mace. Higher proportion of these components in nut and mace are indicative of better quality of these products of commerce.

The data on nutmeg butter and mace oil composition of 34 nutmeg genotypes recorded during 1999 and 2000 are given in Table 28 and illustrated with Fig. 8. The pooled data for both the years showed that on an average the nutmeg genotypes under study had 36.33 per cent nutmeg butter in nut and 14.13 per cent oil in mace. The nutmeg butter observed in N49 (45.00%) was the highest among all the 34 nutmeg genotypes followed by N38 (44.8%) and N24 (41.6%) whereas it was minimum in N26 (27.6%) followed by N23 (29.1%) and N57 (29.7%). The maximum pooled mace oil was noticed in N34 (19.2%) followed by N42 (19%) and N63 (18.7%). In genotype N11 (6.5%) the mace oil was the minimum followed by N29 (8.5%) and N4 (9.1%).

Table 28. Nutmeg butter and mace oil (%) of nutmeg genotypes.

Genotype	Nutmeg butter (%)			Mace oil (%)		
	1999	2000	Pooled	1999	2000	Pooled
N-1	32.8	33.8	33.3	9.6	9.2	9.4
N-4	37.4	34.4	35.9	9.2	9.0	9.1
N-5	40.8	38.0	39.4	17.0	17.0	17.0
N-7	34.6	38.4	36.5	10.4	10.2	10.3
N-10	38.8	38.4	38.6	17.0	16.8	16.9
N-11	34.6	35.4	35.0	7.0	6.0	6.5
N-22	39.0	35.4	37.2	10.6	11.4	11.0
N-23	29.2	29.0	29.1	12.2	12.4	12.3
N-24	43.2	40.0	41.6	17.8	17.4	17.6
N-26	25.4	29.8	27.6	18.4	18.0	18.2
N-27	35.8	33.4	34.6	13.4	13.6	13.5
N-29	36.2	33.8	35.2	9.0	8.0	8.5
N-30	39.0	36.0	37.5	9.6	10.8	10.2
N-32	37.4	34.6	36.0	16.4	16.6	16.5
N-33	33.0	37.4	35.2	16.8	16.6	16.7
N-34	35.0	34.2	34.6	19.0	19.4	19.2
N-36	34.0	32.6	33.3	12.6	12.4	12.5
N-37	38.5	36.8	37.7	10.8	10.8	10.8

Table 28 continued.....

Genotype	Nutmeg butter (%)			Mace oil (%)		
	1999	2000	Pooled	1999	2000	Pooled
N-38	43.8	45.8	44.8	17.6	18.0	17.8
N-41	36.7	34.8	35.8	10.8	9.6	10.2
N-42	42.0	39.0	40.5	19.0	19.0	19.0
N-43	42.0	38.2	40.1	16.9	16.8	17.3
N-46	34.2	33.0	33.6	17.8	17.8	17.8
N-49	44.0	46.0	45.0	13.4	13.0	13.2
N-51	36.0	37.6	36.7	10.6	9.6	10.1
N-55	29.2	33.4	31.3	17.2	16.4	16.8
N-56	33.8	37.6	35.7	13.6	13.6	13.6
N-57	31.8	27.6	29.7	18.2	18.0	18.1
N-61	35.8	39.0	37.4	16.6	17.0	16.8
N-63	38.4	33.0	35.7	18.4	19.0	18.7
N-66	38.0	37.4	37.7	13.4	13.6	13.5
N-70	40.4	40.2	40.3	12.2	12.4	12.2
N-72	38.2	39.6	38.9	10.6	11.2	10.9
N-74	35.4	32.8	34.1	18.4	18.4	18.4
Mean	36.61	36.07	36.33	14.06	14.09	14.13
SEM $\pm$	0.61	0.53	0.51	0.72	1.47	0.37
C.D. at 5%	1.76	1.53	1.47	2.08	4.24	1.07

The genetic parameters for nutmeg butter and mace oil recorded for the nutmeg genotypes under study are presented in Table 29. It can be seen that both the components vary significantly. The values for PCV and GCV were lower for nutmeg butter (10.70 and 10.52, respectively) as compared to mace oil (26.39 and 26.13, respectively). The environment plays negligible role in deciding these components as the magnitudes of ECV were very low for both these components and very high values of heritability confirmed this suggesting the usefulness of these parameters for selection of nutmeg genotypes on per se performance basis. Thus using the mean values of nutmeg butter and mace oil as truncation value the genotypes N5, N10, N24, N38, N42, N43, N61 can be treated as the better genotypes whereas the genotypes N24, N38, N42 can be considered as most promising genotypes for these traits.

Fig. 8. Nutmeg butter (%) and mace oil (%) in nutmeg genotypes

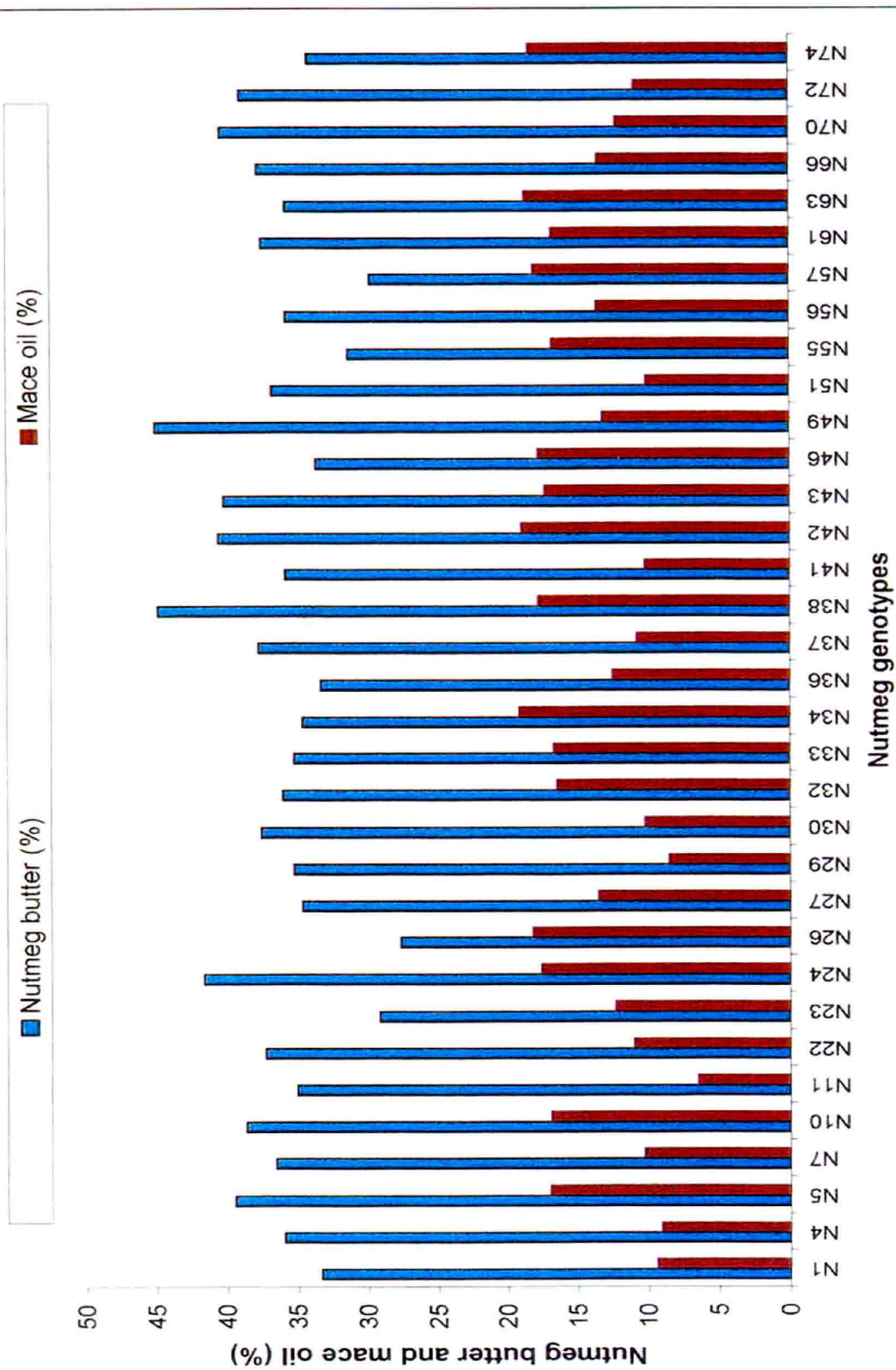


Table 29. Genetic parameters for nutmeg butter and mace oil in nutmeg

Sr. No.	Particulars	Nutmeg butter	Mace oil
1.	Mean sum of squares for treatments	29.72**	27.55**
2.	Mean sum of squares for Error	0.511	0.267
3.	Phenotypic variance	15.12	13.91
4.	Genotypic variance	14.61	13.54
5.	Environmental variance	0.51	0.27
6.	Phenotypic coefficient of variation (PCV)	10.70	26.39
7.	Genotypic coefficient of variation (GCV)	10.52	26.13
8.	Environmental coefficient of variation (ECV)	0.18	0.26
9.	Heritability (h^2b)	96.6	98.1
10.	Genetic advance (GA)	7.74	7.54
11.	Genetic Advance on % mean basis (GAM)	21.29	53.32

** Significant at 1 per cent level of significance.

4.6.6 Fresh and Dry Pericarp : Nut : Mace ratio :

Pericarp, nut and mace are the components of nutmeg fruit. Among these the nut and mace are the most important parts from the economical point of view. The proportion of these components vary among nutmeg genotypes. The genotypes having more proportion of nut and mace can be considered as promising. The proportion of pericarp, nut and mace in fruit was studied in all the 34 bearing nutmeg genotypes on fresh as well as dry basis and the data are presented in Table 30 and illustrated with Fig. 9 and 10. The perusal of data shows that on an average freshly harvested nutmeg fruit had pericarp : nut : mace ratio of 80 : 16 : 4 which alters to 44 : 48 : 8 after drying. It can also be noticed that the genotypes which had high proportion of nut and mace on fresh basis also indicate same trend on dry basis. The maximum proportion of nut and mace on fresh basis was recorded in N72 (76 : 20 : 4) and N22 (76 : 18 : 6) followed by N10 (78 : 18 : 4). The minimum mace and nutmeg proportion was noticed in N51 and N63 (84 : 13 : 3). On dry matter basis the maximum proportion of nut and mace to pericarp was maximum in N22 (36 : 54 : 10) followed by N72 (39 : 53 : 8) and

Fig. 9. Fresh pericarp : Nut : Mace ratio of nutmege genotypes

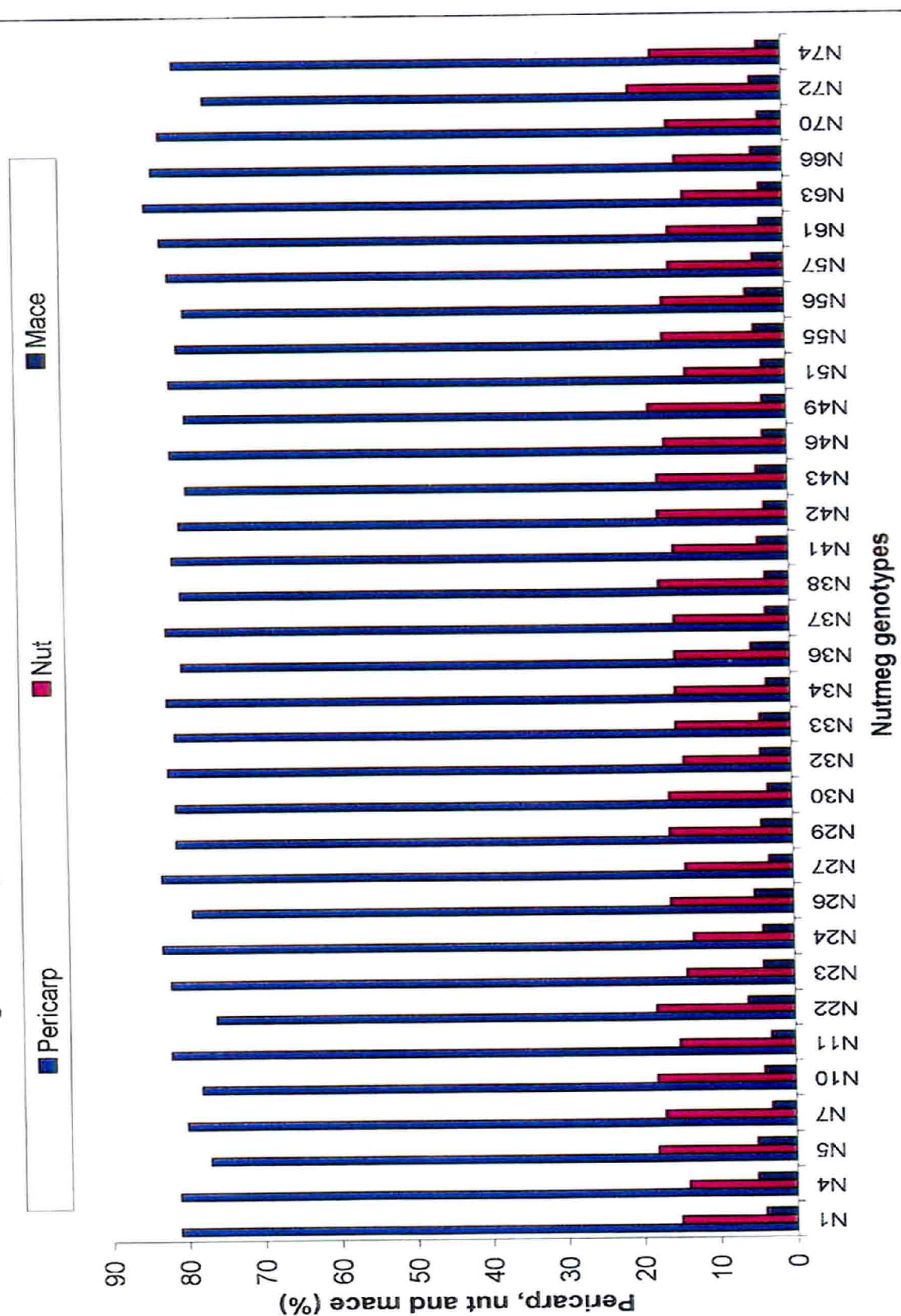
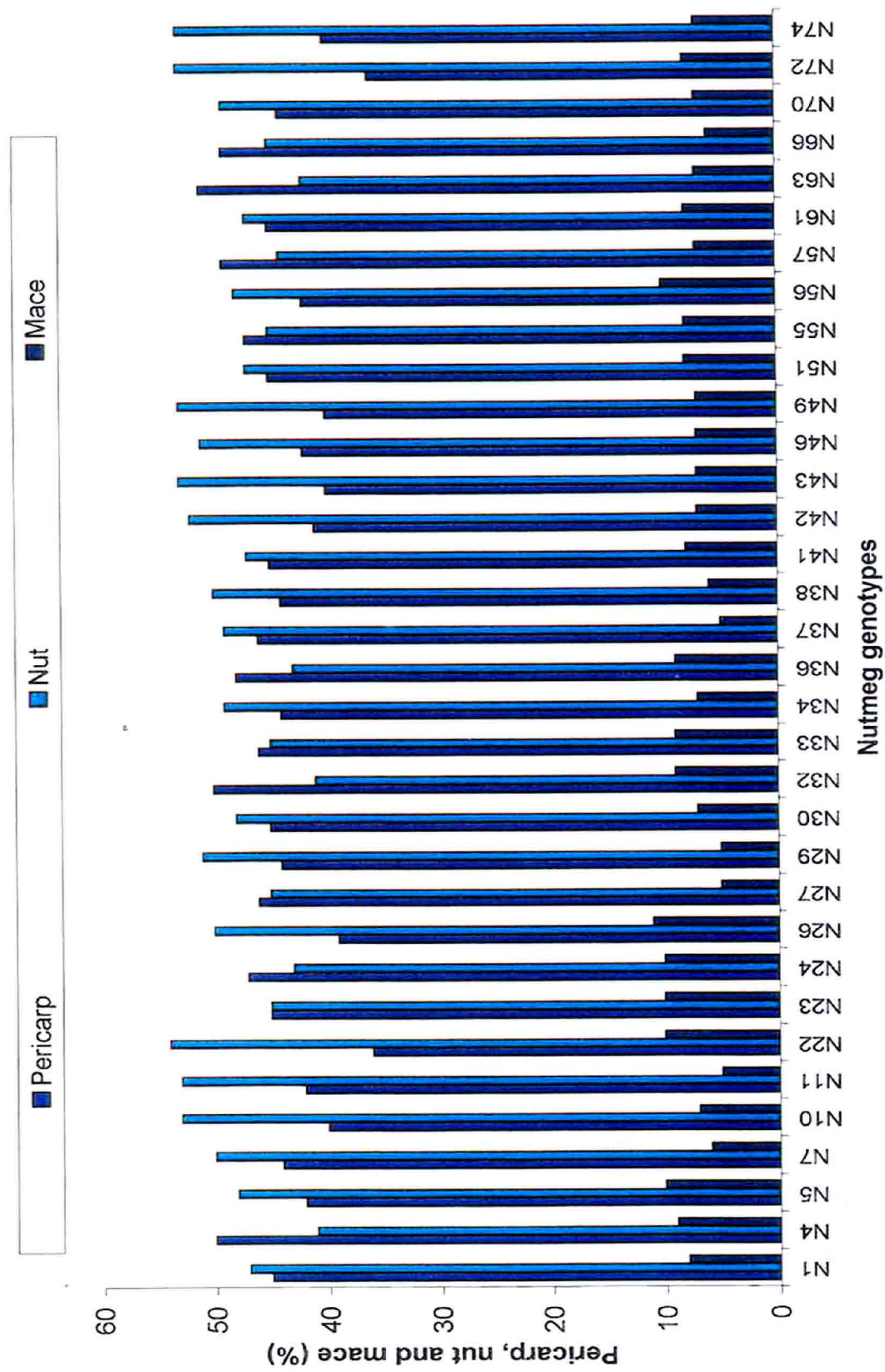


Fig. 10. Dry pericarp : Nut : Mace ratio of nutmege genotypes



N26 (39 : 50 : 11). In N63 (51 : 42 : 7) the minimum proportion of nut and mace was seen followed by N32 and N4 (50 : 41 : 9). Based on the dry flesh : mace : nut ratio, the genotypes N5, N10, N11, N22, N26, N42, N43, N46, N49, N57, N72 and N74 can be rated as the promising genotypes whereas genotypes N22 and N72 are the most promising genotypes among them.

Table 30. Fresh and dry Pericarp : Nut : Mace ratio of different nutmeg genotypes

Genotype	Pericarp : Nut : Mace			Pericarp : Nut : Mace		
	Fresh			Dry		
	1999	2000	Pooled	1999	2000	Pooled
1	2.	3.	4.	5.	6.	7.
N-1	79:16:5	84:14:3	81:15:4	42:50:8	47:44:9	45:47:8
N-4	80:15:5	83:12:5	81:14:5	46:46:8	55:36:9	50:41:9
N-5	76:19:5	78:18:4	77:18:5	41:49:10	43:48:9	42:48:10
N-7	79:18:3	81:16:3	80:17:3	42:52:6	45:49:6	44:50:6
N-10	79:17:4	76:20:4	78:18:4	42:51:7	37:56:7	40:53:7
N-11	81:16:3	82:16:2	82:15:3	41:53:6	42:54:4	42:53:5
N-22	74:19:7	78:17:5	76:18:6	34:55:11	38:53:9	36:54:10
N-23	82:14:5	83:13:4	82:14:4	43:47:10	46:43:11	45:45:10
N-24	84:12:4	82:14:4	83:13:4	49:41:10	45:45:10	47:43:10
N-26	75:19:6	82:14:4	79:16:5	33:54:13	44:47:9	39:50:11
N-27	85:13:2	81:16:3	83:14:3	43:43:4	47:48:5	46:45:5
N-29	80:16:5	82:16:2	81:16:4	43:52:5	45:50:5	44:51:5
N-30	81:16:3	81:16:3	81:16:3	44:50:6	46:47:7	45:48:7
N-32	82:14:4	83:13:4	82:14:4	49:42:9	51:39:9	50:41:9
N-33	80:16:4	82:14:4	81:15:4	45:46:9	47:45:8	46:45:9
N-34	82:15:3	82:15:3	82:15:3	42:51:7	45:48:7	44:49:7
N-36	78:16:6	82:14:4	80:15:5	44:45:11	51:41:8	48:43:9
N-37	82:15:3	82:15:3	82:15:3	45:50:5	46:49:5	46:49:5
N-38	81:16:3	78:17:5	80:17:3	45:48:7	42:52:6	44:50:6
N-41	80:16:4	83:13:4	81:15:4	82:50:8	47:45:8	45:47:8
N-42	80:16:4	80:17:3	80:17:3	41:51:8	41:53:6	41:52:7
N-43	79:17:4	78:17:5	79:17:4	40:53:7	40:52:8	40:53:7
N-46	81:16:3	81:16:3	81:16:3	43:50:7	42:51:7	42:51:7

Table 30 continued....

1	2.	3.	4.	5.	6.	7.
N-49	79:18:3	79:18:3	79:18:3	41:53:6	40:53:7	40:53:7
N-51	83:13:4	83:14:3	84:13:3	45:46:9	45:47:8	45:47:8
N-55	79:16:5	81:15:4	80:16:4	46:45:9	48:44:8	47:45:8
N-56	76:16:5	80:15:5	79:16:5	40:50:10	44:46:10	42:48:10
N-57	80:15:5	82:15:3	81:15:4	47:45:8	50:43:7	49:44:7
N-61	81:15:4	82:16:3	82:15:3	46:46:8	44:48:8	45:47:8
N-63	84:13:3	85:12:3	84:13:3	50:43:7	52:41:7	51:42:7
N-66	82:16:4	84:13:3	83:14:3	48:46:6	51:43:6	49:45:6
N-70	82:15:3	83:14:3	82:15:3	43:50:7	45:48:7	44:49:7
N-72	77:19:4	76:20:4	76:20:4	38:54:8	41:52:7	39:53:8
N-74	80:17:3	80:17:3	80:17:3	40:53:7	40:53:7	40:53:7
Mean	80:16:4	80:16:4	80:16:4	43:49:8	45:47:8	44:48:8

4.7 Repeatability of yield in nutmeg :

Yield of any crop is the harvested produce of economic importance of that crop. Nutmeg produces two distinct products viz. nutmeg and mace. It is an obligatory cross-pollinated crop and eventually the variation in yield of this crop with respect to nuts and mace is remarkable. Exploitation of the natural variability for yield improvement of this precious crop has a great practical significance. Being a tree spice of perennial nature it is rather inconvenient to apply the biometrical techniques which are commonly applicable for annual field crops. Falconer (1981) has proposed the concept of repeatability of multiple measurement of yield attributes. In nutmeg the yield is expressed in several ways like number of fruits per tree, weight of nuts per tree, weight of kernel per tree and weight of mace per tree. Such kind of data could be used for assessing the inherent ability of an individual tree to give the desired economic produce consistently over its life span.

The yield of 34 nutmeg genotypes in terms of number of fruits per year over six bearing seasons from 1995 to 2000 is presented in Table 31

and illustrated with Fig. 11. The average number of fruits obtained from the genotypes under study was 275.29. The standard deviation noticed was 175.41 whereas the coefficient of variation was 63.72. Among the nutmeg genotypes N42 produced the maximum fruits per tree (789.16) followed by N72 (711) and N37 (570.66). The minimum fruits were recorded in N23 (46.83) followed by N4 (86) and N32 (98).

Table 31. Yield in number of fruits per tree of nutmeg genotypes

Sr. No.	Genotype	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	377	149	376	111	489	379	1881	313.5
2.	N4	16	172	51	49	157	71	516	86
3.	N5	270	136	447	29	196	92	1170	195
4.	N7	58	373	185	173	239	557	1585	264.16
5.	N10	130	475	163	295	237	744	2044	340.67
6.	N11	638	59	651	20	472	615	2455	409.17
7.	N22	86	307	274	246	432	411	1756	292.67
8.	N23	26	66	12	48	89	40	281	46.83
9.	N24	348	309	253	89	260	338	1597	266.16
10.	N26	130	301	35	566	131	80	1243	207.16
11.	N27	190	166	57	79	67	117	676	112.66
12.	N30	121	423	4	219	621	214	1602	267
13.	N32	39	103	11	185	211	39	588	98
14.	N33	292	173	113	240	159	313	1290	215
15.	N34	365	89	265	873	108	1001	2701	450.16
16.	N36	388	289	210	652	621	529	2689	448.16
17.	N37	393	347	966	86	1391	241	3424	570.66
18.	N38	299	278	36	205	417	90	1325	220.83
19.	N41	930	260	830	33	1194	107	3354	559
20.	N42	304	644	364	1550	334	1539	4735	789.16
21.	N43	102	54	76	172	318	185	907	151.16
22.	N46	66	10	160	19	102	233	590	98.33
23.	N49	188	74	98	48	300	404	1112	185.33
24.	N51	226	105	261	18	213	519	1342	223.66
25.	N55	97	233	3	36	118	180	667	111.16
26.	N56	50	315	15	43	97	172	692	115.33
27.	N57	174	174	116	125	331	464	1384	230.66
28.	N61	274	194	52	43	109	72	744	124
29.	N63	24	34	78	168	96	177	577	96.16

Table 31 continued.....

Sr. No.	Genotype	1995	1996	1997	1998	1999	2000	Total	Average
30.	N66	84	199	381	158	255	216	1293	215.5
31.	N70	117	334	211	253	425	484	1824	304
32.	N72	1041	467	1078	107	1179	394	4266	711
33.	N74	261	122	721	30	210	474	1818	303
34.	N29	355	385	209	368	247	468	2032	338.66
	Total	8459	7819	8762	7336	11825	11959		9359.9
	Mean	248.79	229.97	251.71	215.76	347.79	351.73		275.29
	S.D.	231.63	145.32	278.86	299.79	318.53	301.25		175.41
	C.V.	93.10	63.19	108.21	138.78	91.59	85.65		63.72

As stated earlier the variation in nutmeg has been recorded in all aspects since it is an obligatory cross pollinated crop. The yield of nutmeg presented in number of fruits per tree may not be a truly representative yield. A tree bearing large number of fruits of small size might have the same yield potential with that of a tree bearing less number of fruits of bold size where the yield of fruits is considered in term of weight. Besides in trade mostly the nutmegs are sold on the basis of weight. Hence the yield of nutmeg on weight basis is very important criterion.

The yield of 34 nutmeg genotypes on weight basis for 6 years from 1995 to 2000 is given in Table 32 and Fig. 11. The critical perusal of data revealed that the mean nut yield obtained from the genotypes under study was 1.24 kg. The standard deviation and the coefficient of variation were 0.76 and 62.14 respectively. N42 (3.58 kg) produced the highest yield of nuts followed by N72 (2.86 kg) and N37 (2.63 kg). The minimum yield was recorded in N23 (0.30 kg) followed by N32 (0.33 kg) and N46 (0.39 kg).

Table 32. Yield in nut weight (kg) per tree of nutmeg genotypes

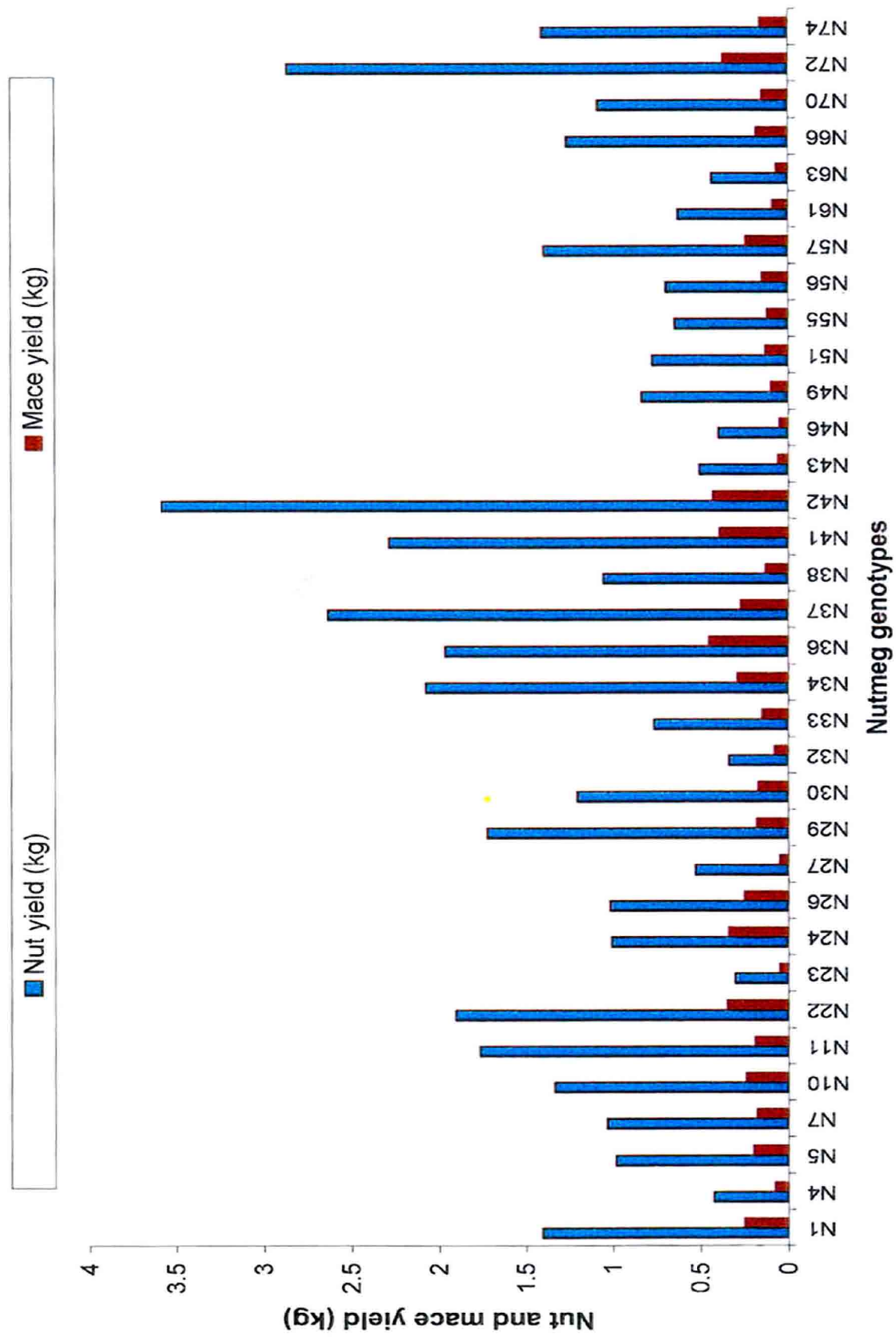
Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	1.69	0.67	1.68	0.50	2.19	1.69	8.42	1.40
2.	N4	0.07	0.85	0.25	0.24	0.77	0.35	2.53	0.42
3.	N5	1.35	0.68	2.23	0.15	0.98	0.46	5.85	0.98

Table 32 continued.....

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
4.	N7	0.23	1.45	0.72	0.67	0.93	2.17	6.17	1.03
5.	N10	0.51	1.85	0.64	1.15	0.92	2.90	7.97	1.33
6.	N11	2.75	0.25	2.81	0.09	2.03	2.65	10.58	1.76
7.	N22	0.56	1.99	1.78	1.60	2.81	2.68	11.42	1.90
8.	N23	0.17	0.42	0.08	0.31	0.57	0.26	1.81	0.30
9.	N24	1.31	1.16	0.95	0.34	0.98	1.27	6.01	1.00
10.	N26	0.70	1.63	0.16	2.61	0.61	0.37	6.08	1.01
11.	N27	0.88	0.77	0.26	0.37	0.31	0.54	3.13	0.52
12.	N30	0.54	1.89	0.02	0.98	2.78	0.96	7.17	1.20
13.	N32	0.13	0.35	0.04	0.63	0.71	0.14	2.00	0.33
14.	N33	1.03	0.61	0.40	0.85	0.56	1.10	4.55	0.76
15.	N34	1.68	0.41	1.22	4.01	0.50	4.61	12.43	2.07
16.	N36	1.70	1.27	0.92	2.86	2.73	2.32	11.8	1.96
17.	N37	1.81	1.59	4.44	0.40	6.40	1.11	15.75	2.63
18.	N38	1.42	1.32	0.17	0.97	1.98	0.43	6.29	1.05
19.	N41	3.80	1.06	3.39	0.13	4.88	0.44	13.7	2.28
20.	N42	1.38	2.92	1.65	7.04	1.52	6.99	21.5	3.58
21.	N43	0.33	0.18	0.25	0.56	1.04	0.61	2.97	0.50
22.	N46	0.26	0.04	0.64	0.08	0.41	0.93	2.36	0.39
23.	N49	0.84	0.33	0.44	0.22	1.35	1.81	4.99	0.83
24.	N51	0.77	0.36	0.90	0.06	0.73	1.78	4.60	0.77
25.	N55	0.55	1.33	0.02	0.21	0.67	1.03	3.81	0.64
26.	N56	0.30	1.88	0.09	0.26	0.58	1.03	4.14	0.69
27.	N57	1.05	1.05	0.70	0.76	2.01	2.81	8.38	1.39
28.	N61	1.37	0.97	0.26	0.21	0.55	0.36	3.72	0.62
29.	N63	0.11	0.15	0.35	0.76	0.43	0.80	2.6	0.43
30.	N66	0.49	1.17	2.23	0.93	1.49	1.27	7.58	1.26
31.	N70	0.41	1.18	0.75	0.90	1.50	1.71	6.45	1.08
32.	N72	4.19	1.88	4.34	0.43	4.75	1.59	17.18	2.86
33.	N74	1.05	0.49	2.91	1.21	0.85	1.91	8.42	1.40
34.	N29	1.81	1.96	1.06	1.87	1.25	2.38	10.33	1.72
Total		37.24	36.11	38.76	34.34	52.77	53.46		42.09
Mean		1.10	1.06	1.14	1.01	1.55	1.57		1.24
S.D.		0.96	0.67	1.20	1.36	1.39	1.36		0.76
C.V.		87.20	63.35	105.22	134.30	89.37	86.34		62.14

Mace is another important spice produced by nutmeg tree apart from nut. It is very attractive scarlet red coloured aril on the nut. The quantity of

Fig. 11. Yield of nuts and mace (kg) in nutmeg genotypes



mace in nutmeg fruit vary greatly among nutmeg genotypes. A nutmeg tree yielding large quantity of nuts may not produce proportionately high quantity of mace. Mace yield of 34 nutmeg genotypes from 1995 to 2000 under study is given in Table 33 and illustrated with Fig. 11. The average mace production of the 34 genotypes was 0.19 kg. The magnitudes of standard deviation and coefficient of variation were 0.11 and 57.67, respectively. The mace produced by N36 (0.45 kg) was the maximum among all the genotypes followed by N42 (0.43 kg) and N41 (0.39 kg). The minimum mace yield was recorded in N23 and N27 (0.05 kg) followed by N43 (0.06 kg) and N63 (0.07 kg).

Table 33. Yield in mace weight (kg) per tree of nutmeg genotypes

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	0.30	0.12	0.29	0.09	0.38	0.30	1.48	0.25
2.	N4	0.02	0.16	0.04	0.05	0.15	0.07	0.49	0.08
3.	N5	0.28	0.14	0.46	0.03	0.20	0.10	1.21	0.20
4.	N7	0.28	0.23	0.09	0.08	0.11	0.27	1.06	0.18
5.	N10	0.59	0.22	0.07	0.13	0.11	0.34	1.46	0.24
6.	N11	0.29	0.03	0.30	0.01	0.21	0.28	1.12	0.19
7.	N22	0.10	0.36	0.33	0.29	0.51	0.49	2.08	0.35
8.	N23	0.04	0.10	0.02	0.06	0.01	0.06	0.29	0.05
9.	N24	0.29	0.26	0.21	0.75	0.22	0.28	2.01	0.34
10.	N26	0.16	0.37	0.04	0.69	0.16	0.10	1.52	0.25
11.	N27	0.09	0.08	0.03	0.04	0.03	0.05	0.32	0.05
12.	N30	0.08	0.27	0.01	0.14	0.39	0.14	1.03	0.17
13.	N32	0.03	0.08	0.01	0.14	0.16	0.03	0.45	0.08
14.	N33	0.20	0.12	0.08	0.16	0.11	0.21	0.88	0.15
15.	N34	0.23	0.06	0.17	0.55	0.07	0.64	1.72	0.29
16.	N36	0.39	0.29	0.21	0.66	0.63	0.53	2.71	0.45
17.	N37	0.19	0.16	0.46	0.04	0.66	0.11	1.62	0.27
18.	N38	0.17	0.16	0.02	0.12	0.24	0.05	0.76	0.13
19.	N41	0.65	0.18	0.58	0.02	0.83	0.07	2.33	0.39
20.	N42	0.17	0.35	0.20	0.85	0.18	0.85	2.6	0.43
21.	N43	0.05	0.02	0.03	0.08	0.14	0.08	0.4	0.06
22.	N46	0.04	0.01	0.09	0.01	0.05	0.12	0.32	0.05
23.	N49	0.10	0.04	0.05	0.03	0.17	0.22	0.61	0.10

Table 33 continued.....

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
24.	N51	0.13	0.06	0.15	0.01	0.13	0.31	0.79	0.13
25.	N55	0.10	0.24	0.01	0.04	0.12	0.18	0.69	0.12
26.	N56	0.06	0.40	0.02	0.05	0.12	0.22	0.87	0.15
27.	N57	0.18	0.18	0.12	0.13	0.34	0.47	1.42	0.24
28.	N61	0.21	0.15	0.04	0.03	0.08	0.06	0.57	0.09
29.	N63	0.02	0.02	0.06	0.12	0.07	0.13	0.42	0.07
30.	N66	0.07	0.17	0.32	0.13	0.21	0.18	1.08	0.18
31.	N70	0.06	0.16	0.10	0.12	0.21	0.23	0.88	0.15
32.	N72	0.54	0.24	0.56	0.05	0.61	0.20	2.2	0.37
33.	N74	0.13	0.06	0.37	0.02	0.11	0.24	0.93	0.16
34.	N29	0.16	0.37	0.09	0.16	0.11	0.21	1.1	0.18
	Total	6.40	5.86	5.63	5.88	7.83	7.82		6.59
	Mean	0.19	0.17	0.17	0.17	0.23	0.23		0.19
	S.D.	0.16	0.11	0.16	0.23	0.20	0.18		0.11
	C.V.	83.34	64.56	99.18	132.72	85.60	78.89		57.67

Kernel and shell are the two components of nut among which kernel is of prime importance since it is the core spice. The variation with respect to recover percentage of kernel has also been recorded in nutmeg. The proportion of kernel vary from nut to nut. The yield of kernel of 34 nutmeg genotypes under study is given in Table 34. The mean kernel produced by the nutmeg genotypes under study was 0.86 kg. The standard deviation for kernel yield was 0.54, whereas the coefficient of variation was 62.57. The kernel production noticed in N42 (2.42 kg) was the maximum followed by N72 (1.95 kg) and N37 (1.77 kg). The minimum kernel yield was observed in N23 (0.20 kg) followed by N32 (0.25 kg).

Table 34. Yield in kernel (kg) per tree of different nutmeg genotypes

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	1.10	0.43	1.10	0.32	1.43	1.10	5.48	0.91
2.	N4	0.05	0.54	0.16	0.15	0.49	0.22	1.61	0.27
3.	N5	0.85	0.43	1.41	0.09	0.62	0.29	3.69	0.62
4.	N7	0.16	1.00	0.50	0.47	0.64	1.50	4.27	0.71
5.	N10	0.34	1.24	0.43	0.77	0.62	1.94	5.34	0.89
6.	N11	1.92	0.18	1.96	0.06	1.42	1.85	7.39	1.23
7.	N22	0.40	1.42	1.27	1.14	2.00	2.00	8.23	1.37
8.	N23	0.11	0.29	0.05	0.21	0.39	0.17	1.22	0.20
9.	N24	1.06	0.94	0.77	0.27	0.79	1.03	4.86	0.81
10.	N26	0.51	1.19	0.14	2.24	0.52	0.32	4.92	0.82
11.	N27	0.60	0.52	0.18	0.25	0.21	0.37	2.13	0.36
12.	N30	0.36	1.25	0.01	0.65	1.84	0.63	4.74	0.79
13.	N32	0.10	0.26	0.03	0.46	0.53	0.10	1.48	0.25
14.	N33	0.75	0.45	0.29	0.62	0.41	0.81	3.33	0.56
15.	N34	1.25	0.30	0.91	2.99	0.37	3.43	9.25	1.54
16.	N36	1.34	0.99	0.73	2.25	2.15	1.88	9.34	1.56
17.	N37	1.22	1.08	3.00	0.27	4.32	0.75	10.64	1.77
18.	N38	0.96	0.89	0.12	0.66	1.33	0.29	4.25	0.71
19.	N41	2.68	0.75	2.39	0.10	3.44	0.31	9.67	1.61
20.	N42	0.93	1.98	1.12	4.76	1.03	4.72	14.54	2.42
21.	N43	0.23	0.12	0.17	0.40	0.73	0.43	2.08	0.35
22.	N46	0.18	0.03	0.44	0.05	0.28	0.63	1.61	0.27
23.	N49	0.59	0.23	0.31	0.15	0.94	1.26	3.48	0.58
24.	N51	0.51	0.24	0.59	0.04	0.48	1.18	3.04	0.51
25.	N55	0.36	0.86	0.01	0.13	0.43	0.66	2.45	0.41
26.	N56	0.22	1.37	0.06	0.02	0.42	0.75	2.84	0.47
27.	N57	0.77	0.77	0.51	0.55	1.47	2.06	6.13	1.02
28.	N61	0.78	0.55	0.15	0.12	0.31	0.21	2.12	0.35
29.	N63	0.07	0.10	0.22	0.47	0.27	0.49	1.62	0.27
30.	N66	0.33	0.78	1.49	0.62	1.00	0.85	5.07	0.85
31.	N70	0.29	0.82	0.52	0.62	1.04	1.18	4.47	0.75
32.	N72	2.85	1.28	2.95	0.29	3.22	1.08	11.67	1.95
33.	N74	0.70	0.33	1.94	0.90	0.57	1.28	5.72	0.95
34.	N29	1.28	1.40	0.75	1.33	0.89	1.69	7.34	1.22
Total		25.85	25.01	26.68	24.42	36.60	37.46		29.35
Mean		0.76	0.74	0.78	0.72	1.08	1.10		0.86
S.D.		0.67	0.47	0.82	0.97	0.96	0.96		0.54
C.V.		87.54	63.78	104.29	135.66	88.81	86.78		62.57

Variation noticed for all the characters was due to two major components. Firstly, there was a wide range of variation due to the genotypes under study. Secondly, there was variation due to seasons. Falconer (1981) reported the term spatial environmental variance and general environmental variance to refer to "Within individual variance" and "Between individual components of variance", respectively. The mean sum of squares due to "Between genotypes" and "Within genotypes" obtained from the converted data of yield parameters indicate that the variation due to "Between genotypes" component was predominantly larger than "Within genotypes" (Table 35). The variation recorded due to "Within genotypes" represent the variation due to spatial environmental circumstances. The results thus indicate that such conditions play very little role in nutmeg yield. The variation obtained due to "Between genotypes" which is the sum total of genotypic variance and general environmental variation plays major role in the yield parameters of nutmeg. Improvement of crop in respect of any character by selection requires collection of genetically varying population. The nutmeg population under study exhibited a large variation in the yield components under study. This suggested good scope for identifying genotype with promising yield potential.

Table 35. Mean sum of squares for yield of nutmeg.

Sr. No.	Sources	d.f.	Yield in no. of nuts/tree	Yield in kg nuts/tree	Yield in kg mace/tree	Yield in kg kernel/tree
1.	Between genotypes	33	153362.8302	2.983241606	0.073557338	1.359477718
2.	Within genotypes	170	41253.23431	0.776045321	0.022478947	0.346877777

It is difficult to obtain the exclusive value of estimate of general environmental variance. However, it is possible to obtain a rough indicator of proportion of genotypic variance in total phenotypic variance by calculating the coefficient of repeatability (R).

Repeatability sets an upper limit of heritability in broad sense. It includes all types of genetic as well as environmental influences which

contribute to real differences among individuals. Furthermore the repeatability indicates the extent to which an early performance can be taken as an indication of subsequent performance. For obtaining the coefficient of repeatability the yields of nutmeg were converted on the basis of first yield record i.e. 1995. Sanders conversion factor (Appendix-III) was estimated and applied for obtaining the corrected values of yield on first year (1995) basis. Since the nut yield has been repeated over seasons the early records of the yearly yield data of 34 nutmeg genotypes in terms of number, weight, kernel and mace yield over six years offered a scope for estimating the coefficient of repeatability.

Table 36. Coefficient of repeatability and its 95% confidence limits for yield in nutmeg genotypes.

Sr. No.	Particulars	Repeatability coefficient 'R'	95% confidence limits of R	
			Ru	Rl
1.	Yield in no. of nuts/tree	0.115211039	0.254363086	0.006842571
2.	Yield in kg nuts/tree	0.117426327	0.25705115	0.008486004
3.	Yield in kg mace/tree	0.106373108	0.243579599	0.000364496
4.	Yield in kg kernel/tree	0.118685695	0.258576642	0.009415714

The coefficients of repeatability for yield components with their 95 per cent confidence limits are presented in Table 36. The magnitudes of repeatability for all the parameters were similar and relatively low. However, the upper confidence limits were reasonably high. The relatively low magnitudes of repeatability could be on account of confounding of general environmental variance with genotypic variance. In current investigation however, the repeatability coefficient are not showing extreme values. The upper limits remained to the extent of 0.25. Hence, the records of earlier observations are not much dependable. Instead of single earlier record the consistency over a wider period is more reliable.

In this connection the converted yield of nutmeg with respect to different parameters is presented in Table 37 to 40.

Table 37. Corrected yield of number of nuts per tree per year of nutmeg genotypes (on first year basis)

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	377	162	342	129	346	265	1621	270.16
2.	N4	16	187	46	57	111	50	467	77.83
3.	N5	270	148	407	34	139	64	1062	177
4.	N7	58	405	168	201	169	389	1390	231.66
5.	N10	130	516	148	342	167	520	1823	303.83
6.	N11	638	64	592	23	334	430	2081	346.83
7.	N22	86	333	249	286	305	287	1546	257.66
8.	N23	26	72	11	56	63	28	256	42.66
9.	N24	348	335	230	103	184	236	1436	239.33
10.	N26	130	327	32	657	93	56	1245	207.5
11.	N27	190	180	52	92	47	82	643	107.16
12.	N30	121	459	4	254	439	149	1426	237.66
13.	N32	39	112	10	215	149	27	552	92
14.	N33	292	188	102	279	112	219	1192	198.66
15.	N34	365	97	241	1013	76	699	2491	415.16
16.	N36	388	314	191	757	439	370	2459	409.83
17.	N37	393	377	879	100	983	168	2900	483.33
18.	N38	299	302	33	238	295	63	1230	205
19.	N41	930	282	755	38	844	75	2924	487.33
20.	N42	304	699	331	1799	236	1075	4444	740.66
21.	N43	102	59	69	200	225	129	784	130.66
22.	N46	66	11	146	22	72	163	480	80
23.	N49	188	80	89	56	212	282	907	151.16
24.	N51	226	114	238	21	150	363	1112	185.33
25.	N55	97	253	3	42	83	126	604	100.66
26.	N56	50	342	14	50	69	120	645	107.5
27.	N57	174	189	106	145	234	324	1172	195.33
28.	N61	274	211	47	50	77	50	709	118.16
29.	N63	24	37	71	195	68	124	519	86.5
30.	N66	84	216	347	183	180	151	1161	193.5
31.	N70	117	363	192	294	300	338	1604	267.33
32.	N72	1041	507	981	124	833	275	3761	626.83
33.	N74	261	132	656	35	148	331	1563	260.5
34.	N29	355	418	190	427	175	327	1892	315.33

Table 38. Corrected yield (kg nuts/tree) of nutmeg genotypes (On first year basis)

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	1.69	0.72	1.73	0.47	1.78	1.18	7.57	1.26
2.	N4	0.07	0.91	0.26	0.22	0.62	0.24	2.32	0.38
3.	N5	1.35	0.73	2.30	0.14	0.79	0.32	5.63	0.94
4.	N7	0.23	1.55	0.74	0.63	0.75	1.51	5.41	0.90
5.	N10	0.51	1.98	0.66	1.07	0.75	2.02	6.99	1.17
6.	N11	2.75	0.27	2.90	0.08	1.65	1.85	9.50	1.58
7.	N22	0.56	2.13	1.83	1.49	2.28	1.87	10.16	1.69
8.	N23	0.17	0.45	0.08	0.29	0.46	0.18	1.63	0.27
9.	N24	1.31	1.24	0.98	0.32	0.79	0.89	5.53	0.92
10.	N26	0.70	1.74	0.16	2.44	0.49	0.26	5.79	0.97
11.	N27	0.88	0.82	0.27	0.35	0.25	0.38	2.95	0.49
12.	N29	1.81	2.10	1.09	1.75	1.01	1.66	9.42	1.57
13.	N30	0.54	2.02	0.02	0.92	2.25	0.67	6.42	1.07
14.	N32	0.13	0.37	0.04	0.59	0.58	0.10	1.81	0.30
15.	N33	1.03	0.65	0.41	0.79	0.45	0.77	4.10	0.68
16.	N34	1.68	0.44	1.26	3.75	0.40	3.22	10.75	1.79
17.	N36	1.70	1.36	0.95	2.67	2.21	1.62	10.51	1.75
18.	N37	1.81	1.70	4.58	0.37	5.19	0.77	14.42	2.40
19.	N38	1.42	1.41	0.18	0.91	1.61	0.30	5.83	0.97
20.	N41	3.80	1.13	3.49	0.12	3.96	0.31	12.81	2.14
21.	N42	1.38	3.13	1.70	6.58	1.23	4.88	18.90	3.15
22.	N43	0.33	0.19	0.26	0.52	0.84	0.43	2.57	0.43
23.	N46	0.26	0.04	0.66	0.07	0.33	0.65	2.01	0.34
24.	N49	0.84	0.35	0.45	0.21	1.09	1.26	4.20	0.7
25.	N51	0.77	0.39	0.93	0.06	0.59	1.24	3.98	0.66
26.	N55	0.55	1.42	0.02	0.20	0.54	0.72	3.45	0.58
27.	N56	0.30	2.01	0.09	0.24	0.47	0.72	3.83	0.64
28.	N57	1.05	1.12	0.72	0.71	1.63	1.96	7.19	1.20
29.	N61	1.37	1.04	0.27	0.20	0.45	0.25	3.58	0.59
30.	N63	0.11	0.16	0.36	0.71	0.35	0.56	2.25	0.38
31.	N66	0.49	1.25	2.30	0.87	1.21	0.88	7.00	1.16
32.	N70	0.41	1.26	0.77	0.84	1.22	1.19	5.69	0.95
33.	N72	4.19	2.01	4.47	0.40	3.85	1.11	16.03	2.67
34.	N74	1.05	0.52	3.00	1.13	0.69	1.33	7.72	1.29

Table 39. Corrected yield of mace (kg/tree) of nutmeg genotypes (first year basis)

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	0.30	0.14	0.33	0.09	0.34	0.24	1.44	0.24
2.	N4	0.02	0.19	0.05	0.05	0.13	0.06	0.50	0.08
3.	N5	0.28	0.16	0.53	0.03	0.18	0.08	1.26	0.21
4.	N7	0.28	0.30	0.10	0.08	0.10	0.22	1.03	0.17
5.	N10	0.59	0.26	0.08	0.13	0.10	0.28	1.44	0.24
6.	N11	0.29	0.04	0.34	0.01	0.19	0.23	1.10	0.18
7.	N22	0.10	0.42	0.38	0.30	0.45	0.40	2.05	0.34
8.	N23	0.40	0.12	0.02	0.06	0.01	0.05	0.30	0.05
9.	N24	0.29	0.30	0.24	0.76	0.20	0.23	2.02	0.34
10.	N26	0.16	0.43	0.05	0.70	0.14	0.08	1.56	0.26
11.	N27	0.09	0.09	0.03	0.04	0.03	0.04	0.32	0.05
12.	N29	0.16	0.43	0.10	0.16	0.10	0.17	1.12	0.19
13.	N30	0.08	0.32	0.01	0.14	0.35	0.11	1.01	0.17
14.	N32	0.03	0.09	0.01	0.14	0.14	0.02	0.43	0.07
15.	N33	0.20	0.14	0.09	0.16	0.10	0.17	0.86	0.14
16.	N34	0.23	0.07	0.20	0.56	0.06	0.52	1.64	0.27
17.	N36	0.39	0.34	0.24	0.67	0.56	0.43	2.63	0.44
18.	N37	0.19	0.19	0.53	0.04	0.59	0.09	1.63	0.27
19.	N38	0.17	0.19	0.02	0.12	0.21	0.04	0.75	0.13
20.	N41	0.65	0.21	0.67	0.02	0.74	0.06	2.35	0.39
21.	N42	0.17	0.41	0.23	0.87	0.16	0.69	2.53	0.42
22.	N43	0.05	0.02	0.03	0.08	0.12	0.06	0.36	0.06
23.	N46	0.04	0.01	0.10	0.01	0.04	0.10	0.30	0.05
24.	N49	0.10	0.05	0.06	0.03	0.15	0.18	0.57	0.10
25.	N51	0.13	0.07	0.17	0.01	0.12	0.25	0.75	0.13
26.	N55	0.10	0.28	0.01	0.04	0.11	0.015	0.69	0.12
27.	N56	0.06	0.47	0.02	0.05	0.11	0.18	0.79	0.13
28.	N57	0.18	0.21	0.14	0.13	0.30	0.38	1.34	0.22
29.	N61	0.21	0.18	0.05	0.03	0.07	0.05	0.59	0.10
30.	N63	0.02	0.02	0.07	0.12	0.06	0.11	0.40	0.07
31.	N66	0.07	0.20	0.37	0.13	0.19	0.15	1.11	0.19
32.	N70	0.06	0.19	0.11	0.12	0.19	0.19	0.86	0.14
33.	N72	0.54	0.28	0.64	0.05	0.37	0.16	2.04	0.34
34.	N74	0.13	0.07	0.43	0.02	0.10	0.20	0.95	0.16

Table 40. Corrected yield of kernel (kg./ tree) on first yield

Sr. No.	Geno-type	1995	1996	1997	1998	1999	2000	Total	Average
1.	N1	1.10	0.45	1.15	0.29	1.06	0.69	4.74	0.79
2.	N4	0.05	0.56	0.17	0.13	0.36	0.14	1.41	0.24
3.	N5	0.85	0.45	1.48	0.08	0.46	0.18	3.50	0.58
4.	N7	0.16	1.04	0.52	0.42	0.48	0.94	3.56	0.59
5.	N10	0.34	1.29	0.45	0.69	0.46	1.22	4.45	0.74
6.	N11	1.92	0.19	2.05	0.05	1.06	1.16	6.43	1.07
7.	N22	0.40	1.48	1.33	1.02	1.49	1.25	6.97	1.16
8.	N23	0.11	0.30	0.05	0.19	0.29	0.11	1.05	0.18
9.	N24	1.06	0.98	0.81	0.24	0.59	0.65	4.33	0.72
10.	N26	0.51	1.24	0.15	2.01	0.39	0.20	4.50	0.75
11.	N27	0.60	0.54	0.19	0.22	0.16	0.23	1.94	0.32
12.	N29	1.28	1.46	0.79	1.19	0.66	1.06	6.44	1.07
13.	N30	0.36	1.30	0.01	0.58	1.37	0.40	4.02	0.67
14.	N32	0.10	0.27	0.03	0.41	0.39	0.06	1.26	0.21
15.	N33	0.75	0.47	0.30	0.56	0.30	0.51	2.89	0.48
16.	N34	1.25	0.31	0.95	2.68	0.28	2.15	7.62	1.27
17.	N36	1.34	1.03	0.76	2.01	1.60	1.18	7.92	1.32
18.	N37	1.22	1.12	3.14	0.24	3.21	0.47	9.40	1.57
19.	N38	0.96	0.93	0.13	0.59	0.99	0.18	3.78	0.63
20.	N41	2.68	0.78	2.50	0.09	2.56	0.19	8.80	1.47
21.	N42	0.93	2.06	1.17	4.26	0.77	2.96	12.15	2.03
22.	N43	0.23	0.12	0.18	0.36	0.54	0.27	1.70	0.28
23.	N46	0.18	0.03	0.46	0.04	0.21	0.40	1.32	0.22
24.	N49	0.59	0.24	0.32	0.13	0.70	0.79	2.77	0.46
25.	N51	0.51	0.25	0.62	0.04	0.36	0.74	2.52	0.42
26.	N55	0.36	0.89	0.01	0.12	0.32	0.41	2.11	0.35
27.	N56	0.22	1.42	0.06	0.02	0.31	0.47	2.50	0.42
28.	N57	0.77	0.80	0.53	0.49	1.09	1.29	4.97	0.83
29.	N61	0.78	0.57	0.16	0.11	0.23	0.13	1.98	0.33
30.	N63	0.07	0.10	0.23	0.42	0.20	0.31	1.33	0.22
31.	N66	0.33	0.81	1.56	0.56	0.74	0.53	4.53	0.76
32.	N70	0.29	0.85	0.54	0.56	0.77	0.74	3.75	0.63
33.	N72	2.85	1.33	3.09	0.26	2.39	0.68	10.60	1.77
34.	N74	0.70	0.34	2.03	0.81	0.42	0.80	5.1	0.85

Considering the mean of each component as a bifurcating value the promising nutmeg genotypes can be identified for all the yield parameters. Thus, the nutmeg genotypes N1, N10, N11, N22, N34, N36, N37, N41, N42, N70, N72, N74 and N29 can be rated as promising genotypes on the basis of number of fruits per tree. On the basis of yield (nut weight) per tree, the genotypes N1, N10, N11, N22, N29, N34, N36, N37, N41, N42, N57, N66, N72 and N74 can be rated as superior. The mace yield in case of N1, N5, N10, N22, N24, N26, N29, N34, N36, N37, N41, N42, N57, N66 and N72 was excellent. The genotypes N1, N11, N22, N26, N29, N34, N36, N37, N41, N42, N57, N66, N72 and N74 could be distinguished for best kernel.

When all the parameters of yield in nutmeg were considered the genotypes N1, N22, N29, N34, N36, N37, N41, N42 and N72 could be rated as the superior genotypes. Among these N42, N72 and N41 are the most promising.

4.8 Germination and seedling characters :

Seed germination is a very complex process. It starts with imbibition of water by the seed coat and culminates by emergence of plumule and radicle under the favourable conditions of temperature and moisture. Several biochemical transformations occur during this process which are determined by the physical and biochemical constitution of the seed material. The genetic constitution of the parental tree is another important factor governing the success and speed of germination. The variability in the per cent germination, duration of germination and vigour of seedling in terms of length of shoot and root, number and size of leaves etc. under similar conditions of temperature and moisture therefore represent the inherent factors which are associated with the genetic constitution of the parental material related with this process. The data on days for germination, per cent germination, length of shoot and roots, number of leaves, dimensions of leaves recorded on the viable seed samples of 34 nutmeg genotypes under study are given in Table 41 to 44 and illustrated with Fig. 12 and 13.

Table 41. Duration (days) for germination and germination (%) of different nutmeg genotypes

Geno- types	Duration for germination (days)			Germination (%)		
	1999	2000	Pooled	1999	2000	Pooled
N1	74	73	74	66 (54.33)	84 (66.42)	75 (60.00)
N4	61	63	62	36 (36.87)	35 (36.27)	36 (36.87)
N5	69	73	70	37 (37.47)	43 (40.98)	40 (39.23)
N7	83	74	68	69 (56.17)	67 (54.94)	68 (55.55)
N10	75	74	75	64 (53.13)	71 (57.42)	68 (55.55)
N11	63	60	62	72 (58.05)	85 (67.21)	79 (62.72)
N22	59	62	60	73 (58.69)	72 (58.05)	73 (58.69)
N23	53	57	55	58 (49.60)	51 (45.57)	55 (47.87)
N24	60	57	59	55 (47.87)	49 (44.43)	52 (46.15)
N26	55	54	54	39 (38.65)	31 (33.83)	35 (36.27)
N27	71	69	70	48 (43.85)	50 (45.00)	49 (44.43)
N29	75	74	75	78 (62.03)	86 (68.03)	82 (64.90)
N30	68	71	69	56 (48.45)	64 (53.13)	60 (50.77)
N32	86	94	90	33 (35.06)	30 (33.21)	32 (34.45)
N33	114	72	93	60 (50.77)	46 (42.71)	53 (46.72)
N34	61	74	68	65 (53.73)	77 (61.34)	71 (57.42)
N36	64	62	63	42 (40.40)	49 (44.43)	46 (42.71)
N37	68	75	71	63 (52.53)	75 (60.00)	60 (50.77)

Table 41 continued

Geno- types	Duration for germination (days)			Germination (%)		
	1999	2000	Pooled	1999	2000	Pooled
N38	65	57	61	59 (50.18)	69 (56.17)	64 (53.13)
N41	77	75	74	35 (36.27)	32 (34.45)	34 (35.67)
N42	72	76	74	82 (64.90)	92 (73.57)	87 (68.87)
N43	62	62	62	79 (62.72)	94 (75.82)	87 (68.87)
N46	108	106	107	31 (33.83)	42 (40.40)	37 (37.47)
N49	86	79	82	71 (57.42)	75 (60.00)	73 (58.69)
N51	88	92	90	70 (56.79)	76 (60.67)	73 (58.69)
N55	76	74	75	58 (49.60)	50 (45.00)	54 (47.29)
N56	56	53	54	62 (51.94)	58 (49.60)	60 (50.77)
N57	74	74	74	37 (37.47)	32 (34.45)	35 (36.27)
N61	69	66	68	61 (51.35)	60 (50.77)	61 (51.35)
N63	69	66	67	66 (54.33)	74 (59.34)	70 (56.79)
N66	64	68	66	63 (52.53)	78 (62.03)	71 (57.42)
N70	48	57	53	73 (58.69)	82 (64.90)	78 (62.03)
N72	63	60	61	67 (54.94)	78 (62.03)	73 (58.69)
N74	80	76	78	75 (60.00)	85 (67.21)	80 (63.44)
Mean	71.06	69.97	70.02	58.91	63.00	60.91
S.E.m $\pm$	2.88	4.91	1.60	1.92	1.76	1.22
C.D. at 5%	8.30	14.15	4.61	5.54	5.09	3.52

Fig. 12. Period require for germination (days) and germination (%) of nutmeg genotypes

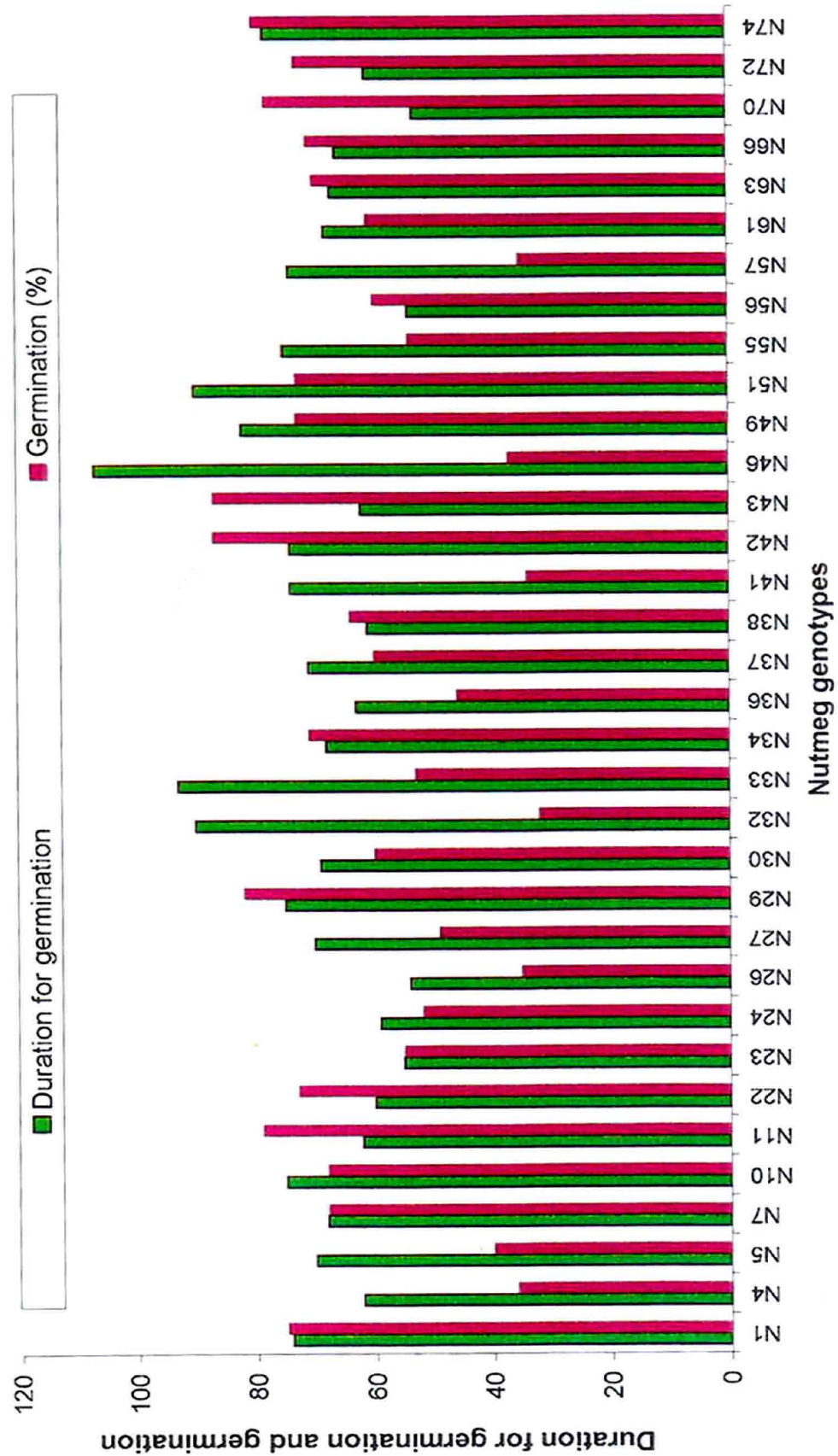




Plate 16. Nutmeg seedling (90 days old) of N29, N5 and N23

The population mean for duration for germination was 70.02 days. However, in genotype N70 the germination occurred in 53 days by providing appropriate moisture and temperature conditions on nursery bed. The period for germination was longest in N46 (107 days). The per cent success of germination in the overall population was 60.91 per cent. In N32 it was very poor (32%) but in N42 and N43, 87 per cent seeds germinated.

Table 42. Shoot characters of seedling in different nutmeg genotypes

Geno- types	Total height (cm)			Shoot height (cm)			Thickness at collar (cm)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N1	20.34	29.22	24.78	10.49	19.10	14.61	0.25	0.37	0.31
N4	27.58	26.29	26.93	13.71	13.51	13.61	0.35	0.35	0.35
N5	27.59	24.79	26.19	13.80	14.84	14.32	0.37	0.37	0.37
N7	25.07	26.27	25.67	11.50	16.53	14.02	0.29	0.38	0.34
N10	20.50	23.01	21.80	10.77	14.21	12.49	0.27	0.31	0.29
N11	20.81	24.52	22.67	9.86	13.91	11.89	0.28	0.38	0.33
N22	24.88	24.55	24.72	13.07	14.70	13.89	0.38	0.38	0.38
N23	26.80	25.69	26.25	13.70	15.27	14.49	0.32	0.36	0.34
N24	29.10	26.86	27.98	16.08	17.38	16.73	0.38	0.38	0.38
N26	28.62	21.63	25.13	15.32	12.88	14.09	0.34	0.33	0.33
N27	25.70	26.63	26.17	12.74	16.77	14.75	0.32	0.37	0.34
N29	21.88	29.72	25.80	11.78	17.76	14.77	0.34	0.41	0.38
N30	22.20	26.72	24.46	11.15	16.57	13.86	0.29	0.36	0.33
N32	26.49	23.75	25.12	13.02	13.84	13.43	0.30	0.34	0.32
N33	23.87	29.46	26.67	11.72	15.33	13.53	0.33	0.39	0.37
N34	24.26	29.49	26.88	12.01	19.10	15.56	0.33	0.35	0.34
N36	21.10	25.65	23.38	10.25	16.85	13.55	0.30	0.35	0.33
N37	28.41	29.12	28.77	13.11	16.05	14.58	0.34	0.40	0.37
N38	24.40	34.62	29.51	11.30	19.42	15.36	0.31	0.40	0.36
N41	21.83	24.09	22.96	11.67	14.18	12.93	0.29	0.36	0.33
N42	24.44	33.92	29.18	12.43	19.14	15.79	0.35	0.38	0.37
N43	25.24	32.90	29.07	12.63	20.24	16.44	0.32	0.37	0.35
N46	26.48	24.88	25.69	14.21	16.54	15.33	0.35	0.36	0.36

Table 42 continued.....

Geno- types	Total height (cm)			Shoot height (cm)			Thickness at collar (cm)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N49	24.12	24.14	24.13	12.54	15.24	13.89	0.33	0.39	0.36
N51	23.15	27.28	25.22	12.53	15.02	13.78	0.32	0.37	0.35
N57	28.35	24.88	26.62	13.55	15.46	14.51	0.34	0.33	0.35
N61	31.46	26.09	28.78	14.85	16.31	13.08	0.36	0.36	0.36
N63	30.96	26.30	27.09	13.43	16.45	14.94	0.32	0.39	0.36
N66	27.88	24.30	23.43	11.98	14.35	13.17	0.30	0.39	0.35
N70	21.03	32.13	26.58	7.68	20.48	14.08	0.24	0.36	0.30
N72	26.77	34.15	30.46	11.57	19.28	15.43	0.34	0.41	0.38
N74	21.41	28.53	24.97	10.85	17.19	14.02	0.32	0.36	0.35
Mean	24.97	27.09	25.93	12.51	16.33	14.34	0.33	0.36	0.35
SE $\pm$	1.09	1.05	0.75	0.60	0.77	0.59	0.02	0.01	0.01
C.D. at 5%	3.15	3.02	2.17	1.74	2.23	1.72	0.05	0.04	0.04

At 90 days after sprouting the mean shoot length was 14.34 cm. In genotypes, N24 it reached 16.73 cm, whereas in genotype N11 it was minimum i.e. 11.89 cm. The genotype N10 showed minimum thickness of collar (0.29 cm) and number of leaves per shoot (3.0). The population average for collar thickness and number of leaves was 0.35 cm and 3.51 respectively. The thickness of the collar was maximum in N24, N29 and N72 (0.38 cm) whereas maximum production of leaves (4.3) was noticed in N38. The mean petiole length was 0.84 cm which was maximum (1.01 cm) in N72 and minimum in N70 (0.72 cm). The 90 day old seedlings produced leaves with 10.71 cm length, 4.00 cm width and 1.12 secondary roots. The genotypes namely N26, N22 and N37 had identical leaf dimensions i.e. 12.15 cm leaf length, 4.51 cm leaf width and 3.53 secondary roots, at 90 days. The culture N30 showed minimum leaf length (19.14 cm) and width (9.39 cm) whereas the culture N7 and N43 had lowest number of secondary roots. The average root length in the initial stage is important for better establishment of seedling. It was 11.52 cm for overall population but it was as long as 15.04 cm in N72 and remained as low as 9.31 cm in N10.

Fig. 13. Shoot height and number of leaves of seedling of nutmeg genotypes

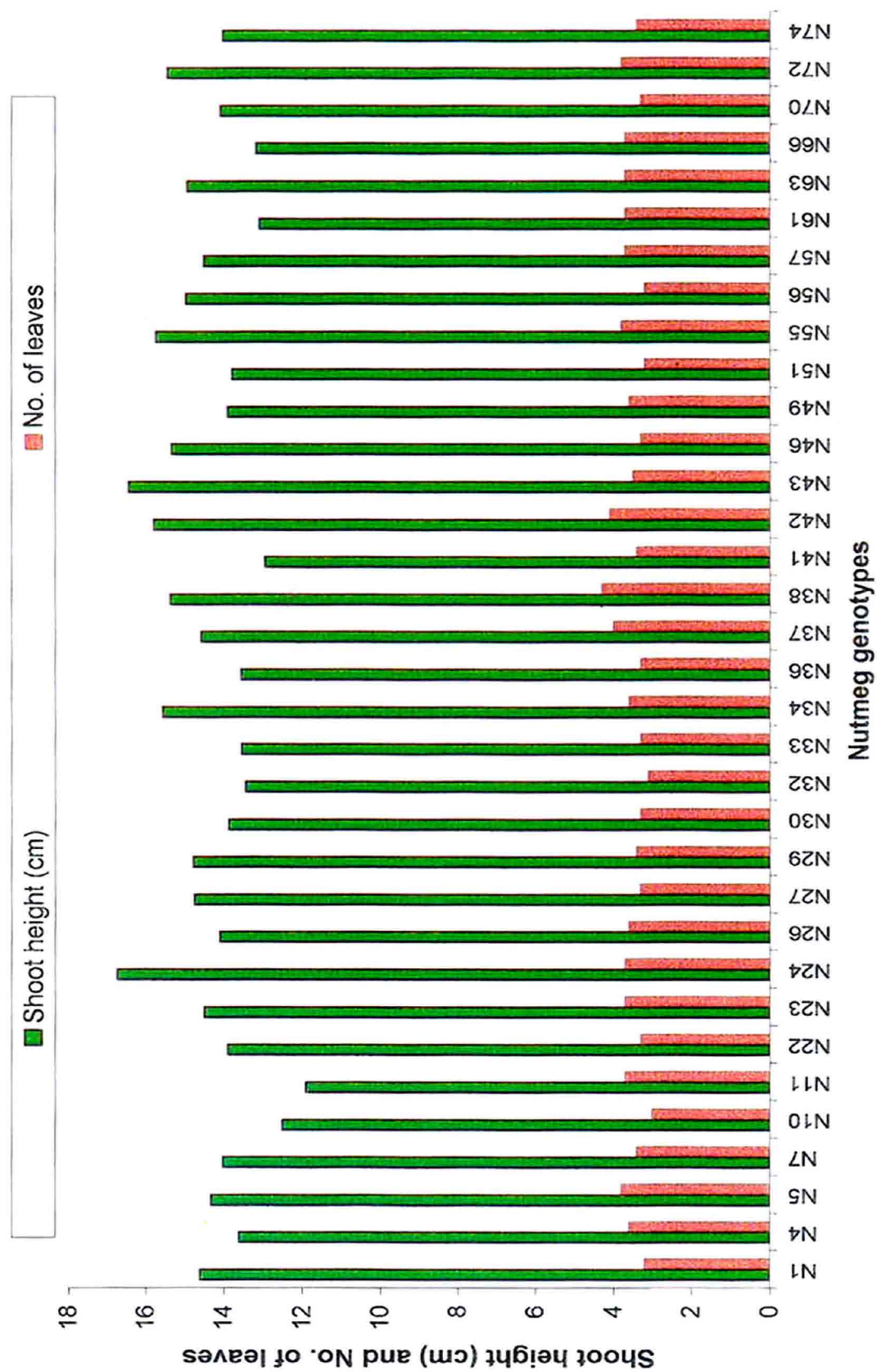




Plate 17. Nutmeg seedling (90 days old) of 36, N30 and N33

Table 43. Leaf characters of seedlings of different nutmeg genotypes.

Geno- type	Total leaves			Petiole length (cm)			Leaf length (cm)			Leaf breadth (cm)		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	3.1	3.3	3.2	0.84	0.89	0.87	9.66	12.22	10.94	3.26	4.81	4.02
N-4	3.70	3.5	3.6	0.80	0.75	0.77	10.01	10.83	10.42	3.75	3.95	3.85
N-5	3.40	4.2	3.8	0.87	0.88	0.88	11.40	11.33	11.37	4.36	4.06	4.21
N-7	3.00	3.8	3.4	0.72	0.99	0.86	9.85	11.61	10.73	3.24	4.09	3.67
N-10	2.8	3.2	3.0	0.67	0.84	0.76	9.47	10.44	9.96	3.46	3.86	3.66
N-11	3.4	3.9	3.7	0.62	0.84	0.73	8.27	11.44	9.86	3.18	4.22	3.70
N-22	3.0	3.5	3.3	0.95	0.93	0.93	9.74	12.97	11.36	4.12	4.89	4.51
N-23	3.6	3.7	3.7	0.95	0.85	0.90	9.93	11.27	10.67	4.22	4.40	4.31
N-24	3.8	3.6	3.7	0.90	0.86	0.88	11.61	10.69	11.15	3.39	4.46	4.43
N-26	4.0	3.3	3.6	0.98	0.88	0.93	11.76	12.55	12.15	3.87	4.38	4.13
N-27	3.4	3.2	3.3	0.78	0.91	0.85	9.73	11.40	10.57	3.58	4.09	3.84
N-29	3.00	3.8	3.4	0.74	0.92	0.83	9.79	12.18	10.99	4.13	4.53	4.33
N-30	3.3	3.3	3.3	0.70	0.82	0.76	7.92	10.35	9.14	2.90	3.87	3.39
N-32	3.2	3.0	3.1	0.75	0.73	0.75	10.98	9.24	10.11	3.82	3.63	3.73
N-33	3.2	3.3	3.3	0.77	0.94	0.86	10.17	12.59	11.38	3.87	4.06	3.97
N-34	3.5	3.7	3.6	0.87	1.06	0.97	10.35	12.80	11.58	3.95	4.36	4.16
N-36	3.3	3.3	3.3	0.85	0.86	0.86	8.42	11.09	9.76	2.85	3.94	3.40
N-37	4.1	3.9	4.0	0.85	0.82	0.84	11.28	12.04	11.66	3.93	4.18	4.06
N-38	3.5	5.1	4.3	0.71	0.94	0.83	10.42	12.02	11.22	3.61	4.71	4.16
N-41	2.8	3.9	3.4	0.70	0.85	0.78	9.86	10.97	10.42	3.92	3.99	3.96
N-42	3.8	4.3	4.1	0.71	0.84	0.78	10.50	10.98	10.74	3.88	4.17	4.03
N-43	3.1	3.9	3.5	0.70	0.86	0.78	10.21	12.84	11.53	3.79	4.44	4.12
N-46	3.2	3.4	3.3	0.70	0.88	0.79	10.27	10.82	10.55	4.05	4.09	4.04
N-49	3.4	3.8	3.6	0.67	0.82	0.75	8.91	10.35	9.63	3.31	4.04	3.68
N-51	3.2	3.1	3.2	0.78	0.90	0.84	10.32	12.03	11.18	3.68	4.34	4.01
N-55	3.9	3.7	3.8	0.90	0.85	0.88	10.33	10.15	10.24	3.95	4.09	4.02
N-56	3.6	2.8	3.2	0.94	0.84	0.90	10.19	9.53	9.86	4.36	3.96	4.16
N-57	4.0	3.3	3.7	0.88	0.82	0.85	9.90	12.25	11.08	3.88	4.36	4.12
N-61	3.5	3.9	3.7	0.85	0.85	0.85	9.96	10.99	10.48	4.05	4.05	4.05
N-63	3.3	4.0	3.7	0.82	0.83	0.83	10.01	10.85	10.43	3.82	3.86	3.84
N-66	3.1	4.3	3.7	0.70	0.89	0.80	9.30	12.49	10.90	3.46	4.97	4.22
N-70	3.0	3.5	3.3	0.59	0.85	0.72	7.56	12.08	9.97	2.50	4.29	3.40
N-72	3.3	4.3	3.8	0.86	1.16	1.01	9.61	12.22	10.92	3.66	5.34	4.50
N-74	3.5	3.2	3.4	0.88	0.91	0.90	10.36	11.95	11.16	4.09	4.34	4.22
Mean	3.38	3.60	3.51	0.79	0.87	0.84	9.94	11.46	10.71	3.73	4.26	4.00
SEM±	0.24	0.28	0.15	0.04	0.04	0.03	0.41	0.44	0.32	0.16	0.17	0.12
C.D. at 5%	0.69	0.80	0.44	0.11	0.11	0.09	1.17	1.28	0.91	0.48	0.50	0.34



Plate 18. Nutmeg seedling (90 days old) of N56, N22 and N55

Table 44. Root characters of seedling of different nutmeg genotypes.

Genotype	Root length			No. of secondary roots		
	1999	2000	Pooled	1999	2000	Pooled
N-1	9.85	10.12	9.99	1.34	0.30	0.81
N-4	14.00	12.78	13.39	1.84	0.50	1.17
N-5	13.79	9.95	11.87	1.63	0.00	0.82
N-7	13.57	9.74	11.66	0.00	0.40	0.20
N-10	9.73	8.89	9.31	1.00	1.20	1.10
N-11	10.95	10.61	10.78	0.50	0.90	0.70
N-22	11.81	9.85	10.83	0.00	1.30	0.65
N-23	13.10	10.42	11.77	1.00	0.65	0.83
N-24	13.02	9.48	10.80	0.75	1.35	1.05
N-26	13.30	8.75	11.03	1.63	2.25	1.94
N-27	12.96	9.86	11.41	1.84	0.70	1.27
N-29	10.10	11.96	11.03	1.00	1.10	1.05
N-30	11.05	10.15	10.60	1.00	0.60	0.80
N-32	13.47	9.92	11.70	0.50	0.00	0.25
N-33	12.15	14.18	13.17	2.75	0.30	1.53
N-34	12.25	9.51	10.88	1.00	0.50	0.75
N-36	10.85	8.95	9.90	1.00	1.80	1.40
N-37	15.30	13.08	14.19	6.25	0.80	3.53
N-38	13.10	15.20	14.15	2.00	1.20	1.10
N-41	10.16	9.92	10.04	1.00	0.13	0.57
N-42	12.01	14.78	13.40	2.00	0.90	1.45
N-43	12.51	12.66	12.59	0.00	0.40	0.20
N-46	12.27	8.35	10.32	1.00	1.00	1.00
N-49	11.58	8.90	10.24	0.50	0.40	0.45
N-51	10.62	12.26	11.44	3.88	1.00	2.44
N-55	12.97	9.30	11.17	1.75	1.10	1.43
N-56	11.68	8.72	10.20	0.0	0.60	0.30
N-57	14.80	9.42	12.11	1.50	1.80	1.65
N-61	16.61	9.78	13.20	2.00	1.40	1.70
N-63	14.45	9.85	12.15	1.25	3.50	2.38
N-66	10.57	9.95	11.52	0.0	2.40	1.20
N-70	13.35	11.65	12.50	0.50	0.10	0.30
N-72	15.20	14.87	15.04	0.50	0.10	0.30
N-74	10.56	11.34	10.95	3.50	0.90	2.20
Mean	12.46	10.74	11.52	1.35	0.89	1.12
SEM $\pm$	1.00	0.78	0.73	1.13	0.43	0.47
C.D. at 5%	2.89	2.26	2.12	3.26	1.23	1.37

From the above results it is evident that there was a great amount of variation for duration of germination, per cent success in germination and overall seedlings growth at 90 days. It is desirable to have a genotype having minimum period for germination, greatest success of germination, vigorous shoot growth with thick collar, profuse foliage and good rooting ability. While making the selections, it is necessary to understand the magnitudes of genetic parameters for all such characters. From the data in Table 45 & 46 it is revealed that there was substantial variability at genotypic as well as phenotypic levels for number of secondary roots, root length, germination percentage and days for germination.

Table 45. Mean squares and components of variance of different seedling characters in nutmeg genotypes.

Sr. No.	Character	Mean	Mean sum of squares for variety	Mean sum of squares for Error	Phenotypic variance	Genotypic variance	Environmental variance
1.	Germination (%)	51.69	205.46**	2.98	104.22	101.24	2.98
2.	Days required for germination	70.02	287.10**	5.11	146.10	140.99	5.11
3.	Total height	25.93	8.38**	1.13	4.76	3.62	1.13
4.	Shoot height	14.34	2.34**	0.71	1.52	0.82	0.71
5.	Total leaves	3.51	0.17**	0.05	0.11	0.06	0.05
6.	Petiole length	0.84	0.01**	0.001	0.00	0.004	0.002
7.	Leaf length	10.71	0.90**	0.20	0.55	0.35	0.200
8.	Leaf breadth	4.00	0.17**	0.03	0.10	0.07	0.028
9.	Thickness at collar	0.35	0.01*	0.003	0.000	0.00	0.00
10.	Root length	11.52	4.65**	1.08	2.86	1.79	1.08
11.	Secondary roots	1.12	1.09**	0.45	0.77	0.32	0.45
12.	Fresh seed weight	6.79	3.77**	0.17	1.97	1.80	0.17

*, ** Significant at 5% and 1% level of significance respectively

For remaining characters the coefficient of variation at phenotypic and genotypic level were relatively low. Further, the heritability in broad sense was very high for germination percentage, duration of germination, height of seedling, petiole length, leaf breadth and root length. Moreover, the magnitudes of GAM for germination, duration for germination and root

length were very high. This suggested that these characters are governed by additive gene action. For weight of fresh seed to be used for germination the variability at genotypic and phenotypic level as well as magnitudes of heritability and GA were very high hence this character could also be considered under the control of additive genes. The results, thus warrant that there is good scope for selecting an elite material at the stage of germination itself preferably on the basis of per cent germination, duration for germination, root length and fresh seed weight.

Table 46. Genetic parameters of seedling characters in nutmeg genotypes

Sr. No.	Character	Phenotypic coefficient of variation	Genotypic coefficient of variation	Environmental coefficient of variation	Heritability (h^2 b)	Genetic Advance	Genetic advance on % mean basis
1.	Germination (%)	19.75	19.46	0.29	97.10	20.42	39.51
2.	Days required for germination	17.26	16.96	0.30	96.50	24.03	34.32
3.	Total height	8.41	7.34	1.07	76.20	3.42	13.20
4.	Shoot height	8.61	6.30	2.31	53.50	1.36	9.49
5.	Total leaves	9.40	7.08	2.32	56.70	0.39	10.98
6.	Petiole length	9.28	7.57	1.71	69.50	0.11	13.28
7.	Leaf length	6.94	5.54	1.40	63.70	0.98	9.11
8.	Leaf breadth	7.91	6.71	1.20	72.40	0.47	11.80
9.	Thickness at collar	9.16	0.00	9.16	43.70	0.03	8.25
10.	Root length	14.67	11.59	3.08	62.40	2.17	18.87
11.	Secondary roots	78.41	50.48	27.93	41.50	0.75	67.03
12.	Fresh seed weight	20.65	19.76	0.89	91.50	2.64	38.93

4.8.1 Correlation studies :

The correlation studies specifically at genotypic level are of great use for choosing the method of selection or for identification of characters upon which more weightage is to be given. The correlation coefficient at genotypic as well as phenotypic level of seedling characters with fresh weight of seed in nutmeg genotypes under study are presented in Table 47.

Table 47. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient of seedling characters in nutmeg types.

Sr. No.	Character	Germi- nation (%)	Days required for germi- nation	Total height	Shoot height	Total leaves	Petiole length	Leaf length	Leaf breadth	Thick- ness at collar	Root length	Second ary roots	Fresh seed weight
1.	Germination (%)	-	-0.177	0.165	0.169	0.119	-0.016	0.061	0.095	0.108	0.162	0.074	-0.267
2.	Days required for germination	-0.172	-	-0.155	-0.138	-0.366*	-0.342*	-0.37	-0.131	0.148	-0.131	0.267	-0.390*
3.	Total height	0.148	-0.124	-	0.749**	0.720**	0.387*	0.524**	0.465**	0.723**	0.933**	0.095	-0.060
4.	Shoot height	0.146	-0.076	0.557**	-	0.467**	0.448**	0.494**	0.633**	0.579**	0.419*	0.051	0.116
5.	Total leaves	0.096	-0.260	0.534**	0.297	-	0.224	0.433*	0.492**	0.790**	0.714**	0.352*	0.336
6.	Petiole length	-0.024	-0.277	0.269	0.301	0.149	-	0.673**	0.703**	0.444**	0.119	0.120	0.484**
7.	Leaf length	0.043	-0.031	0.382*	0.274	0.266	0.463**	-	0.746**	0.545**	0.478**	0.448**	0.184
8.	Leaf breadth	0.069	-0.080	0.375*	0.348*	0.259	0.601**	0.658	-	0.733**	0.306	-0.018	0.490**
9.	Thickness at collar	0.105	0.095	0.437**	0.312	0.416*	0.281	0.372	0.574**	-	0.672**	0.437*	0.335
10.	Root length	0.140	-0.074	0.776**	0.179	0.493**	0.145	0.321	0.285	0.374*	-	0.135	-0.179
11.	Secondary roots	-0.009	0.142	0.090	-0.126	0.199	0.116	0.298	0.135	0.184	0.201	-	0.113
12.	Fresh seed weight	-0.242	-0.386	-0.19	0.054	0.290	0.378*	0.139	0.393*	0.211	-0.127	0.064	-

*, ** significant at 5% and 1% level of significance respectively.

The germination percentage did not show any kind of association with any other character under study which suggested that it is difficult to go for identifying the genotype with promising performance for germination merely on the basis of related characters.

The duration for germination showed negative correlation with total leaves, petiole length and fresh seed weight. This suggested that the genotype with bolder fresh seeds can produce the seedlings having longer roots, profuse foliage having long and broad leaves with longer petiole in a short period from sowing. The seedling height showed positive correlation with shoot height, root length, total number of leaves, petiole length, length of leaves, breadth of leaves, thickness of collar and root length but did not indicate correlation with fresh seed weight. Among the remaining characters' petiole length and leaf breadth showed highly significant positive correlation with fresh seed weight. This provides evidence for the role of the character determining vigour of leaf with that of the seed. The strong thick petiole and broad leaves thus appeared to be the direct determinants of boldness of seeds and hence the selections can be executed even at seedling stage for bolder seeds on the basis of the leaf breadth and petiole length. The petiole length and leaf breadth had alternatively strong positive correlation with seedling length and shoot length and the leaf breadth individually had significant positive correlation with total number of leaves, leaf length and also with the petiole length. In general it can be concluded that selection of genotypes even at seedling stage on the basis of the characters of vigour namely number of leaves, length and breadth of leaves, thickness of collar and petiole length would lead to isolation of genotypes with better seed parameter for propagation of nutmeg.

4.9 Grafting and graft characters :

Plant propagation deals with the multiplication and production process using propagules representing a specific genotype. Nutmeg is conventionally propagated by seed. It is an obligatory cross pollinated crop and hence the resultant seedlings not only differs from each other with respect to economical features but also turn into 50 per cent male seedlings. Vegetative propagation

Table 48. Graft sprouting, survival and mortality of different nutmeg genotypes.

Genotype	Sprouting %			Survival %			Mortality %		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	100 (90.00)	85 (67.21)	92.5 (74.11)	90 (71.56)	80 (63.44)	85.0 (67.21)	10 (18.44)	20 (26.56)	15.0 (22.79)
N-4	100 (90.00)	90 (71.56)	95.0 (77.08)	95 (77.08)	80 (63.44)	87.5 (69.30)	5 (12.92)	20 (26.56)	12.5 (20.70)
N-5	100 (90.00)	95 (77.08)	97.5 (80.90)	90 (71.56)	80 (63.44)	85.0 (67.21)	10 (18.44)	20 (26.56)	15.0 (22.79)
N-7	100 (90.00)	95 (77.08)	97.5 (80.90)	75 (60.00)	75 (60.00)	75.0 (60.00)	25 (30.00)	25 (30.00)	25.0 (30.0)
N-10	90 (71.56)	90 (71.56)	90.0 (71.56)	70 (56.79)	75 (60.00)	72.5 (58.37)	30 (33.21)	25 (30.00)	27.5 (31.63)
N-11	100 (90.00)	90 (71.56)	95.0 (77.08)	80 (63.44)	75 (60.00)	77.5 (61.68)	20 (26.56)	25 (30.00)	22.5 (28.32)
N-22	95 (77.08)	80 (63.44)	85.0 (67.21)	70 (56.79)	65 (53.73)	67.50 (55.24)	30 (33.21)	35 (36.27)	32.5 (34.76)
N-23	70 (56.79)	65 (53.73)	67.5 (55.24)	50 (45.00)	35 (36.27)	42.50 (40.69)	50 (45.00)	65 (53.73)	57.5 (49.31)
N-24	100 (90.00)	90 (71.56)	95.0 (77.08)	95 (77.08)	80 (63.44)	87.50 (69.30)	5 (12.92)	20 (26.56)	12.5 (20.70)
N-26	90 (71.56)	70 (56.79)	80 (63.44)	80.00 (63.44)	65 (53.73)	72.5 (58.37)	20 (26.56)	35 (36.27)	27.5 (31.63)
N-27	95 (77.08)	80 (63.44)	87.5 (69.3)	75.00 (60.00)	65 (53.73)	70.0 (56.79)	25 (30.00)	35 (36.27)	30.0 (33.21)
N-29	90 (71.56)	90 (71.56)	90.0 (71.56)	90.00 (71.56)	80 (63.44)	85.0 (67.21)	10 (18.44)	20 (26.56)	15.0 (22.79)
N-30	90 (71.56)	70 (56.79)	80.0 (63.44)	70.00 (56.79)	60 (50.77)	65.0 (53.73)	30 (33.21)	40 (39.23)	35.0 (36.27)
N-32	100 (90.00)	70 (56.79)	85.0 (67.21)	85 (67.21)	70 (56.79)	77.5 (61.68)	15 (22.79)	30 (33.21)	22.5 (28.32)

Table 48 continued.....

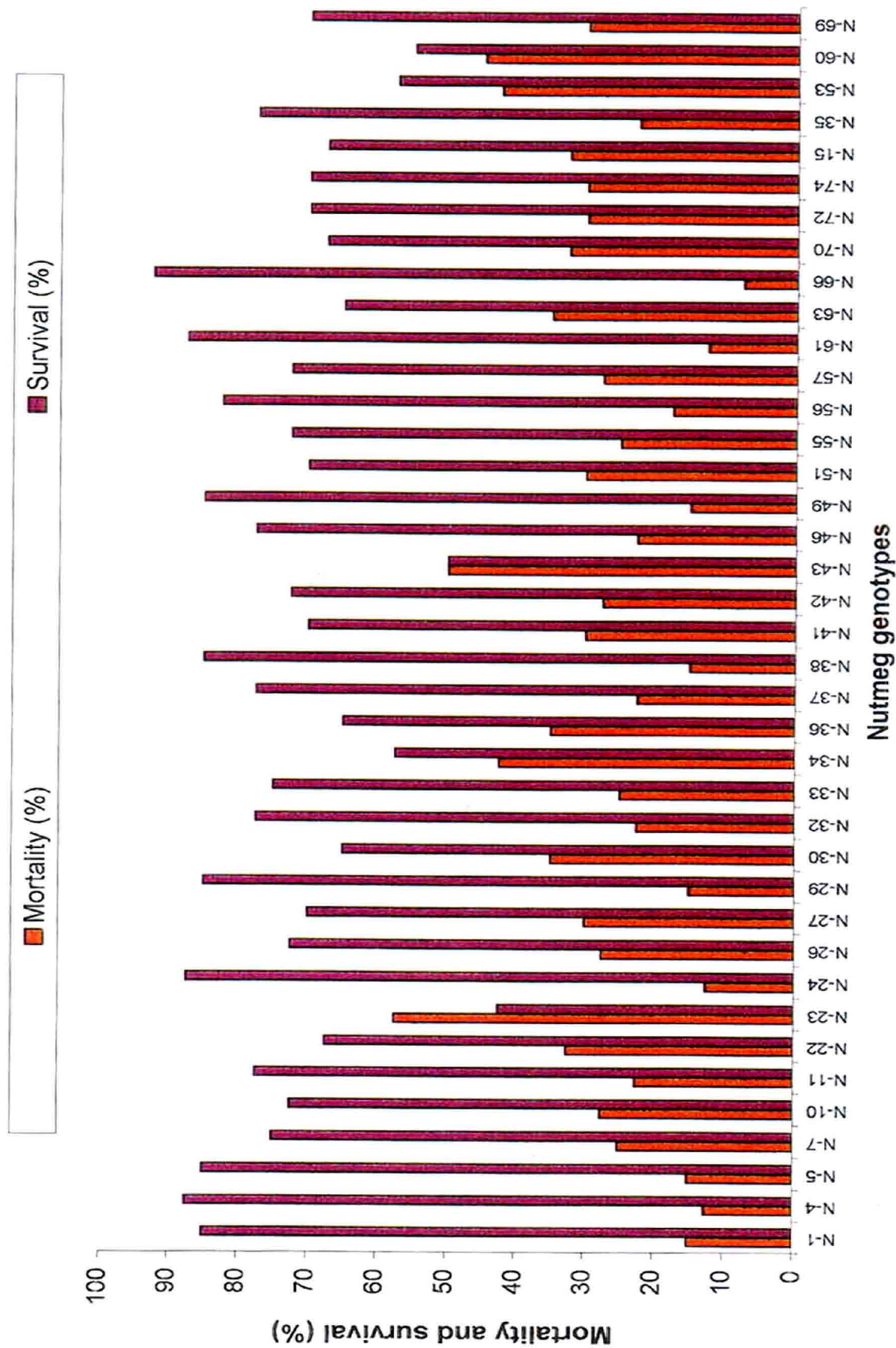
Genotype	Sprouting %			Survival %			Mortality %		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-33	100 (90.00)	80 (63.44)	90.0 (71.56)	85 (67.21)	65.0 (53.73)	75.0 (60.00)	15 (22.79)	35 (36.27)	25.0 (30.00)
N-34	80 (63.44)	70 (56.79)	75.0 (60.00)	60 (50.77)	55 (47.87)	57.5 (49.31)	40 (39.23)	45 (42.13)	42.5 (40.69)
N-36	95 (77.08)	70 (56.79)	82.5 (65.27)	70 (56.79)	60 (50.77)	65.0 (53.73)	30 (33.21)	40 (39.23)	35.0 (36.27)
N-37	90 (71.56)	80 (63.44)	85.0 (67.21)	85 (67.21)	70 (56.79)	77.5 (61.68)	15 (22.79)	30 (33.21)	22.5 (28.32)
N-38	95 (77.08)	85 (67.21)	90.0 (71.56)	90 (71.56)	80 (63.44)	85.0 (67.21)	10 (18.44)	20 (26.56)	15.0 (22.79)
N-41	85 (67.21)	75 (60.00)	80.0 (63.44)	70 (56.79)	70 (56.79)	70.0 (56.79)	30 (33.21)	30 (33.21)	30.0 (33.21)
N-42	95 (77.08)	80 (63.44)	87.5 (69.30)	80 (63.44)	65 (53.73)	72.5 (58.37)	20 (26.56)	35 (36.27)	27.5 (31.63)
N-43	80 (63.44)	70 (56.79)	75.0 (60.00)	50 (45.00)	50 (45.00)	50.0 (45.00)	50 (45.00)	50 (45.00)	50.0 (45.00)
N-46	95 (77.08)	75 (60.00)	85.0 (67.21)	85 (67.21)	70 (56.79)	77.5 (61.68)	15 (22.79)	30 (33.21)	22.5 (28.32)
N-49	95 (77.08)	85 (67.21)	90.0 (71.56)	95 (77.08)	75 (60.00)	85.0 (67.21)	5 (12.92)	25 (30.00)	15.0 (22.79)
N-51	85 (67.21)	70 (56.79)	77.5 (61.68)	75 (60.00)	65 (53.73)	70.0 (56.79)	25 (30.00)	35 (36.27)	30.0 (33.21)
N-55	100 (90.00)	70 (56.79)	85.0 (67.21)	80 (63.44)	65 (53.73)	72.5 (58.37)	15 (22.79)	35 (36.27)	25.0 (30.00)
N-56	100 (90.00)	80 (63.44)	90.0 (71.56)	90 (71.56)	75 (60.00)	82.5 (65.27)	10 (18.44)	25 (30.00)	17.5 (24.73)
N-57	100 (90.00)	70.00 (56.79)	85 (67.21)	80 (63.44)	65 (53.73)	72.5 (58.37)	20 (26.56)	35 (36.27)	27.5 (31.63)

Table 48 continued.....

Genotype	Sprouting %			Survival %			Mortality %		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-61	100 (90.00)	85 (67.21)	92.5 (74.11)	95 (77.08)	80 (63.44)	87.5 (69.30)	5 (12.92)	20 (26.56)	12.5 (20.70)
N-63	100 (90.00)	80 (63.44)	90.0 (71.56)	70 (56.79)	60 (50.77)	65.0 (53.73)	30 (33.21)	40 (39.23)	35.0 (36.27)
N-66	100 (90.00)	85 (67.21)	92.5 (74.11)	100 (90.00)	85 (67.21)	92.5 (74.11)	0 (0.00)	15 (22.79)	7.5 (15.89)
N-70	90 (71.56)	75 (60.00)	82.5 (65.27)	75 (60.00)	60 (53.73)	67.5 (55.24)	25 (30.00)	40 (39.23)	32.5 (34.76)
N-72	95 (77.08)	75 (60.00)	85.0 (67.21)	70 (56.79)	70 (56.79)	70.0 (56.79)	30 (33.21)	30 (33.21)	30.0 (33.21)
N-74	100 (90.00)	80 (63.44)	90.0 (71.56)	75 (60.00)	65 (53.73)	70.0 (56.79)	25 (30.00)	35 (36.27)	30.0 (33.21)
N-15	100 (90.00)	75 (60.00)	87.5 (69.30)	65 (53.73)	70 (56.79)	67.5 (55.24)	35 (36.27)	30 (33.21)	32.5 (34.76)
N-35	95 (77.08)	80 (63.44)	87.5 (69.30)	85 (67.21)	70 (56.79)	77.5 (61.68)	15 (22.79)	30 (33.21)	22.5 (28.32)
N-53	90 (71.56)	55 (47.87)	72.5 (58.37)	65 (53.73)	50 (45.00)	57.5 (49.31)	35 (36.27)	50 (45.00)	42.5 (40.69)
N-60	90 (71.56)	55 (47.87)	72.5 (58.37)	60 (50.73)	50 (45.00)	55.0 (47.87)	40 (39.23)	50 (45.00)	45.0 (42.13)
N-69	80 (63.44)	70 (56.79)	75.0 (60.00)	75 (60.00)	65 (53.73)	70.0 (56.79)	25 (30.00)	35 (36.27)	30.0 (33.21)
S.E. $\pm$	6.61	4.49	3.80	6.68	3.49	3.58	6.61	4.62	3.53
C.D. at 5%	18.90	12.84	10.85	19.08	9.98	10.23	18.90	13.18	10.11

Figures in the parenthesis indicate arcsine transformed values.

Fig. 14. Graft survival and mortality (%) of nutmeg genotypes



which reproduces progeny plants identical to a single mother plant is a solution to overcome this problem of dioeciousness in nutmeg. Recently the vegetative plant propagation methods mainly softwood grafting has shown promise in nutmeg. The genetic variability plays an important role in grafting technique. In view of this the 39 genotypes of nutmeg under study were assessed for success in softwood grafting. Period required for graft sprouting, sprouting (%), survival (%), mortality (%) and growth parameters of grafts were studied and the results are presented in Table 48 to 50 and illustrated with Fig. 14 and 15.

The population mean for sprouting (%) in nutmeg was 83.62 per cent (Table 48). It was maximum in N5 and N7 (97.5%) whereas it was minimum in N23 (67.5%). The genotype N66 featured highest survival (92.5%) and lowest mortality (7.5%). The other genotypes namely N4, N24 and N61 also showed higher magnitude of survival (87.5%) and lower mortality (12.5%). The population average for survival and mortality was 72.75 and 27.25 per cent, respectively. In genotypes N23 maximum mortality (57.5%) and minimum survival (42.5%) was recorded. Thus there was variation among the genotypes for success of grafting by softwood technique.

The average period required for graft sprouting in nutmeg was 23.21 days (Table 49). The sprouting was early in N42 (16 days) followed by the N22, N24, N26 and N38 (17 days). In N27 late sprouting was noticed (35 days) followed by N11 and N46 (34 days).

The growth parameters of the grafts prepared by using scion sticks of 39 nutmeg genotypes are given in Table 50. The average length of the new shoot, produced was 3.38 cm. It was maximum in N61 and N70 (4.71 cm) followed by N10 (4.5 cm). The grafts of N30 exhibited shortest length of new shoot (2.15 cm) followed by N37 (2.27 cm). The population mean for total new leaves was 2.09. In N1 it was maximum (3.3) followed by N60 (3.1). The production of new leaves on graft was minimum in N49 (1.3) followed by N23 (1.4).

Table 49. Period required for graft sprouting and new shoot length of the grafts prepared from nutmeg genotypes.

Genotype	Period required for sprouting (days)			New shoot length (cm)		
	1999	2000	Pooled	1999	2000	Pooled
N-1	25	28	26	3.76	3.76	3.76
N-4	21	23	22	3.98	2.50	3.24
N-5	17	20	18	4.28	4.31	4.30
N-7	26	28	27	3.41	2.57	2.99
N-10	26	29	28	4.60	4.39	4.50
N-11	32	34	34	3.98	3.84	3.91
N-22	16	19	17	4.03	2.84	3.44
N-23	17	19	18	3.88	2.10	2.99
N-24	16	18	17	5.25	3.05	4.15
N-26	16	17	17	3.65	2.39	3.02
N-27	31	38	35	3.48	2.47	2.97
N-29	20	25	23	3.85	3.15	3.50
N-30	19	19	19	2.59	1.70	2.15
N-32	23	24	23	3.65	1.88	2.72
N-33	23	24	24	3.20	1.81	2.51
N-34	23	27	25	5.46	3.48	4.47
N-36	24	25	24	3.04	1.90	2.47
N-37	31	32	31	2.69	1.85	2.27
N-38	16	18	17	3.76	3.10	3.33
N-41	22	23	22	3.81	2.03	2.92
N-42	15	18	16	3.55	2.00	2.78
N-43	30	35	32	3.40	1.67	2.54
N-46	34	34	34	3.84	2.08	2.96
N-49	29	29	29	3.30	2.12	2.71
N-51	19	23	21	3.14	2.83	2.99
N-55	24	24	24	3.32	2.40	2.86
N-56	20	22	21	4.04	2.88	3.46
N-57	23	24	23	3.98	2.68	3.33
N-61	22	24	23	5.97	3.45	4.71
N-63	18	20	19	4.88	2.00	3.44
N-66	25	27	26	4.27	3.08	3.68
N-70	21	23	22	5.99	3.42	4.71
N-72	26	27	26	3.93	2.93	3.43
N-74	21	25	23	3.92	3.08	3.50
N-15	21	24	22	5.38	3.25	4.32
N-35	22	24	23	4.58	2.65	3.62
N-53	16	19	18	4.02	2.07	3.04
N-60	17	20	18	5.26	3.57	3.98
N-69	21	23	22	5.18	3.10	4.14
SEM $\pm$	2.03	1.99	1.47	0.55	0.22	0.34
C.D. at 5%	5.78	5.71	4.19	1.57	0.63	0.97

Table 50. Growth parameters of graft prepared from nutmeg genotypes.

Geno- type	Total new leaves			Length of leaf petiole			Length of leaf			Breadth of leaf		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-1	3.2	3.5	3.3	1.0	1.0	1.0	9.04	9.80	9.42	3.05	3.27	3.16
N-4	2.0	2.1	2.1	0.9	0.9	0.9	11.04	10.43	10.74	3.93	3.91	3.92
N-5	2.8	2.6	2.7	0.8	0.8	0.8	9.70	10.77	10.24	3.19	3.40	3.30
N-7	1.7	1.5	1.6	0.8	0.7	0.7	7.31	5.15	6.23	2.51	2.32	2.42
N-10	2.6	2.3	2.2	0.8	0.7	0.8	8.34	8.20	8.27	2.92	2.79	2.86
N-11	2.4	2.6	2.5	0.7	0.8	0.7	7.34	6.68	7.03	2.88	2.86	2.87
N-22	2.2	1.5	1.8	0.9	0.7	0.8	9.44	9.09	9.27	3.31	3.25	3.28
N-23	1.5	1.3	1.4	0.9	0.7	0.8	8.97	7.44	8.21	3.25	2.83	3.04
N-24	2.1	1.6	1.9	0.8	0.7	0.7	10.81	8.66	9.74	4.81	4.03	4.42
N-26	3.6	1.5	2.6	0.7	0.6	0.7	9.07	9.07	9.07	2.94	2.84	2.89
N-27	2.0	1.3	1.7	0.9	0.8	0.8	9.20	9.20	9.20	3.18	2.52	2.85
N-29	2.7	1.0	1.9	1.0	0.9	0.9	10.12	10.55	10.34	4.19	2.36	3.28
N-30	2.2	1.9	2.0	0.7	0.7	0.7	8.41	8.57	8.49	3.25	2.82	2.80
N-32	2.5	1.3	1.9	0.6	0.6	0.6	7.42	7.13	7.28	4.27	3.16	3.72
N-33	2.1	1.3	1.7	0.7	0.7	0.7	8.68	7.03	7.86	3.24	2.65	2.95
N-34	2.9	2.0	2.4	0.9	1.0	0.9	8.66	6.43	7.55	3.20	2.73	2.97
N-36	2.2	1.2	1.7	0.8	0.7	0.7	10.42	10.42	10.42	3.41	3.09	3.26
N-37	1.9	1.5	1.7	0.9	0.9	0.9	11.05	8.80	9.93	3.24	3.15	3.19
N-38	2.7	2.3	2.5	0.8	0.8	0.8	7.97	7.27	7.62	2.95	3.12	3.04
N-41	2.4	1.0	1.7	1.0	1.0	1.0	12.19	10.48	11.34	3.97	3.23	3.60

Table 50 continued.....

Geno- type	Total new leaves			Length of leaf petiole			Length of leaf			Breadth of leaf		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
N-42	2.4	1.5	2.0	0.9	0.8	0.8	9.91	8.83	9.37	3.67	3.08	3.38
N-43	2.0	1.0	1.5	1.0	0.8	0.9	8.13	6.85	7.49	3.03	2.60	2.82
N-46	1.9	1.2	1.5	0.8	0.7	0.7	8.14	6.97	7.56	2.75	2.43	2.60
N-49	1.5	1.0	1.3	0.8	0.8	0.8	10.10	8.12	9.11	3.33	2.68	3.01
N-51	1.9	1.5	1.7	0.9	0.7	0.8	8.50	7.43	7.97	2.91	2.60	2.76
N-55	2.1	2.0	2.1	0.8	0.8	0.8	9.02	8.46	8.74	3.38	3.27	3.33
N-56	2.5	2.5	2.5	0.9	0.9	0.9	10.15	8.90	8.52	4.02	3.37	3.70
N-57	2.1	2.3	2.2	0.9	0.9	0.9	9.82	8.18	9.00	3.85	3.48	3.67
N-61	2.7	2.4	2.5	0.8	0.9	0.8	8.58	8.20	8.39	3.40	3.23	3.32
N-63	2.5	1.5	2.0	0.8	0.8	0.8	8.85	8.85	8.85	3.42	2.98	3.20
N-66	2.5	2.2	2.3	0.9	0.8	0.8	7.73	7.73	7.73	2.89	3.28	3.09
N-70	2.8	2.0	2.4	1.0	1.0	1.0	10.92	10.41	10.67	3.68	3.30	3.49
N-72	2.3	1.9	2.1	0.8	0.8	0.8	9.15	8.55	8.85	3.02	3.67	2.85
N-74	2.5	2.0	2.2	0.7	0.8	0.8	8.63	8.00	8.32	2.94	2.82	2.88
N-15	2.8	2.6	2.7	1.1	1.0	1.0	9.39	8.04	8.72	3.82	3.21	3.51
N-35	2.3	2.0	2.2	1.1	1.0	1.0	9.88	9.88	9.88	3.51	3.33	3.42
N-53	2.2	2.2	2.2	0.7	0.7	0.7	11.16	9.20	10.18	4.46	3.26	3.86
N-60	3.3	2.9	3.1	0.7	0.7	0.7	8.53	7.83	8.19	2.92	2.92	2.92
N-69	2.3	1.7	2.0	0.9	0.9	0.9	10.12	9.24	9.68	4.07	3.25	3.66
SEM ±	0.31	0.19	0.21	0.07	0.03	0.04	0.76	0.46	0.55	0.28	0.18	0.17
C.D. at 5%	0.88	0.54	0.60	0.19	0.07	0.11	2.18	1.32	1.56	0.80	0.51	0.49

The grafts prepared by using the scion of N7 produced relatively smaller leaves having shortest length (6.23 cm) and breadth (2.42 cm). The longest length of leaf was recorded in N41 (11.34 cm) followed by N70 (10.67 cm). Whereas the broadest leaves were noticed in N24 (4.42 cm). The mean values for length and breadth of leaf were 8.89 cm and 3.04 cm, respectively. The leaf of N32 graft had short petiole (0.6 cm) and the grafts of N1, N41, N70, N15 and N35 and had long petiole (1.0 cm). The average petiole length was 0.82 cm.

Table 51. Mean, Mean sum of squares and genetic variance of graft parameters of nutmeg genotypes

Sr. No.	Character	Mean	Mean sum of squares for treatment	Mean sum of squares for error	Genotypic variance	Phenotypic variance	Environmental variance
1.	Days required for sprouting	23.21	49.58**	4.31	22.64	26.95	4.31
2.	Sprouting (%) of grafts	83.62	82.25**	28.89	26.68	55.58	28.89
3.	Survival (%) of grafts	72.75	104.20**	25.67	39.28	64.96	25.68
4.	Mortality (%) of grafts	27.25	104.20**	25.04	39.62	64.67	25.04
5.	New shoot length on graft	3.38	0.91**	0.23	0.34	0.57	0.23
6.	New leaves on graft	2.09	0.40**	0.09	0.16	0.25	0.09
7.	Length of leaf petiole	0.82	0.03**	0.003	0.01	0.02	0.003
8.	Length of leaf	8.89	2.61**	0.60	1.01	1.61	0.60
9.	Breadth of leaf	3.04	1.31**	0.06	0.63	0.69	0.06

** Significant at 1 per cent level of significance

The variation among genotypes for the period required for sprouting, sprouting (%), survival (%), mortality (%) and growth parameters was statistically significant (Table 51). The extent of variance at genotypic and phenotypic levels was high for sprouting, survival and mortality. The growth parameters of graft showed lower levels genotypic and phenotypic variance. The magnitudes of phenotypic coefficient of variation (PCV) and

Genotypic coefficient of variation (GCV) were lowest for sprouting followed by survival (Table 52). The magnitudes for PCV and GCV were highest for mortality followed by period required for sprouting. The heritability in broad sense for width of leaf was very high (91.3). It was moderately high for other components. The relatively low genetic advance on percent mean basis for sprouting and survival suggested that these parameters for softwood grafting in nutmeg are governed by nonadditive gene action.

Table 52. Genetic components of graft parameters of nutmeg genotypes

Sr. No.	Character	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Environmental coefficient variation (ECV)	Heritability (h^2 b)	Genetic Advance	Genetic advance on % mean basis
1.	Period required for sprouting	22.37	20.50	1.87	84.0	8.98	38.70
2.	Sprouting (%)	10.85	7.52	3.33	48.0	7.37	10.73
3.	Survival (%)	13.64	10.61	3.03	60.5	10.05	17.00
4.	Mortality (%)	26.03	20.37	5.66	61.3	10.15	32.86
5.	New shoot length	22.34	17.25	5.09	59.6	0.93	27.40
6.	New leaves	23.92	19.14	4.78	64.0	0.65	31.26
7.	Length of leaf petiole	17.25	12.20	5.05	79.4	0.20	24.43
8.	Length of leaf	14.27	11.30	2.97	62.8	1.64	18.46
9.	Breadth of leaf	27.32	26.11	1.21	91.3	1.56	51.24

4.9.1 Correlation studies :

The correlation studies particularly at genotypic level are of great importance for determining the method of selection or for identifying the characters upon which more weightage can be given. The correlation coefficients of grafting components with graft survival at genotypic as well as phenotypic level are given in Table 53.

Table 53. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients of graft parameters in nutmeg types.

Sr. No.	Particulars	Days required for sprouting	Sprouting (%)	Mortality	New shoot length	New leaves	Petiole length	Leaf length	Leaf breadth	Survival
1.	Days required for graft sprouting	1.000	0.275	-0.159	-0.132	-0.273	0.136	-0.394*	0.032	0.160
2.	Sprouting (%)	0.069	1.000	-0.886**	0.257	0.222	-0.115	-0.066	-0.154	0.891**
3.	Mortality (%)	-0.29	-0.707**	1.000	-0.202	-0.251	-0.042	-0.234	0.330*	-0.001
4.	New shoot length	-0.135	0.225	-0.164	1.000	0.658**	0.328*	0.004	0.040	0.211
5.	New leaves	-0.241	0.129	-0.130	0.597**	1.000	0.302	0.002	-0.339*	0.256
6.	Petiole length	0.082	0.021	-0.033	0.268	0.161	1.000	0.466**	-0.161	0.043
7.	Leaf length	-0.229	-0.050	-0.042	0.083	0.057	0.325*	1.00	-0.280	0.236
8.	Leaf breadth	0.083	-0.163	0.223	0.051	-0.243	-0.126	-0.191	1.000	-0.331*
9.	Survival (%)	0.028	0.707**	-0.999**	0.165	0.128	0.034	0.043	-0.222	1.000

*, ** significant at 5% and 1% level of significance respectively.

The graft survival showed strong positive correlation with graft sprouting. Further it had strong negative correlation with leaf breadth. However, it did not exhibit any kind of association with any other character under study.

The graft sprouting displayed strong negative correlation with graft mortality. The graft shoot height recorded positive association with new leaves and petiole length but did not indicated any correlation with graft survival. This suggested that the genotype with longer new shoot on graft had more number of leaves of longer petiole. Leaf breadth showed positive relation with graft mortality suggesting that the broad leaves on graft are indication of low success in grafting. In general, it is evident that sprouting percentage of graft is the most important factor to be considered for identification of nutmeg genotypes having better take of the graft.



DISCUSSION

CHAPTER V

DISCUSSION

Among the tree spices nutmeg has distinct position, specifically as a potential spice yielding intercrop in coconut plantation. Patil *et al.* (1991) have reported that among the three tree spices viz. nutmeg, clove and cinnamon intercropped in coconut plantation, nutmeg was the most remunerative and its intercropping increased the yield levels of main crop coconut significantly. The area under horticultural crops coconut including coconut is expanding rapidly in Konkan region as well as in other parts of Maharashtra due to implementation of Employment Guarantee Scheme linked with horticulture. Nutmeg being a shade loving crop provides scope for its cultivation particularly in coconut plantations. Such a large scope for plantation of nutmeg however, demands generation of adequate planting material of good quality. So far, nutmeg research has been confined mainly to standardization of propagation techniques. The research on cultivar development has not been very attempted. Recently the first high yielding hermaphrodite variety of nutmeg named “Konkan Sugandha” has been released by the Konkan Krishi Vidyapeeth (Sawke *et al.*, 1998). The research work on collection, conservation and identification of better nutmeg genotypes is also being carried out at Calicut and Yeracud (Peter 1996).

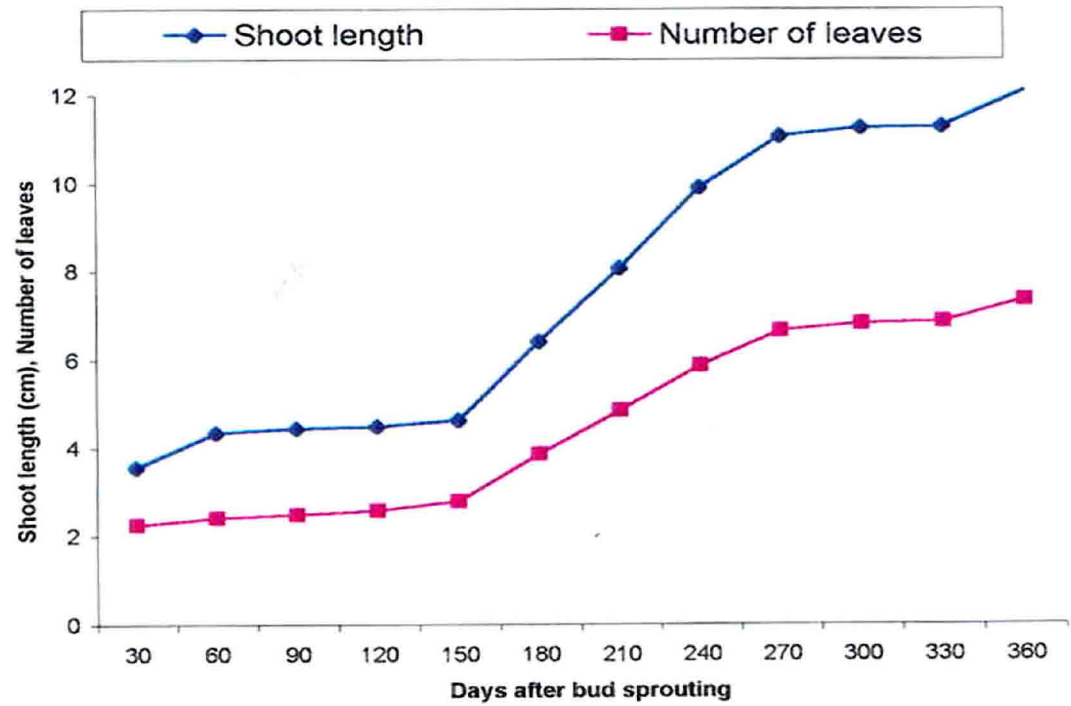
In nature good amount of variability exists in respect of the growth, vigour, sex expression, size and shape of nutmeg and quantity of mace (Anon, 1989). Selection of a genotype having all desirable characters is a basic requirement in a cultivar development programme in any crop. Defining the features of ideal genotype which can give high yield of quality nutmeg is the foremost requirement in the improvement of this crop. In current investigation 39 genotypes maintained at Regional Coconut Research Station, Ratnagiri have been investigated for assessing the variability, character association for high yield and screening of promising genotypes. These 39 genotypes comprised of 22 female, 12 hermaphrodite and 5 male genotypes. The results are discussed in this chapter.

5.1 Growth and development :

Nutmeg tree is densely foliated and grows to a height of 10 to 20 m. (Shanmugavelu and Madhava Rao, 1977; Purseglove *et al.*, 1981). The population of 22 female and 12 hermaphrodite genotypes under this investigation showed an average height of 7.87 m with 4.30 m spread of plant. The girth at bottom remained around 46 cm. The tree had on an average 34 crotches producing 119 primary, 2932 secondary and 18,576 tertiary branches. They showed mean crown volume of 42.19 m³ with a surface area of 72.50 m². In a period of six years after start of bearing phase the average yield was 275 nuts per tree. Nevertheless in recent two years there was remarkable yield increase with a population mean of 352 nuts per tree. The male genotypes had an average height of 8.76 m with a mean spread of branches 4.87 m. The girth at bottom was 52.0 cm. The mean crotches produced by male nutmeg tree were 35.8. The average 116.20 primary branches produced 3143 secondary branches and 20649 tertiary branches. The average crown volume recorded was 65.66 m³ with a surface area average of 99.56m². Krishnamoorthy *et al.* (1996) observed the total canopy of nutmeg tree to be 40 to 109.4 m³ among the genotypes they studied. The stem girth ranged from 30 to 47 cm.

Study of growth of vegetative flushes indicated that in general the trees produced new vegetative shoots two times in a year. The first shoot was most commonly produced in second fortnight of January. The second flush occurred in the second fortnight of May to first fortnight of June. In some genotypes like N5, N7, N29, N37, N43, N49, N66, N70 and N72 a third vegetative flush also emerged mostly in November which extended upto December. Under Kerala conditions Nazeem and Nair (1981) observed two peaks in nutmeg flushes in May and September. Further the cyclic growth i.e. a period of growth followed by a quiescence in nutmeg has been also noticed under Kerala conditions (Thomas, 1997). The average shoot length of the nutmeg genotypes under study suggested that nutmeg tree is slow grower. This could be attributed to the inherent genetic makeup of the genotypes. The observations in accordance with this findings were also recorded by Nazeem (1979) and Ram (1982) in the nutmeg crop. Further

Fig. 15. Shoot length and number of leaves during different period of growth



the shoot elongation was rapid during 150 to 270 days from shoot emergence (Fig. 15). This appeared to be due to congenial agroclimatic conditions prevailing during the monsoon period. Appearance of flower occurred in 3 to 4 flushes in most of the genotypes. The first flush occurred in May, second in June or July, third in September and fourth in October or November. In the genotype, N43 there was only one flowering flush which occurred in first fortnight of June. In genotypes namely, N5, N21, N23, N26, N27, N30, N51, N66, N70, N72 and N74 the flowering occurred in two flushes starting from May to July. Subsequent to flowering September and October was found to be the period of fruit setting in most of the genotypes. However, in N1, N26, N27, N30, N42, N43, N51, N66 and N72 the fruit set occurred in June as well as in July. The flowering in male genotypes however continued round the year in frequent flushes. Restricted flowering in female genotypes and continuous flowering in male genotypes has been reported under Kerala conditions (Nazeem, 1979; Nazeem *et al.*, 1981). Further under Dapoli conditions also variation in flowering flushes in male and female genotypes has been recorded (Ram, 1982).

5.2 Flowering and fruit set :

The period from appearance of floral bud to anthesis was very long in nutmeg. The two year population average was 40.83 days. Interestingly on female genotypes, the period from bud to flowering stage was shortest (39.13 days) whereas, it was longest in male flowers (46.05 days). The hermaphrodite flowers showed an intermediate period (41.89 days). There were some genotypes in female population which flowered within 34.5 days (N34) whereas, the genotype N42 required longest period (47.25 days). Among the hermaphrodite genotypes N26 exhibited minimum period for bud to flowering stage whereas, maximum 51.25 days were needed in N63. The male genotypes required a period between 43.25 to 48.75 days from bud to flowering. Under Kerala conditions Nazeem (1979) noticed 84.20 and 154.10 days respectively for anthesis in male and female genotypes whereas Ram (1982) reported 42.66 and 42.45 days respectively for anthesis in male and female genotypes under Dapoli conditions. This indicate that period required for anthesis very according to genotypes and location.

The flower production occurred innumerable. For understanding the percentage of flowers which can lead to set the fruits 100 flowers in two sets were tagged randomly on each genotype. It was revealed that on an average the fruit set was 15 per cent and ranged from 2 to 41 per cent indicating wide variability in flowering as well as fruit set. The varying percentage of fruit set has also been reported by Flach (1966), Nazeem (1979) and Ram (1982) from 0 to 50 per cent.

5.3 Fruit development :

The developing fruit is a potential sink which derives assimilates from the neighbouring functional leaves. According to Hay and Walker (1989) the availability of assimilates in formative stages of economic sink development is an important determinant of yield. It is therefore important to understand the partitioning process which determines, how much of the assimilates become available for different components of fruit in ontogeny. The nutmeg fruit has three major components namely, fleshy pericarp, feathery colourful mace and hard stony nut. The term assimilate partitioning encompasses the biochemical and spatial compartmentation of the fixed carbon within the photosynthesising cells as well as the subsequent movement of sucrose to the phloem of the minor veins where it is loaded into sieve elements. In this sense partitioning started with the divergence of photosynthetic metabolism at the very point of fruit development in nutmeg.

The assimilate partitioning in the three components of fruit showed a peculiar pattern. In initial 100 days the fleshy pericarp was a predominant sink (Table 54; Fig. 16 and 17). The nut became a stronger sink from 125 days onwards and the mace grew steadily throughout the course of fruit ontogeny. About 96 per cent photosynthates accounted in terms of dry matter were accumulated in fleshy pericarp at 25th day of development. At this stage the nut derived only 3 per cent assimilates and mace had only 1 per cent biomass in total fruit weight. In further period of time there was continuous decline in per cent proportion of fleshy pericarp which was accompanied by a continuous increase in per cent biomass proportion of nut

Table 54. Proportion of fruit components at various stages in developing nutmeg fruit.

Particulars	Days after fruit set																							
	25	50	75	100	125	150	175	200	225	250	275	300												
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Wt.	%
Pericarp	0.16	96	0.63	95	1.54	89	2.18	84	2.83	77	3.33	72	3.82	65	4.17	55	4.33	49	3.47	48	2.21	47	1.56	47
Nut	0.006	3	0.03	4	0.15	9	0.35	13	0.75	20	1.16	25	1.90	32	3.06	41	4.02	46	3.19	44	2.09	45	1.48	44
Mace	0.001	1	0.006	1	0.04	2	0.08	3	0.09	3	0.12	3	0.19	3	0.31	4	0.46	5	0.51	8	0.37	8	0.29	9
Total	0.167		0.666		1.73		2.61		3.67		4.61		5.91		7.54		8.81		7.17		4.67		3.33	

Fig. 16. Dry pericarp, nut and mace weight during fruit development

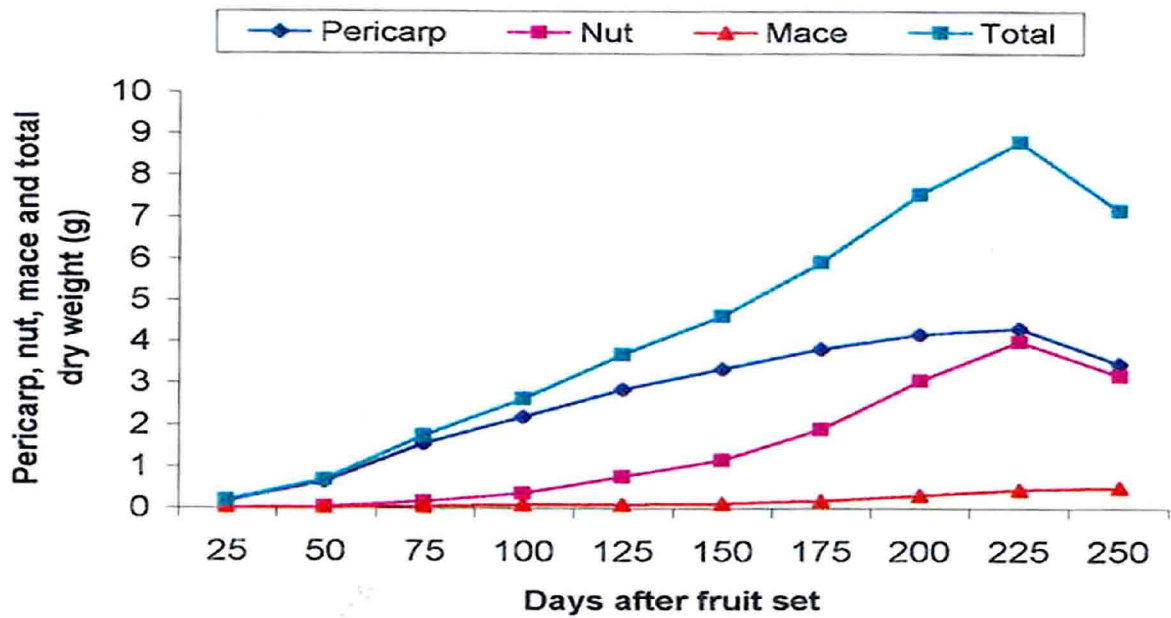
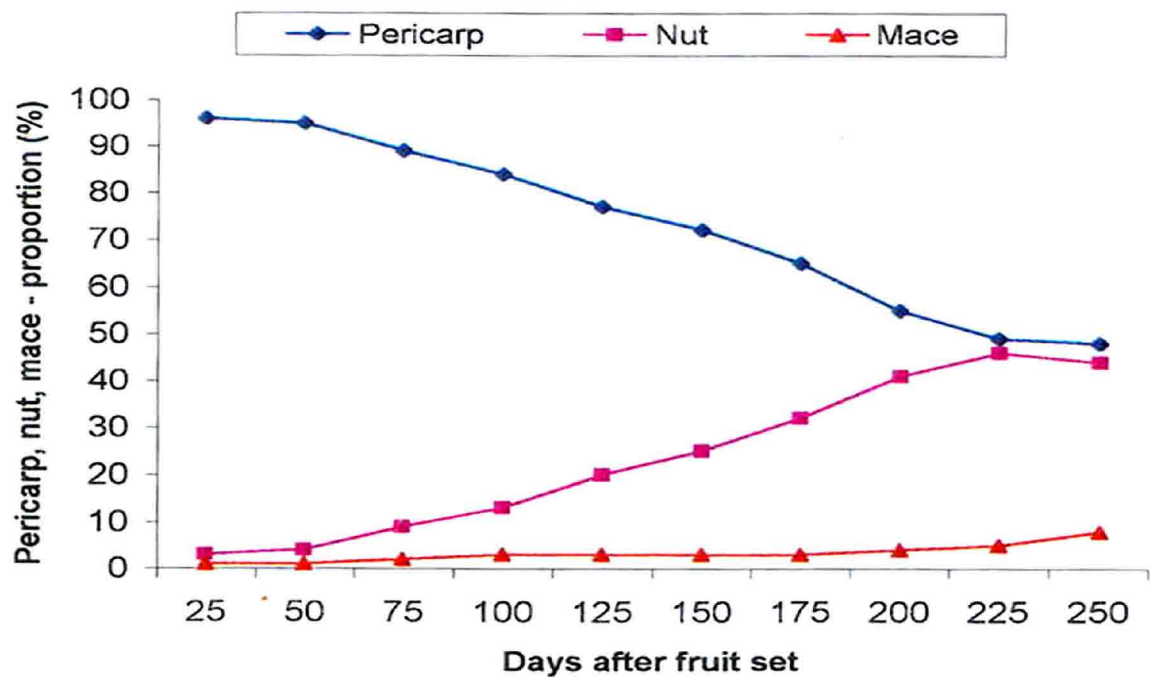


Fig. 17. Dry pericarp, nut and mace - proportion during fruit development



as well as mace. It must be noted that upto 200 days the pericarp was a more dominant sink than nut and mace taken together. From 225 days onwards the growth of nut and mace when taken together derived more proportion of assimilated than the pericarp. The trend continued till the maturity of fruit.

Thus, the fleshy pericarp remained the site of unloading the phloem sink in the initial period. The rapid growth of nut from 125 days onwards was concomitant with rapid decline in proportion of biomass into pericarp (Fig. 17). This suggested that the fleshy pericarp acted as a temporary and primary sink for assimilates which were further contributed for growth of nut as well as mace. Importantly the nut and mace development followed a linear curve in most of genotypes. The fruits matured in about 250 days in most of the genotypes reaching a total weight of 7.17 g. Out of this 48 per cent was contributed by fleshy pericarp, 44 per cent was shared by nut and 8 per cent portion was allocated to mace. The substantially long period for fruit development has also reported by Flach (1966), Nazeem (1979) and Anonymous (1989) in nutmeg. Further Nazeem (1979) also reported the slow growth in the later stages of fruit development in nutmeg.

The fruit growth also showed some apparent qualitative changes (Appendix IV & V). Upto 150 days most of the genotypes showed pale green fruit colour. At this stage, the average fruit weight was 4.61 g with perportion of 72 per cent fleshy pericarp, 25 per cent of nut and 3 per cent mace. From 175 days the colour of the fruit started becoming pale yellow. By this time the proportion of fleshy pericarp declined below 65 per cent whereas, that of nut was rose to 32 per cent. At 200 days, majority of genotypes had yellow coloured fruit whereas, some fruits retained greenness to some extent. It is therefore inferred that the fruits might produce some photosynthates of their own upto 150 days but they had to depend upon the neighbouring leaves and other green parts for supply of metabolites from 200 days onwards when they became yellow. In further course of time the skin colour of fruit was yellow with a remarkable variability in the colour density among the genotypes. The genotypes N4, N23, N24, N55 and N56 had pale yellow skin with brownish tinge whereas,

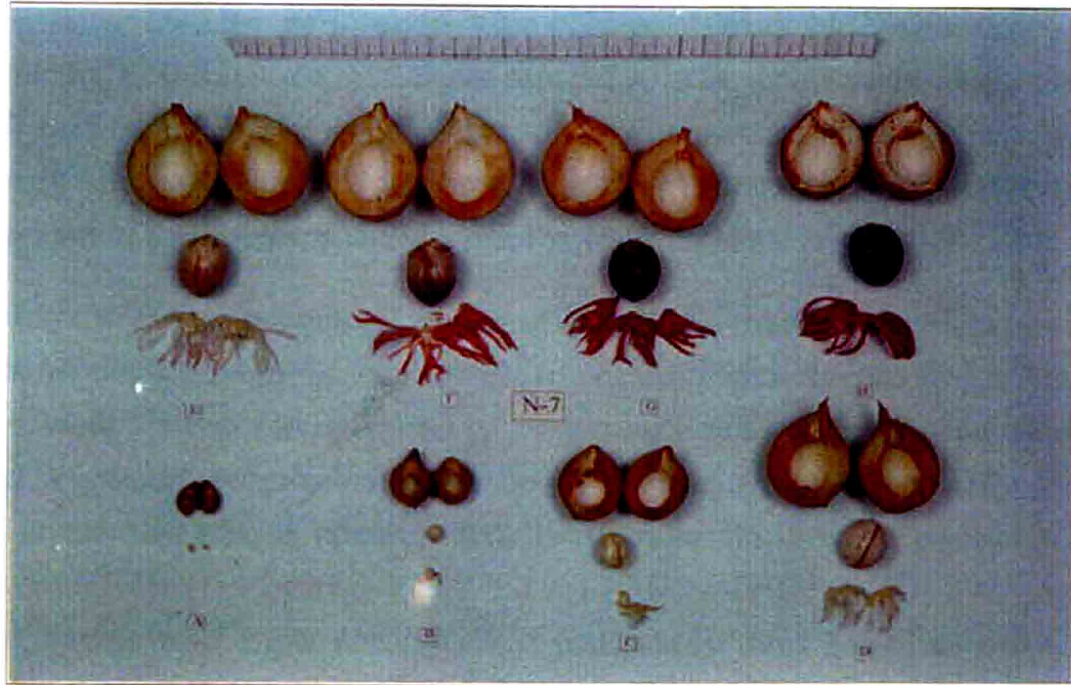


Plate 19. Fruit development in nutmeg genotype N7

- | | | |
|--------------|----------------|--------------|
| A - 25 days | B - 50 days | C - 75 days |
| D - 100 days | E - 125 days | F - 150 days |
| G - 225 days | H - At harvest | |

the genotypes N1, N7, N10, N11, N29, N34, N42, N43, N66, N70, N72 exhibited dense yellow colour.

The mace in early 50 days was papery thin and white. It gained some thickness and turned yellowish in most of genotypes at 75 days. From 100 days onwards the mace became more thick. At this stage, the contribution of mace to the total fruit weight was only 2 per cent. The thickening continued upto 150 days. In the genotypes viz. N7, N10 and N51 the mace started turning red by 150 days. At 175 days almost all the genotypes except N4, N23, N26, N55 and N61 developed a red tinge to the extent of 50 per cent. By 200 days almost all the genotypes had red coloured mace. In some genotypes N36, N55, N56 and N7 mace remained pink for long time.

Thus the fruit growth in nutmeg had a distinct pattern of qualitative and quantitative changes occurred in about 225 to 300 days showing distinct role of fleshy pericarp as a temporary sink over a long period and remained a major component of fruit at maturity. Deinum (1949) noticed Pericarp to be the major component in nutmeg fruit with its proportion of 77.8 per cent followed by nut (18.2 %) and Mace (4.0 %). Higher proportion of pericarp was also reported by Shanmugavelu and Madhava Rao (1977) and Krishnamoorthy *et al.* (1996) in nutmeg.

5.4 Propagation :

Clonal multiplication of the selected genotypes is an important component for achieving a desired success in Agriculture. Use of seeds is the principal method of multiplying the population in most field crops whereas, vegetative propagation is preferred in multiplication of fruit crops. The regeneration ability of the planting material is therefore a necessary characteristic for assessing the cultivar development and its further use for large scale cultivation. The genotypes of nutmeg under investigation showed a great variability for various aspects of regeneration by seed as well as vegetative propagation.

5.4.1 Germination and seedling characters :

In a dioecious woody plant like nutmeg the vegetative propagation is most desirable to eliminate the chance of occurrence of male plants by retaining all the desirable properties of parental genotype. However, the saplings raised from seeds for rootstock also play an important role in graft propagation. The rootstocks used for grafting purpose may influence fruiting ability of the grafted plant (Hartmann *et al.*, 1997). Furthermore the seedlings directly used for plantation purpose should ensure longer life span, hardiness and resistance to biotic and abiotic stresses. Hence, assessment of the genotypes for propagation by seeds is also an important aspect.

It was noticed that the period from sowing to germination in nutmeg is exceptionally longer requiring about 70 days. There was wide variation for speed of germination among the genotypes studied. For example, in N70 the germination occurred within 53 days whereas, the seeds of N46 required more than 100 days for germination. The assessment for germination is usually done on the basis of duration, percentage and vigour of germination. The population under study showed larger variability for percent germination with an average of 60.91 per cent. Some genotypes like N42, N43 were very promising as they showed 87 per cent germination, whereas the genotypes, N32 (32%), N41 (34%), N57 (35%) and N4 (36%) had relatively low germination. Flach (1966), Pursegone *et al.* (1981) also reported long period for seed germination in nutmeg. Flach (1966) also reported 35 to 70 per cent germination in nutmeg whereas Prabhu (1978) recorded 89.3 per cent germination under Dapoli conditions. Madhusudanan and Babu (1994) observed 50 per cent germination in nutmeg.

The vigour of germination can be evaluated in terms of growth of root and shoot arising from the germinating seed. Longer roots and their secondaries, length of shoot and its thickness at collar, number and size of leaves and their petiole at certain stage after germination are the important morphological characters to evaluate the vigour of growth. In this connection the mutual relationship of all such characters can give clues for identification of promising genotypes.

The per cent germination had no correlation with any other character under study hence it is difficult to use germination percentage as a single criterion for isolation of promising genotype on the basis of the characters related with per cent germination. In general it was noticed that the genotypes with bolder fresh seed can produce the seedlings having longer roots and profuse foliage having long and broad leaves with longer petiole in the short period from sowing. Similar results are also recorded by Lila Mathew (1979) and Lila Mathew (1992) in nutmeg.

The correlation studies further suggested that the long petiole and broad leaves are the direct determinants of boldness of seed and hence the selection can be done even at seedling stage for bolder seeds on the basis of leaf breadth and petiole length. This had a great practical implication in attempts for developing new cultivars by collecting the saplings from naturally occurring nutmeg biodiversity.

On the basis of above discussion it can be concluded that the genotypes, N22, N24, N26, N29, N34, N37, N38, N42, N43, N51, N63 and N72 deserve due attention in selecting promising genotypes of this crop using seed and seedling characters.

5.4.2 Grafting and graft vigour :

Obtaining the progeny plants identical to a single source genotype is the main objective of vegetative propagation. The response of genotypes to the process of grafting forms an important aspect in horticultural nursery industry. The genotypes in current investigation are primarily seedling population and their assessment for ability to graft with the rootstock of nondescript and discript nature needs critical evaluation. The success in grafting involves the compatibility of stock and scion, vigour of scion after grafting and ability to maintain the characters of parental genotype used for the purpose of grafting without any adverse influence of rootstock on quality and quantity performance of the grafted shoot.

In present investigation, the average duration for sprouting from the day of grafting was about 23 days. The genotype N27 required a

remarkably longer period (35 days) than the population mean whereas, the genotypes viz. N42, N22, N24 and N26, sprouted within 16 to 17 days. The sprouting of scion on graft is the first step in success of propagation. Almost all the genotypes showed a successful sprouting. However, there was a noteworthy variation in per cent sprouting. The population mean was 83.62 per cent and the maximum sprouting was noticed in N5 and N7 (97.5%) whereas it was minimum in N23 (67.5%). The sprouting in scion usually depends upon the availability of moisture, food material, hormonal balance and the environmental conditions (Hartmann *et al.*, 1997).

It must be noted that the variability in success of graft sprouting inspite of using uniform rootstock and the scion stick of uniform maturity provided an evidence for the effect of genetic makeup of the scionstick on the grafting compatibility and eventually graft success. The large amount of variability in success of grafting suggested that there was a good amount of genetic variability for grafting in the population.

The survival and growth of sprouted shoot is another important step in success of grafting. This depends upon successful development of the grafting union in which the vascular cambium of rootstock and scion are aligned properly to develop a callus bridge. The repairs of wound in xylem and phloem, differentiation of vascular cambium across the cambium bridge are the further events in development of successful graft union (Hartmann *et al.*, 1997) which are predominantly under control of the structural configuration of cellular systems and the protoplasm of the root stock and scion material. In the current investigation, the survival percentage varied depending upon the nutmeg genotypes and it was positively correlated with sprouting ability. This suggested that the per cent sprouting itself is an indication of success in grafting and survival. The survival was appreciably high in N66 (92.5%), N4, N24 and N61 (87.5%) whereas it was very low in N23 (42.5%), N43 (50.00%) and N60 (55.0%). Little work has been reported in fruit crops with respect to effect of scion on grafting. In mango the significant effect of scion on success in epicotyl grafting (Dhakal, 1979; Radhamony, 1987) and softwood grafting (Kulwal and Tayde, 1985) has been reported.

Thus, the ability to form the graft union was also found to be under profound control of the genetic makeup of rootstock and scion in nutmeg.

The extent of the vigour of the graft is determined mainly by the amount of nutrients, water and other food material which is principally derived by rootstock from soil and transported efficiently from the newly developed vascular bundles towards the bud sprouts of scion. Hence, the rapidity of graft sprout is an important determinant of early growth of graft. Alternatively, the vigour of sprouted shoot of graft is an indication of the rate and success of grafting. In the current investigation the genotypes N5, N1, N15, N70 showed long shoots with profuse long foliage and hence the vigorous growth. The petiole length and number of new leaves were found to be positively correlated with the growth of shoot in terms of length. The leaf petiole is the vascular system engaged in nurturing the lamina of leaf and hence the development of leaves with longer petiole indicates the formation of efficient vascular system for nurturing the leaves in a desired way. Emergence and expansion of leaves is a basis for overall growth in any planting material. Positive correlation of number of leaves with vigour is therefore an important aspect for consideration in rating the success of grafting. Importantly, the width of leaf showed a negative correlation with production of new leaves and survival percentage. The linear measurements of leaf lamina namely length and width are the resultants of the hormonal levels in them. The negative correlation of leaf width with survival of grafts and number of newly produced leaves thus suggested that the wider leaves have some substances which inhibit the production of new leaves and process of grafting. Secondly, the wider leaves provide more exposed surface for intercepting large energy leading to increased evaporation and consequently imbalance between water uptaken and its transpiration loss which ultimately caused reduced graft survival.

From the foregoing discussion it can be concluded that for higher graft sprouting, the faster production of new leaves with less breadth and longer petiole is the basis for successful grafting in nutmeg. In this context the genotypes N66, N24, N61, N1, N5, N29, N38, N49 can be rated as the most promising genotypes whereas for the genotypes having wider leaves

at seedling stage may need physical intervention by clipping off leaves to some extent which need further studies.

5.5 Genetic nature of Nutmeg population :

In the process of crop improvement, desirable genotypes are continuously selected from genetically variable population. The selection process can be effectively operated only if the characters under consideration are heritable. The efficiency of selection largely depends upon the genetic variability present in the plant population. The biological variation present in the population is primarily of three genotypes i) Phenotypic, ii) Genotypic, iii) Environmental. The phenotypic variability observed includes genotypic as well as environmental variation. The genotypic variation is a variation which occurs because of inherent or genetic factors and remains unaltered by environmental conditions. Such variation is measured in terms of genotypic variance which consists of additive, dominance and epistatic components. The environmental variation refers to nonheritable variation which is entirely due to environmental effects and varies under different environmental conditions (Falconer, 1981)

The growth and yield are the quantitative characters and are governed by the contribution of several genes (Allard, 1960; Falconer, 1981 ; Mather and Jinks, 1971). The variability in growth and yield of any crop can therefore be assessed by employing the biometrical techniques which are commonly described by Falconer (1981), Mather and Jinks (1971), and Dabholkar (1992).

The variability in population thus could be divided into three major components i.e. phenotypic, genotypic and environmental. The phenotypic variability was substantially larger than genotypic variability in some characters like yield in terms of number of nuts, mace yield and yield in forms of nut weight (Table 55). These three are the characters of central importance and showed a predominant influence of environmental components on their expression. The heritability for these characters was very low and the genetic advance was also very low.

Table 55. Genetic parameters of some characters in nutmeg genotype.

Sr. No.	Name of character	Genetic parameters				
		PCV	GCV	ECV	h ² b	GAM
1.	Yield (No. of nuts)	89.95	11.69	78.26	1.70	3.15
2.	Mace yield	84.36	24.02	60.34	8.20	14.25
3.	Yield (kg of nuts)	89.31	17.55	71.76	3.80	6.98
4.	Average spread	22.768	22.767	0.001	100.00	46.90
5.	No. of primary branches	27.832	27.805	0.027	99.80	57.22
6.	Crown volume	53.499	53.490	0.009	100.00	110.21
7.	Crown surface Area	36.400	34.860	1.540	91.68	68.75
8.	Fruit set	36.500	35.470	1.030	94.44	103.30
9.	Total fruit weight	23.190	22.490	0.700	94.10	44.95
10.	Fresh mace weight	41.040	40.330	0.710	96.40	81.49
11.	Dry mace weight	37.650	36.660	0.990	94.80	73.53
12.	Kernel weight	20.130	19.240	0.890	91.40	37.89

Thus, it is clear that the three important yield characters are profoundly influenced by environmental effects and the selection on per se performance basis is rather ineffective. Krishnamoorthy *et al.* (1996) also noticed low estimates of genetic parameters for yield in nutmeg. In a precious spice crop like nutmeg there should be some effective way for improvement. Examination of values of PCV and GCV and their relationship with ultimate yield could therefore be employed to the yield performance indirectly. In this connection, the crown volume, crown surface area, per cent fruit set, fruit weight, fresh and dry weight of nut in individual fruit, weight of kernel in individual fruits, number of primary branches and average spread of crown showed a noticeably large variability at phenotypic as well as genotypic level. Moreover the magnitudes of PCV and GCV were closer to each other indicating negligible influence of environmental components on their expression. Furthermore the heritability and genetic advance for all these characters were very high suggesting the predominance of additive gene effects in their inheritance.

Among these characters crown volume and crown surface area have significant positive correlation with number of nuts per tree. Further, the other characters namely number of primaries had significant positive correlation with crown surface and crown volume. Moreover a multiple regression analysis has also revealed that the crown volume and crown surface are the important determinants of yield in nutmeg. Hence it can be suggested that the indirect selection on the basis of crown volume, crown surface area and number of primary branches would lead to successful screening of a high yielding genotype in this crop. Earlier high PCV for height, mean girth and weight of fruit in nutmeg had been recorded (Krishnamoorthy *et al.*, 1996).

Another important feature is that the yield determining characters like kernel weight, fresh and dry weight of mace and shell weight had reasonably high magnitudes of PCV and GCV and very high magnitudes of heritability in broad sense and GAM indicating a scope for selection on per se performance basis. The nutmeg butter and mace oil are the important principles in this crop. The mace oil showed high amount of PCV and GCV and very high heritability accompanied by high GAM. This warrants that formation of mace oil and nutmeg butter occurs under control of additive genes and it is possible to select the promising genotypes on per se performance basis for these traits.

From the foregoing discussion it is clear that though it is not possible to apply pressure of selection for yield on per se performance, the correlated response to selection can be achieved to a reasonable extent by applying the selection pressure on the relevant characters namely crown volume, crown surface and crown spread.

5.6 Path analysis for weight of individual fruit :

Yield is the ultimate character of ultimate importance in almost all the commercial crops. In nutmeg the yield can be expressed in two different terms viz. i) The number of nuts per tree, ii) The weight of nuts per tree. In current investigation the yield variation of nutmeg in both these terms was not significant. The number as well as weight of nuts per tree was found to be

under profound influence of environmental factors. However, there was a considerably wide range in number as well as weight of nuts per tree. In N42 it was maximum i.e. 789.16 nuts weighing 3.58 kg and it was minimum in N23 (46.83 nuts weighing 0.30 kg). Grafius (1959) expressed that the genes do not exist for yield on per se basis but the expression of yield is rather governed by inheritance of component characters. In nutmeg fruit length, fruit breadth, weight of pericarp, length and breadth of nut, weight of nut and mace, kernel weight, nutmeg butter and mace oil are the immediate components which decide the ultimate size of fruit. The size of fruit has a direct relevance with the demand of commodity for trade purpose. The big sized fruits and nuts are more preferred hence it is necessary to understand the basis of expression of the weight of individual fruits in terms of the contribution made by component character directly or indirectly.

Dewey and Lu (1959) have proposed a technique of path analysis with which the cause and effect relationship of different characters becomes clear. From the path values estimated on the basis of correlation at genotypic level (Table 56) it is clear that mace oil and recovery (%) has no relationship with fruit size. The nutmeg butter has a negative correlation with fruit size. The length and breadth of fruit, pericarp weight, fresh and dry weight of mace, length and breadth of nut, fresh and dry weight of nut and kernel weight have a significant positive correlation with fruit size even at genotypic level.

A critical perusal of path values suggested that the positive correlation with fruit size, fruit length and breadth did not play any direct positive role. However, the strong positive indirect contribution by fresh and dried weight of nut and pericarp weight nullified the negative contribution of all other characters which resulted in developing positive association with fruit size.

The pericarp weight also showed negative direct contribution to individual fruit weight. However, very strong positive indirect associating via fruit length, fresh and dry weight of nut could nullify the negative indirect contribution of all the other component characters and as such

Table 56. Path analysis for weight of individual fruit in nutmeg genotypes.

Particulars	Fruit Length	Fruit breadth	Pericarp weight	Fresh mace weight	Dried mace weight	Nut length	Nut breadth	Fresh Nut weight	Dried Nut weight	Kernel weight	Shell weight	Recovery	Nut oil	Mace Oil	Total
Fruit length	-0.394	-0.595	2.196	-0.208	-0.024	-0.133	-0.304	1.597	1.562	-0.403	-2.295	-0.136	-0.031	-0.001	0.831**
Fruit breadth	-0.835	-0.281	2.476	-0.255	-0.029	-0.087	-0.425	1.774	1.661	-0.456	-2.315	-0.240	-0.065	-0.001	0.922**
Pericarp weight	2.694	-0.321	-0.768	-0.258	-0.029	-0.093	-0.402	1.762	1.670	-0.441	-2.702	-0.059	-0.057	0.000	0.996**
Fresh mace weight	-0.345	-0.237	-0.617	2.018	-0.037	-0.078	-0.424	1.640	1.573	-0.417	-2.056	-0.175	-0.055	-0.001	0.790**
Dried mace weight	-0.038	-0.246	-0.633	2.073	-0.337	-0.083	-0.409	1.621	1.583	-0.404	-2.109	-0.151	-0.058	-0.001	0.806**
Nut length	-0.154	-0.340	-0.474	1.625	-0.175	-0.021	-0.215	1.459	1.394	-0.363	-2.00	-0.067	-0.017	-0.001	0.652**
Nut Breadth	-0.516	-0.232	-0.689	2.100	-0.284	-0.030	-0.064	1.842	1.666	-0.451	-2.261	-0.216	-0.055	-0.000	0.809**
Fresh nut weight	2.065	-0.304	-0.718	2.299	-0.274	-0.030	-0.109	-0.460	1.928	-0.510	-2.786	-0.158	-0.046	-0.000	0.897**
Dried nut weight	2.013	-0.305	-0.689	2.235	-0.270	-0.030	-0.106	-0.427	1.978	-0.506	-2.884	-0.086	-0.047	-0.000	0.876**
Kernel weight	-0.538	-0.295	-0.708	2.209	-0.267	-0.029	-0.104	-0.432	1.957	1.892	-2.419	-0.349	-0.050	0.000	0.688**
Shell weight	-3.272	-0.276	-0.591	2.225	-0.217	-0.024	-0.094	-0.356	1.759	1.774	-0.398	0.339	-0.037	0.000	0.832**
Recovery	-1.012	-0.053	-0.198	0.156	-0.060	-0.006	-0.010	-0.110	0.322	0.171	-0.185	1.096	-0.006	-0.000	0.105
Nut oil	0.118	0.103	0.460	-1.306	0.160	0.019	0.022	0.242	-0.805	-0.799	0.228	1.028	0.053	-0.000	-0.476**
Mace oil	-0.006	-0.042	-0.073	-0.040	-0.034	-0.004	-0.031	-0.029	0.074	0.047	0.009	0.160	-0.048	0.001	-0.017

** significant at 1 % level of significance.

nearly perfect correlation of these characters was established with weight of individual fruit.

Fresh mace weight could establish very strong positive association with individual fruit weight by substantial direct contribution as well as positive indirect contribution via fresh and dried nut weight towards the weight of individual fruit. The high negative indirect contribution via shell weight, nut breadth, length and breadth of fruit and pericarp weight did not reduce the associating of fresh mace weight with individual fruit weight.

The dry mace weight had negative direct contribution but the high values of positive indirect relationship via fresh mace weight, fresh and dry nut weight could establish strong positive association with weight of individual fruit inspite of the negative indirect contribution via all the other characters.

Nut length and nut breadth also had negative direct contribution but the positive indirect association of fresh mace weight, fresh nut weight and dry nut weight helped in establishing the highly significant positive correlation of these two characters with individual fruit weight.

The fresh nut weight had negative direct contribution towards yield. Nevertheless very high positive contribution via fruit length and fresh mace weight could mitigate the negative effects of all the other characters in establishing a strong positive correlation with yield.

Dry nut weight and kernel weight were the two characters having direct positive association with the weight of individual fruits. Strong positive indirect contribution via fresh mace weight and fruit length was also evident.

The shell weight also had a negative direct relationship with yield whereas the substantial positive effects of fresh mace weight, dry nut weight and recovery percentage helped in establishing the positive correlation with nut yield.

The percent recovery of kernel infact had a strong positive direct contribution. It was supported by positive contribution via fresh mace weight, dry nut weight and kernel weight. However very high negative contribution via fruit length, pericarp weight and other characters nullified the positive direct and indirect effects which ultimately resulted in loss of correlation with fruit size.

The nutmeg butter had a weak but positive contribution towards yield. Further, it was supported by positive indirect effects via recovery percentage, shell weight, fresh nut weight, nut breadth, nut length, dry mace weight, pericarp weight, fruit breadth and fruit length. However, substantial indirect negative contribution via fresh mace weight, dry nut weight and kernel weight nullified the positive effects of all the other characters and resulted in negative correlation with weight of individual fruit.

The mace oil did not indicate any kind of correlation with fruit size due to mutual suppressing effects of component characters.

From the foregoing discussion it is clear that the weight of individual fruit is decided by direct and indirect contribution of several component characters. Apparently the non-significant variability for yield restricts the scope for selection for yield on per se performance basis. However, the association of component characters with fruit size is of great importance for obtaining character associated response to selection. Further the plant architectural studies have also revealed that volume of crown and surface area have direct positive correlation with yield suggesting that the need for indirect selection is the only way for improvement of nutmeg genotypes as a first step of cultivar development. The direct and indirect contribution of component characters for fruits have been observed in fruit crops viz. Banana (Rosamma and Narayan^{un} Namboodⁱri, 1990), Kagzi lime (Ranpise and Desai, 1994 a), litchi (Dwivedi and Mitra, 1995) and *Garcinia cambogia* (Muthulakshmi, 1998).

5.7 The elite genotypes :

The base population of 34 female and hermaphrodite genotypes has shown a substantial variability for several characters of growth and yield. The extent of variability however, is not uniform for all the characters. The nature of genetic control for expression of various characters also varied among the genotypes. The regression analysis revealed that crown surface area and crown volume are the most important determinants of yield performance in nutmeg whereas, other characters like height, spread, number of crotches, girth at bottom and number of primary branches have a significant relation with crown surface area and crown volume. Further, the flowering and fruit growth have also a great bearing on the ultimate yield of the crop. There are several other characters like laminar dimentionces of leaves, germination and grafting ability which need to be considered in the overall performance of a genotype. On this background, it is imperative to evaluate the genotypes by simultaneous consideration of all such characters of growth and yield. For this purpose relative ranking procedure was followed. Gautam (2000) followed this procedure for mango.

The relative ranks of 34 female and hermaphrodite genotypes in respect of the architectural characters, flowering and fruit set behaviour, components of fruit growth, germination, graftability and yield performance are given in Appendix IV & VII. From this overall rating 5 promising cultures have been identified.

Based on relative ranking N42 was found to be the most promising genotype as it had first ranking performance with respect to crown volume, crown surface area, number of fruits per tree, yield in kg per tree, kernel yield and germination (%) (Table 57). It secured second rank for spread, mace oil content, mace yield and total leaves on seedling. It secured either third or forth rank for the rating on the basis of height, number of crotches, number of secondaries, nutmeg butter, shoot height of seedling and root length. However, this promising genotype has low ranking for period required for anthesis, total fruit weight, dry mace weight, recovery (%), duration for germination, seedling petiole length, height of new shoot on graft and leaf breadth of graft. This

warrants that it is difficult to achieve the goal of selecting the genotype having all the merit points in a single genotype.

Table 57. Relative ranking of some nutmeg genotypes for overall performance

Sr. No.	Particulars	Elite genotypes					Nonelite genotypes		
		N42	N24	N22	N37	N26	N32	N46	N43
1.	Height	4	12	5	6	1	17	28	30
2.	Spread	2	9	1	20	19	21	34	30
3.	Girth at bottom	11	21	2	10	4	28	27	32
4.	No. of crotches	3	22	14	11	20	24	28	14
5.	No. of primaries	11	13	32	9	16	5	28	29
6.	No. of secondaries	4	5	32	7	11	3	26	25
7.	No. of tertiaries	9	4	30	12	10	2	21	32
8.	Crown volume	1	7	2	15	11	21	33	29
9.	Crown surface area	1	7	2	15	11	22	34	29
10.	Period for anthesis	31	5	17	1	8	19	19	22
11.	Fruit set (%)	15	24	23	8	24	33	20	13
12.	Total fruit weight	23	9	5	16	6	26	37	34
13.	Dry nut weight	16	30	1	14	7	33	27	34
14.	Dry mace weight	23	10	4	28	3	14	24	33
15.	Kernel weight	17	18	1	16	5	31	27	33
16.	Recovery (%)	23	1	6	21	3	24	18	7
17.	Nutmeg butter	4	3	14	11	34	17	28	6
18.	Mace oil	2	9	24	26	3	16	7	10
19.	Yield (no. of fruits)	1	14	13	4	17	30	32	25
20.	Yield (kg nuts)	1	20	7	3	16	33	32	29
21.	Mace yield	2	4	4	7	9	29	32	31
22.	Kernel yield	1	16	7	3	14	33	31	29

Table 57 continued....

Sr. No.	Particulars	Elite genotypes					Nonelite genotypes		
		N42	N24	N22	N37	N26	N32	N46	N43
23.	Duration for germination	22	5	6	21	2	31	34	9
24.	Germination (%)	1	25	8	19	31	34	29	1
25.	Seedling shoot height	3	1	22	14	18	29	8	2
26.	Thickness at collar	5	1	1	5	25	31	9	14
27.	Total leaves	2	7	23	3	14	33	23	18
28.	Petiole length	25	8	3	18	3	31	24	25
29.	Leaf length	17	11	7	2	1	27	21	4
30.	Leaf breadth	18	3	1	15	12	27	17	13
31.	Root length	4	25	24	2	20	14	28	8
32.	No. of secondary roots	9	17	26	1	5	32	19	33
33.	Graft sprouting (%)	18	3	19	19	28	19	19	32
34.	Graft survival (%)	17	2	27	11	17	11	11	33
35.	Shoot height	27	6	13	33	19	28	24	30
36.	Total new leaves	17	20	23	24	3	20	31	31
37.	Length of leaf petiole	11	26	11	4	26	34	26	4
38.	Leaf length	11	8	12	7	15	32	28	31
39.	Leaf breadth	27	34	22	19	11	32	2	5
	Total	439	465	494	480	502	946	946	849

The second ranking genotype N24 had first ranking performance for recovery (%) shoot height and thickness at collar of seedling. It also had higher rank for number of secondary and tertiary branches, period for anthesis, nutmeg butter, mace yield, duration for germination, leaf breadth of seedling, sprouting and survival of graft and shoot height on graft.

The third ranking genotype N37 had a high ranking for period for anthesis, yield in number of nuts, yield in nut weight, kernel yield, thickness at collar of seedling, total leaves on seedling, root length of seedling, number of secondary roots and length of leaf petiole.

N22 could rank fourth on the basis of high ranking for spread, girth at bottom, crown volume, crown surface area, dry nut and mace weight, kernel weight, recovery (%), mace yield, duration of germination, thickness at collar of seedling and leaf breadth of seedling.

The culture N26 was characterized by maximum height and higher rank for dry mace weight, girth at bottom, kernel weight, recovery (%), mace oil, duration for germination, petiole and leaf length of seedling, secondary roots and total new leaves on graft.

From the foregoing discussion it is clear that even the elite genotypes varied greatly for overall performance. A chance of assemblage of all the desirable characters in a single genotype in nature appears to be rare possibility. Hence, the intervention of scientific breeding technology other than mere selection from the natural base population appears to be a step ahead in search of more desirable types in this crop. It must be noted that some low ranking genotypes like N32 had merit points in respect of number of primary, secondary and tertiary branches. Further, the genotypes like N43 has an appreciably good performance for recovery (%), mace oil, germination, shoot height of seedling and length of leaves on seedling whereas N46 had good performance for seedling shoot height and thickness at collar and leaf breadth on graft as well as mace oil. Thus a genotype having demerits for several characters can also have merit points for some important commercial characters which could be explained in genetic transfer by suitable breeding techniques. Elimination of undesired traits is possible by employing suitable breeding technique of conventional as well as modern nature.

The discussion about the overall rating of the genotypes on the basis of simultaneous consideration of several characters lead to a conclusion that the genotypes N42, N24, N22, N37 and N26 could be launched for general

cultivation under recommended management cover as a part of first step of popularising and promoting cultivation of this crop in Konkan in particular and other regions generally wherever, the agroclimatic conditions are favourable for this spice crop. Improvement of this crop by employing the techniques like hybridization, mutation and biotechnology is however essential as a next step of further improvement of this crop in future.

5.8 Clustering pattern of nutmeg genotypes :

Assessment of a base population for existence of genetic diversity is a first step for selecting the parents of divergent genotypes in scheduling an effective crop improvement programme Mahalonobis (1936) proposed a concept of D^2 statistics for study of anthropometry and psychometry. Rao (1952) suggested the application of this technique for assessment of genetic diversity in plant breeding. Now this technique is extensively exploited in plant breeding and genetics for study of genetic divergence in various breeding materials. It is very successfully employed in almost all the field crops like soybean (Verma *et al.*, 1973), Lentil (Chandra *et al.*, 1978), Chickpea (Narayan and Macefield, 1976) and Ricebean (Thaware, 1996).

In horticultural crops the use of such biometrical technique is very rarely attempted. The 34 genotypes of nutmeg population under current investigation are required to be categorised in suitable groups on the basis of several characters simultaneously. The genotypes varied remarkably in respect of the 15 fruit characters like length and breadth of fruit, weight of pericarp, dry and fresh weight of nut and mace, nutmeg butter, mace oil, recovery (%) and total fruit weight etc. It could be imperative to categorise these genotypes into different groups on the basis of simultaneous consideration of fruit characters. Use of D^2 statistics of Mahalonobis helped in dividing the base population in 12 divergent groups (Table 58).

Among the 12 divergent groups the cluster 1 was the largest and comprised of 10 genotypes namely N1, N7, N27, N30, N37, N41, N49, N51, N70 and N72. Cluster 2 was the second largest group made up of 8 genotypes viz. N10, N32, N33, N34, N42, N46, N61 and N74. Cluster 3

Table 58. Average intra and inter cluster distance $(D) = (\sqrt{D^2})$ value of nutmeg clusters.

Cluster No.	1	2	3	4	5	6	7	8	9	10	11	12
1	13.70	23.70	19.19	30.31	39.66	26.94	20.22	19.98	28.47	30.72	22.11	24.57
2		12.75	20.96	20.39	27.41	26.04	35.51	17.26	32.09	20.71	28.82	16.49
3			16.12	22.73	35.39	23.45	28.56	20.61	29.26	26.98	19.20	21.50
4				15.21	31.17	27.89	38.96	25.71	37.79	29.04	29.99	28.97
5					16.89	25.27	52.64	40.17	28.22	20.82	36.68	27.60
6						18.11	37.18	34.29	18.82	24.81	22.38	25.36
7							14.61	28.62	38.52	45.48	29.49	37.33
8								0.00	39.14	29.37	30.69	21.46
9									0.00	27.06	21.68	28.20
10										0.00	30.91	18.65
11											00.00	25.62
12												00.00

Cluster 1	- N1 N7, N27, N30, N37, N41, N49, N51, N70, N72	Cluster 7	- N11, N29
Cluster 2	- N10, N32, N33, N34, N42, N46, N61, N74	Cluster 8	- N43
Cluster 3	- N24, N56, N36	Cluster 9	- N4
Cluster 4	- N26, N57	Cluster 10	- N5
Cluster 5	- N55, N63	Cluster 11	- N22
Cluster 6	- N23, N66	Cluster 12	- N38

included only 3 genotypes namely N24, N36 and N56. Cluster 4, 5, 6 and 7 had only 2 genotypes each whereas, cluster 8 to 12 were solitary.

The intracluster value was maximum in cluster 6 (18.11) and cluster 3 (16.12) (Table 58). It was almost zero in group no. 8 to 12 as they were solitary clusters. The intercluster distance as measured by D^2 value was maximum between cluster 5 and 7 (52.64) it was followed by that between 7 to 10 (45.48), 5 and 8 (40.17), 7 and 9 (39.14) and 4 and 7 (38.96). This suggested that these clusters are adequately diverse from each other. The minimum intercluster distance was noticed in 2 and 12 (16.49). Thus, the inter and intracluster values confirmed the existence of great degree of diversity among the genotypes of the nutmeg population under study.

5.8.1 Intracluster means for different characters :

The genotypes grouped in different clusters and the cluster means for 15 fruit characters of 34 nutmeg genotypes under study are given in Table 59. It was revealed that cluster 1 was characterized by medium fruit having 5.01 cm length, 3.80 cm breadth, 38.93 g weight with 6.01 g nut and 1.18 g mace. The dry nut and mace weight of this cluster was 4.16 and 0.57 g, respectively with recovery percentage of 67.93 per cent. The cluster 2 was also characterised by medium sized fruits similar to those of cluster 1 but differed with respect to high weight of fresh and dry mace (1.28 and 0.62 g respectively) and high mace oil (17.66%). The cluster 3 exhibited big size fruit (51.36 g) with bold nut (7.51 g), highest recovery (72.77%), high nutmeg butter (36.86%). Cluster 4 had maximum fresh mace weight (2.45 g), high recovery (72.68%) and highest mace oil (18.20%). Cluster 5 recorded moderate parameters for the fruit characters. Cluster 6 showed first ranking performance for fruit length (6.16 cm), total weight of fruit (66.01 g), length of nut (3.16 cm), Pericarp weight (54.91 g) and shell weight (2.01 g). Cluster 8 was characterised by the lowest magnitudes for fruit length (4.55 cm), fruit breadth (3.67 cm), total weight of fruit (26.98 g), length of nut (2.28 cm), fresh nut weight (4.73 g), dry nut weight (3.28 g), fresh mace weight (0.93 g), dry mace weight (0.45 g), kernel weight (2.30 g) and shell weight (0.98 g). Cluster 11 exhibited first ranking

Table 59. Intracluster means for different fruit characters of nutmeg genotypes.

Cluster No.	Length of fruit (cm)	Breadth of fruit (cm)	Total weight of fruit (g)	Length of nut (cm)	Breadth of nut (cm)	Fresh nut weight (g)	Dry nut weight (g)	Peri-carp weight (g)	Fresh mace weight (g)	Dry mace weight (g)	Kernel weight (g)	Shell weight (g)	Reco-very (%)	Nut-meg butter (%)	Mace oil (%)
1	5.01	3.80	38.93	2.73	1.96	6.01	4.16	31.37	1.18	0.57	2.83	1.34	67.93	37.63	11.08
2	4.87	3.82	37.37	2.70	2.01	5.92	4.12	30.12	1.28	0.62	2.80	1.33	68.16	36.25	17.66
3	5.43	4.35	51.36	2.92	2.16	7.51	4.71	41.87	2.28	1.04	3.62	1.42	72.77	36.86	14.57
4	5.84	4.74	57.13	3.11	2.28	8.88	5.74	45.71	2.45	1.12	1.20	1.55	72.68	28.65	18.20
5	5.46	4.29	50.60	3.00	2.15	7.61	5.12	43.58	1.94	0.88	3.25	1.89	63.14	33.50	17.75
6	6.16	4.56	66.01	3.16	2.20	8.92	6.15	54.91	2.26	1.15	4.15	2.01	67.50	33.40	12.9
7	4.96	4.07	42.55	2.68	2.04	6.75	4.70	34.71	0.84	0.45	3.32	1.51	69.49	35.10	7.5
8	4.55	3.67	26.98	2.28	1.97	4.73	3.28	21.31	0.93	0.45	2.30	0.98	70.46	40.10	17.3
9	5.00	4.19	53.14	2.60	2.11	7.19	4.92	43.38	2.28	0.95	3.12	1.81	62.85	35.90	9.1
10	5.28	4.09	43.82	3.05	2.15	8.06	5.00	33.64	1.94	1.04	3.15	1.73	64.39	39.40	17.0
11	5.53	4.31	55.41	3.01	2.31	9.73	6.51	41.56	2.98	1.19	4.63	1.89	71.16	37.20	11.0
12	5.04	3.92	41.43	2.83	2.05	7.07	4.74	33.05	1.27	0.59	3.20	1.55	67.47	44.80	17.8

performance for fresh nut weight (9.73 g), dry nut weight (6.51 g), fresh and dry mace weight (2.98 and 1.19 g respectively) and kernel weight (4.63 g). Highest nutmeg butter (44.80%) was noticed in cluster 12. The cluster 9 had lowest mace oil (9.1%) and recovery (62.85%).

It must be noted that every cluster has a characteristic feature of fruit growth. Moreover the elite cultures namely N42, N22, N24, N37 and N26 did not belong to any particular group but were distributed in 5 distinct clusters. The success of breeding programme usually depends upon the extent of divergence of the parental material. On this background the 5 elite cultures thus identified would form the best parent lines for developing new cultivars by employing suitable breeding technique.

Pool *et al.* (1986) has suggested the scope for improvement of clove on the basis of cluster analysis by giving more emphasis on reproductive characters rather than other growth characters. The cluster analysis of nutmeg in the current investigation was principally done on fruit characters and hence appears to be useful for planning further strategies of cultivar development in nutmeg.

5.9 Modelling yield in nutmeg :

The information on various attributes of growth, flowering and yield of 34 female and hermaphrodite nutmeg genotypes could be employed for constructing a planned growth simulator. Development of such a simulator or model gives a simplified description or model gives a simplified description of the real system under consideration. The structure of such models and their relationship are given below.

The architecture of tree includes the pattern and extent of growth, number and angle of branches, canopy surface, crown volume, area of individual leaves, number of fruits, test weight of fruits and yield. The ultimate aim of developing the model is to propose a architecture with which the higher possible economic yields could be realised by harnessing various components in soil-plant-atmosphere system. Such models have made a revolution in field crops like wheat, soybean, sorghum, rice and

maize etc. (Vrijs *et al.*, 1990; Boersma and Lindstrom, 1990; Gutschick *et al.*, 1990; Keating *et al.*, 1990; Khanna Chopra and Sinha, 1990 and Charles Edwards *et al.*, 1986).

According to (Baker *et al.*, 1985) the control of yield manifestation occurs by communication processes in different morphophysiological characters of the crops in response to environmental conditions. Milthorpe (1965) proposed a need for development of dynamic model and suggested a framework with which the yield response to changes in environment could be calculated by describing yield in terms of components developed at different stages of ontogeny and by describing growth by sigmoid functions. He suggested the mathematical relationship between component characters of the plant and major environmental variables. The most important step in developing model is to quantify growth of component characters in relation to each other (Morgan, 1984). In current investigation an attempt was made to find out the dependence of yield in terms of fruits per tree on various component characters.

The characters like height, spread, number of crotches, girth at bottom, number of primaries, secondaries and tertiaries did not show any direct relationship with number of fruits per tree. However, crown volume and crown surface area were found to be the significant determinants of yield in terms of number of fruits per plant even on long term basis.

A simultaneous consideration of height, spread, number of secondaries, crown volume and crown surface area by technique of multiple regression also provided satisfactory explanation for yield variation in this crop. On this basis the following multiple regression may be regarded to provide description of the near ideal plant architecture explaining the yield performance of nutmeg in terms of height, spread, secondaries, crown volume and crown surface area.

$$\hat{Y} = 1215.65 - 213.27 (X1) - 505.64 (X2) + 0.01 (X6) - 46.6 (X8) + 68.23(X9)$$

A search of still precise model for predicting the yield by step down method lead to development of an equation as a brief descriptor of the

dependence of the yield on single component character. This equation suggested that the crown surface dictates the substantial yield of the crop.

$$\hat{Y} = 65.29 + 2.90 (X9)$$

In another equation plant height, spread and crown surface simultaneously showed a significant bearing on yield performance. Thus the following regression equations could be considered as heuristic aids for explaining architectural requirements for higher yields in nutmeg.

i) $\hat{Y} = 127.70 + 3.50 (X8)$

ii) $\hat{Y} = 65.29 + 2.90 (X9)$

iii) $\hat{Y} = 687.37 - 64.85 (X1) - 133.11(X2) + 9.27 (X9)$

iv) $\hat{Y} = 254.28 - 32.02 (X1) + 3.77 (X9)$

In this connection greater plant height, wider spread, larger crown surface and greater crown volume are the features of the ideal plant of nutmeg.

In nutmeg the attempts for developing growth model are seldom made. Flach (1966) could found relation of stem girth with yield in nutmeg. Teotia *et al.* (1970) noticed significant relationship of tree spread, height and circumference of stock with yield in mango. The number of primary branches per plant and number of secondary branches per plant were major contributors towards fruit yield in chilli (Usha Rani, 1995).

The crown surface is alternatively decided by the area of foliage whereas crown volume is decided by number of tertiaries and number of leaves on tertiaries. Hence, indirectly the tertiaries, number of leaves and surface of leaves have a relevance with yield performance of the nutmeg crop.

Generally, the leaf area is determined by either using planimeter or graph paper which necessarily demands detachment of leaves from plants. These method, are tedious and time consuming. Development of a technique of estimating the leaf area without detaching leaves has therefore, great practical significance. Attempts have been made by several

authors for predicting the area of leaves by measuring the simple laminar dimensions by fitting it into regression model in nutmeg (Prasad^a Rao and Sebastian, 1994, Sudhadevi *et al.*, 1990). Further the concept of leaf area prediction was used in clove (Nazeem *et al.*, 1989), coconut (Ramdasan and Jacob Mathew, 1987), cardamom (Karibasappa and Dhiman, 1987) and cinammon (Rema Menon *et al.*, 1993). Similarly Montgomery, (1911), Bhan and Pandey (1966), Balakrishnan *et al.*, (1987) and Shelke^{et al.} (1991) have proposed a non-destructive method of estimating leaf area in different field crops. In this technique the linear measurements like length and breadth are employed for constructing the regression models with which their leaf area can be predicted by non-destructive way.

In the current investigation an attempt to predict leaf area on the basis of length of leaf, breadth of leaf and their product were found to be highly precise as more than 85 per cent variation in leaf area was explained by the linear regressions with these dimensions. Hence the following regression equations may be taken as the empirical tools for predicting area of individual leaves by nondestructive method in nutmeg.

- i) $\hat{Y} = -16.96 + 4.62 (L)$
- ii) $\hat{Y} = -16.51 + 11.32 (B)$
- iii) $\hat{Y} = 1.78 + 0.65 (L \times B)$

This could be further utilized for predicting the crown surface after ascertaining the number of leaves on shoots, number of leaves an tertiaries and the relationship between number of tertiaries and overall surface.

Hunt (1982) described the functional approach for developing the models of plant growth and suggested the use of polynomial functions for growth of plant or plant parts. In nutmeg the reproductive growth occurs for a long period. Fruits become ready for harvest in about 9 months after flowering (Flach, 1966; Nazeem (1979); Anon., 1989). The development of fleshy pericarp, nut and mace occurs in sequential manner during the ontogenetic course of fruit growth. The precise description of the growth of

these three components is essential for assessing the comparative performance of different genotypes.

For pericarp, nut and mace development the following equations were found to be the best prediction equations

$$Y (\text{pericarp}) = -1.788 + 0.0592 (X) - 0.000157 (X^2)$$

$$Y (\text{nut}) = 1.353 - 0.057 (X) + 0.000593 (X^2) - 0.00000134 (X^3)$$

$$Y (\text{mace}) = 0.157 - 0.006 (X) + 0.0000607 (X^2) - 0.00000012 (X^3)$$

The equations for prediction of pericarp, mace and nut yield in some promising genotypes were different than the models for population. They were mostly of linear nature and occasionally quadratic fit. N42 is the most promising among all the genotypes. The following models gave condensed summary of the phenomenon of development of fleshy pericarp, nut and mace during ontogeny of fruit.

$$Y (\text{pericarp}) = -0.248 + 0.017(X)$$

$$Y (\text{nut}) = 0.656 - 0.025 (X) + 0.00019 (X^2)$$

$$Y (\text{mace}) = 0.085 - 0.003 (X) + 0.000022 (X^2)$$

In mango it was reported that the fruit growth rate of cv. "Langra" fruits was significantly higher than that for cv. "Dashehari" indicating high rate of assimilate deposition in cv. "Langra" (Ram and Rajput, 1999).

From the foregoing discussion it is concluded that it is possible to propose some features of ideal plant genotype in nutmeg. According to Grafius (1959) there are no genes for expression of yield *per se*. In this connection evaluation of the genotypes on the basis of height, spread, crown surface and crown volume contributing toward yield would be more effective. The volume and surface of the crown involve the consideration of secondary and tertiary branches as well as number of leaves and their area. Hence consideration of such characters though not revealed from the fitted models, is reasonably important. In this connection nutmeg genotypes N42, N22, N24, N26, N11, N55 and N56 deserve due attention.

5.10 Integration :

Cultivation of tree spices has a bright future in context of globalization of agricultural commodities. Mass planting of the horticultural crops under “Employment Guarantee Scheme” has provided an opportunity for cultivation of shade loving tree spices in fruit orchards grown during past decade in Maharashtra. Availability of promising genotypes however, imposes limitations on large scale commercial cultivation of spices. In nutmeg very meagre attempts have been made for cultivar development. The current investigation is principally aimed at isolating the promising nutmeg genotypes from the population of available 39 genotypes at Regional Coconut Research Station, Ratnagiri.

The 20 year old nutmeg plant had on an average 7.87 m height with 4.30 m spread. On an average the plants produced 34 crotches produced 119 primary branches, 2932 secondary branches and 18576 tertiary branches. The tree had crown with an average volume of 42.19 m³ having a crown surface of 72.50 m². The mean girth of the trunk at the base was 46 cm.

Existence of genetic variability in base population is the basis for success in selection. In current investigation the variability for yield was very low. However, there was a great variation for the characters of growth, flowering and yield components. The characters like crown volume crown surface, fruit set, fruit weight, fresh and dry weight of mace, kernel weight, number of primary branches and average spread of crown exhibited a large variability at genotypic as well as phenotypic level. Further the relationship of crown surface and crown volume with yield and mutual interrelationship of different growth characters suggested scope for getting correlative response to selection. The D² statistics helped in grouping the genotypes into 12 distinct clusters of which 5 were solitary, 4 were composed of 2 genotypes and remaining 3 were made up of several genotypes. The clustering helped in isolating the genotypes with desired characters. For e.g. for higher nut weight cluster 3, 4, 6 and 11 (N24, N56, N36, N26, N57, N23, N66 and N22), for higher fleshy pericarp cluster 6 (N23, N66), for higher mace weight cluster and 6 (N22, N23, N66), for higher nutmeg butter cluster 8 and 12 (N43 and

N38) and for higher mace oil cluster 12 and 5 (N55, N63, N38) formed genetic pools for the respective traits.

Deciding the features of ideal plant type is an important aspect in cultivar development programme. Further, the extent of predictability of the performance of the selected types has a practical significance in yield improvement programme. The concept of crop modelling employed in current investigation led to a conclusion that a simultaneous consideration of plant height, spread, number of tertiary branches, crown volume and crown surface helps in precise prediction of yield performance of this crop and hence greater weightage should be given on these characters in operational selection procedure in isolating the promising genotypes.

The information on phenological events of different genotypes is the basis for exploitation of performance by managing the critical inputs at critical stages. The tree volume, crown surface, height and spread can also be managed effectively by providing some inputs like irrigation and fertilizer in addition to the inherent ability of selected genotypes.

The reproductive phase in nutmeg is very lengthy and has not been properly studied so far. The current investigation could bring out the clear picture about the exact tenures for flowering and fruiting behaviour in the naturally occurring nutmegs. The period between appearance of floral bud to anthesis varies between 35.25 to 52.00 days and the fruit set on female/hermaphrodite genotypes occurs in varied magnitudes. A maximum of 41 per cent of fruit set can be noticed in N72.

The fruit growth is again a lengthy process requiring a period of about 212 to 300 days from the date of setting. The initial phase of fruit development is marked by heavy deposition of assimilates in fleshy pericarp. The period from 125 days onwards is characterized by rapid development of nuts and steady growth of mace over a prolonged period of about 300 days is the third important feature of fruit growth.

In spite of the great variability in different attributes of fruit growth, it is possible to obtain the fruits as long as 6.29 cm (N23), as broad as 5.10

cm (N57) having maximum weight of 68.74 g (N23). The nut was as long and broad as 3.2 cm (N66) and 2.32 cm (N55) respectively with maximum nut weight of 6.51 g (N22) containing maximum kernel of 4.63 g (N22) with highest recovery of 74.27 per cent (N24). The mace obtained was as heavy as 1.46 g (N23) with highest oil of 19.2 per cent (N34) whereas, the nutmeg butter obtained was as high as 45 per cent (N49).

The propagation is an important aspect in any horticultural crop. In a precious crop like nutmeg which is of dioecious nature propagation of elite material constitutes selection of good rootstock and the compatible scion stick. An intensive study of 34 female and hermaphrodite genotypes revealed that the period for germination from sowing varied from 53 to more than 100 days with a success of germination to the extent of 60.91 per cent. The genotype N70 exhibited germination within 53 days whereas N43 and N42 showed most promising performance for percent germination. In general the genotypes with bolder fresh seed can produce the seedlings having longer roots and profuse foliage having long and broad leaves with longer petiole in a short period after sowing.

The graft take and graft vigour are the other important aspects in vegetatively propagated crops. The survival percentage of grafts varied from 42.5 per cent (N23) to 92.5 per cent (N66) indicating the genetic variability for success of grafting in the population. In general, higher graft sprouting, rapid production of new leaves with less breadth and longer petiole was found to be the basis for successful grafting in nutmeg. In this connection the genotypes N66, N24, N61, N1, N5, N29, N38 and N49 were most promising.

The technique of path analysis brought out a clear picture of cause and effect relationship regarding the relation of fruit size with other characters of fruit growth. The weight of individual fruit was decided by direct and indirect contribution of several component characters hence the barrier of apparently nonsignificant variability for yield could be eliminated by employing the correlation analysis and indirect method of selection on the basis of association of component characters with fruit size.

It is difficult to achieve a goal of selecting a genotype having all merit points in a single genotype. However, an attempt was made to identify elite genotypes on the basis of their rating on simultaneous consideration of 39 characters of growth, development, yield and regeneration. N42 was the most promising genotype as it had maximum crown volume, crown surface, highest number of fruits, highest yield in kg per tree, maximums kernel yield and germination percentage. It also possessed good rank for plant spread, mace yield and mace oil, height, nutmeg butter, shoot height of seedling and root length. The demerit of this genotype were that it had low test weight, mace weight, recovery and duration for germination.

The genotype N24 was found to be the best for recovery percentage, shoot height, number of secondary and tertiary branches, period for anthesis, nutmeg butter, mace yield, sprouting, survival and growth of graft whereas, N37 had a high rating for period for anthesis, number of nuts, yield in nut weight, kernel yield, thickness at collar and total leaves on seedlings etc.

Thus, on the basis of simultaneous consideration of several characters N42, N24, N37, N22 and N26 could be rated as the most promising genotypes proposed to be launched for general cultivation under recommended management practices as a first step of systematic promotion of this crop in Konkan as well as other region wherever the agroclimatic conditions are favourable for this crop and as commercial mixed crop in coconut plantations.

The current investigation is perhaps the first and foremost attempt of studying an adequately large populate of nutmeg from natural biodiversity. The assessment is based on the sound principles of biometrical genetics, concepts of mathematical modelling and giving a good consideration to the aspects from horticultural point of view such as selection of rootstock, scion, germination percentage etc. The studies have broughtout the characteristic features of ideal plant genotype on the basis of cause and effect relationship and have emerged a good way for continuing a line of cultivar development in nutmeg. Identification of 5

genotypes namely N42, N22, N37, N24 and N26 forms the first step which could be continued further by employing the conventional as well as modern techniques of plant breeding in future strategies of improvement process in this crop. These promising genotypes exhibited close proximity of yield and associated characters to the first ever developed nutmeg variety Konkan Sugandha very recently (Sawke *et al.*, 1998).

SUMMARY AND CONCLUSION



CHAPTER VI

SUMMARY AND CONCLUSION

The investigation on "Phenological studies in nutmeg (*Myristica fragrans* Houtt.) was carried out at Regional Coconut Research Station, Ratnagiri, Maharashtra, India which is a component of the Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during 1999-2000. The results of the investigation are summarized in this chapter.

Thirty-nine nutmeg genotypes mixed cropped under coconut plantation in 1979 were used as experimental material. The observations on phenological events, plant architecture, assimilate partitioning, fruit parameters, yield performance, regeneration and grafting ability were recorded during the period 1999 and 2000. The data were subjected to biometrical analysis with a view to assess the variability for growth and yield. The simulation models were constructed by using step down regression technique for deciding the features of ideal plant type. The cause and effect relationship for fruit weight was ascertained by the technique of path analysis. The repeatability for fruit yield was assessed on the basis of yield data over 6 years by Sanders conversion factor. These results are summarized in this chapter.

6.1 Phenological Studies :

January and February was found to be a period of first flush appearance in nutmeg in a calendar year. The elongation of first shoot completed within the period from 30 to 90 days after its appearance. The shoots remained in the quiescent state for a period of 60 to 90 days. At about 150 to 180 days from tagging, the mature shoots exhibited production of new shoot primordia at apex and simultaneously a floral bud appeared in the axil of the basal mature leaves. The period of maturity of first shoot, quiescent state, appearance of new vegetative shoot and floral primordia varied among the genotypes under study. The genotypes N36

and N72 showed shortest span of lag period. The longest period for initiation of flowering was observed in N70.

The flowering commenced from second fortnight of May. Flowers exhibited fruit set in a period of about 20 days after flowering. The fruitset continued from June to October.

The genotypes under study produced average 11.78cm long shoot with 7.38 leaves on it. Considerable variation was noticed for these two parameters among the genotypes under study.

6.2 Plant architecture :

The 20 year old hermaphrodite and female nutmeg plant had on an average 7.87 m height with 4.30 m spread. An average plant produced 34 crotches, 119 primary branches, 2932 secondary branches and 18576 tertiary branches. The tree had crown with volume of 42.19 m³ having a crown surface of 72.50 m². There was significant variation for all the architectural characters in the population under study. Among these characters crown volume showed the largest variation (53.49 %). The smallest magnitude of coefficient of variation was noticed for plant height (14.27 %).

The male nutmeg plant recorded 8.76 m average height and 35.8 crotches with 116.20 primary branches, 3143 secondary branches and 20649 tertiary branches. The average male tree had a crown volume of 65.66 m³ with 99.56 m² crown surface area. The girth at the base was 52 cm.

The crown volume and crown surface area had close association with yield and were immediate determinants of yield in nutmeg. The volume and surface area of crown had a very strong association with other architectural characters like height, spread, crotches, girth at bottom, number of primaries and number of tertiories.

The equation $\hat{Y} = 1215.65 - 213.27 (X1) - 505.64(X2) - 0.01 (X6) - 46.67 (X8) + 68.23 (X9)$ explained the extent of dependence of nut yield on plant height, spread, number of secondaries, crown volume and crown

surface area when considered simultaneously. Crown surface was the most crucial determinant of yield in nutmeg.

6.3 Leaf area :

The average nutmeg leaf of the genotypes under study was 10.09 cm long, 4.16 cm broad, weighing 0.87 g as fresh and 0.29 g as dry. The actual average leaf area was 30 cm² and the product of length and breadth was 42.49 cm².

The following regression equation may be taken as the empirical tools for predicting area of individual leaves by non-destructive method in nutmeg.

- i) $\hat{Y} = -16.96 + 4.62 (L)$
- ii) $\hat{Y} = -16.51 + 11.32 (B)$
- iii) $\hat{Y} = 1.78 + 0.65 (L \times B)$

6.4 Flowering and fruitset :

Flowering occurred in 3 to 5 flushes throughout the year in nutmeg. The major flush occurred with onset of monsoon. The duration from appearance of floral bud to anthesis ranged between 35.25 and 52 days. The population average was 40.83 days. The period from bud appearance to flowering was the shortest on female genotypes (39.13 days) whereas it was longest in male genotypes (46.05 days). The hermaphrodite genotypes showed an intermediate period of 41.89 days.

The fruitset ranged from 2 to 41 per cent with mean fruitset of 15 per cent. It was maximum in N72 (41 %). The lowest fruitset was recorded in N27 (2 %).

The variation in the period required for anthesis and fruitset (%) was significant. Both these characters appeared to be under the control of additive gene effect.

6.5 Fruit Development :

The growth of the nutmeg fruits occurred in a sigmoid fashion over a period ranging between 212 and 300 days. The three major component of fruits viz. pericarp, nut and mace showed varied pattern of growth during fruit ontogeny.

The pericarp grew rapidly upto 100 days from fruit set to reach a magnitude of 2.18 g and thereafter it grew steadily to reach a value of 4.33 g by 225 days. At this time the contribution of dry pericarp in total weight of fruit was 49 per cent. The following equation described the growth of fleshy pericarp during the ontogeny of nutmeg fruit.

$$Y (\text{pericarp}) = - 1.788 + 0.0592(X) - 0.000157 (X^2) \quad (R^2 = 0.92)$$

During the initial stage of fruit development the proportion of nut in the total fruit weight was only 3 per cent. The nut development was steady upto 150 days from fruit set when it reached a magnitude of 1.16 g. It grew rapidly thereafter upto 200 days (3.06 g) when its growth was steady to reach 4.02 g at 225 days. Its share in total weight of fruit was 46 per cent. The following equation explained the pattern of nut development during the ontogeny of nutmeg fruit.

$$Y (\text{nut}) = 1.353 - 0.057 (X) + 0.000593(X^2) - 0.00000134(X^3) \quad (R^2 = 0.93)$$

The proportion of mace was the lowest among rest of the components in nutmeg fruit. It steadily increased upto 175 days and thereafter it grew rapidly upto 225 days (0.46 g) and remained steady afterwards to reach 0.51 g at 250 days after fruit set. The equation below represented the mace development during ontogeny of fruit.

$$Y (\text{mace}) = 0.157 - 0.006 (X) + 0.0000607 (X^2) - 0.00000012(X^3) \quad (R^2 = 0.91)$$

At the time of fruitset the colour of fruit was green to greenish brown. Upto 150 days fruits of most of the nutmeg genotypes showed pale

green colour. At 200 days majority of genotypes had yellow coloured fruits. The mace in early 50 days was papery thin and white. By 200 days almost all the genotypes had red coloured mace.

The fruit development in nutmeg showed distinct role of fleshy pericarp as a temporary sink over a long period and remained a major component of fruit at maturity.

6.6 Fruit characters :

On an average the nutmeg fruit had 5.16 cm length, 4.03 cm breadth and 43.80 g weight. The genotypes N4, N5, N22, N23, N24, N26, N27, N29, N36, N55, N56, N57, N61, N63 and N66 deserve due attention on the basis of fruit length, breadth and weight.

The nut was observed to be 2.83 cm long, 2.05 cm broad with average fresh weight of 6.79 g and dry weight of 4.58 g. On the basis of nut characters N4, N5, N22, N23, N27, N29, N34, N38, N55, N56, N57, N61 and N66 proved to be superior genotypes.

The average pericarp weight of the genotypes under study was 35.62 g. The average fresh and dry mace weights were 1.56 g and 0.74 g, respectively. The genotypes N1, N4, N5, N22, N23, N26, N27, N32, N36, N55, N56, N57, N61 and N66 were most promising for mace weight.

On an average the nutmeg genotypes under study recorded 3.17 g Kernel, 1.47 g shell and 68.42 per cent recovery. The genotypes possessing lowest kernel weight had the minimum shell weight. As the nut weight increased the weight of kernel and shell also proportionately increased. On the basis of kernel weight and recovery N22, N26, N29, N34, N36, N56 and N57 were the most superior genotypes.

The percentage of nutmeg butter and mace oil was observed to be 36.33 and 14.13 per cent respectively in the genotypes studied. The genotypes N5, N10, N24, N38, N42, N43 and N61 were promising in this regard.

The average freshly harvested nutmeg fruit had pericarp : nut : mace ratio of 80 : 16 : 4 which altered to 44 : 48 : 8 after drying. The genotypes N5, N10, N11, N22, N26, N42, N43, N46, N49, N57, N72 and N74 were elite with respect to dry pericarp : nut : mace ratio.

There was a good amount of variability for all the fruit characters at phenotypic as well as genotypic level with a least influence of environmental components.

From the path analysis it was noticed that mace oil and recovery (%) had no relationship with fruit size. The nutmeg butter had a negative correlation with fruit size. The length and breadth of fruit, pericarp weight, fresh and dry weight of mace, length and breadth of nut, fresh and dry weight of nut and kernel weight have a significant positive correlation with fruit size even at genotypic level.

6.7 Repeatability of yield :

The yield of nutmeg in terms of number of fruits per tree, weight of nuts per tree, weight of kernel per tree and weight of mace per tree were assessed for the extent of repeatability in successive six harvesting seasons. The coefficient of variation for all the yield parameters was over 60. The variation, "Between genotypes" which was the sum total of genotypic variance and general environmental variation played major role in developing yield parameters of nutmeg. The magnitudes of repeatability for all the yield parameters were similar and relatively low. Its upper confidence limit remained to the extent of 0.25. The investigation suggested that in nutmeg instead of single yield performance record the consistency in yield and yield contributory parameters over a wider period is more reliable. When all the parameters of yield in nutmeg were considered the genotypes N1, N22, N29, N34, N36, N37, N41, N42 and N72 could be rated as superior genotypes.

6.8 Germination and seedling characters :

The population mean for period required for germination was 70.02 days. It was longest in N46 (107 days) and shortest in N70 (53 days). The percent success of germination in the overall population was 60.91 per cent. It was poor in N32 (32%) and remarkably high in N42 and N43 (87 %). At 90 days of sprouting the average seedling attained mean shoot length of 14.34 cm with 0.29 cm thick collar and 3.51 leaves. The leaf length and breadth and petiole length of seedlings were 10.71 cm, 4.00 cm and 0.84 cm, respectively. The average root length was 11.52 cm.

Substantial variability at genotypic as well as phenotypic levels was recorded for period required for germination, germination (%), root length and secondary roots. For these parameters the heritability and GAM was also high.

The germination percentage did not show any kind of association with any other characters under study. The duration for germination showed negative correlation with total leaves, petiole length and fresh seed weight indicating the genotype with bolder fresh seeds can produce the seedlings having longer roots, profuse foliage having long and broad leaves with longer petiole in a shorter period from sowing. The strong thick petiole and broad leaves were the direct determinants of boldness of seeds.

6.9 Grafting and graft characters :

The softwood grafts prepared by using the nutmeg genotypes under study recorded 83.62 per cent sprouting, 72.75 per cent survival and 27.25 per cent mortality. The genotype N66 featured highest survival (92.5 %) and lowest mortality (7.5 %) whereas, in N23 the reverse was true (42.5 and 57.5 % respectively) . The graft prepared recorded 3.38 cm average length of new shoot with 2.09 new leaves 90 days after sprouting. The length and breadth of leaves on the new shoot was 8.89 and 3.04 cm, respectively.

The variation for grafting parameters was significant. The heritability for width of leaf was very high. The magnitudes for GAM for sprouting and survival were low.

The graft survival had strong negative correlation with graft sprouting and leaf breadth. Sprouting is the most important factor to be considered for identification of nutmeg genotypes having better take of the graft.

6.10 The elite genotypes :

The nutmeg genotypes were evaluated by simultaneous consideration of the economical characters viz. plant architecture, flowering and fruit set, fruit characters, yield, germination and graftability. N42 was found to be the most promising genotype which showed first ranking performance with respect to crown volume, crown surface area, number of fruits per tree, yield in terms fruit weight, kernel yield and germination. However, this promising genotype has low ranking for period required for anthesis, total fruit weight, dry mace weight and recovery (%), duration for germination and graft vigour components.

The genotypes N24 ranked second which had first ranking performance for recovery (%), shoot height and thickness at collar of seedling. It also had higher rank for number of secondary and tertiary branches, period for anthesis, nutmeg butter, mace yield, duration for germination and graft parameters. The genotypes N37, N22 and N26 ranked third, fourth and fifth, respectively.

From the ranking it is clear that even the elite genotypes varied greatly for overall performance. A chance of assemblage of all the desirable characters in a single genotype in nature appears to be rare possibility. It was also noticed that some low ranking genotypes like N32 had merit points in respect of number of primary, secondary and tertiary branches. The low ranking genotype N43 has an appreciably good performance for recovery (%), mace oil, germination, shoot height of seedling and seedling vigour parameters.

6.11 Clustering of nutmeg genotypes :

The base population of 34 female and hermaphrodite nutmeg genotypes was divided into 12 divergent groups with the help of D^2 statistics based on fruit characters. Among these the cluster 1 was the largest and comprised of 10 genotypes namely N1, N7, N27, N30, N37, N41, N49, N51, N70 and N72. Cluster 2 was the second largest group made up of 8 genotypes viz. N10, N32, N33, N34, N42, N46, N61 and N74. Cluster 3 included N24, N36 and N56. Cluster 4, 5, 6 and 7 had only 2 genotypes each whereas cluster 8 to 12 were solitary.

The intracluster value was maximum in cluster 6 (18.11). The intercluster distance was maximum between cluster 5 and 7 (52.64) whereas, the minimum distance was noticed between cluster 2 and 12 (16.49).

Every cluster revealed a characteristic feature of fruit growth. The elite cultures namely N42, N22, N24, N37 and N26 did not belong to any particular group but were distributed in 5 distinct clusters.

Conclusion :

From the project entitled "Phenological studies in nutmeg" the important conclusions emerged are as below.

i) The nutmeg tree is a slow grower and produces new vegetative shoots twice in a year. The shoots and leaves showed cyclic growth pattern.

ii) The flowering in female and hermaphrodite genotypes was restricted whereas it was continuous in male genotypes. The period required from flower initiation to anthesis was least in female (39.13 days) and longest in male (46.05 days).

iii) The fruit set was 15 per cent with a wide range of 2 to 41 per cent among genotypes.

iv) The fruit growth is a lengthy process in nutmeg requiring a period of 212 days to 300 days from the date of fruit set. The initial phase of fruit development is marked by heavy deposition of assimilates in fleshy

pericarp. The period from 125 days onwards is characterized by rapid development of nut and steady growth of mace over a prolonged period of fruit development.

v) The nutmeg fruit had maximum of 6.29 cm length (N23), 5.10 cm breadth (N57), 68.74 g fruit weight (N23) 3.2 cm nut length (N66), 2.32 cm nut breadth (N55), 6.51 g dried nut weight (N22), 4.63 g kernel (N22), 74.27 per cent recovery (N24), 45.00 per cent nutmeg butter (N49) and 19.2 per cent mace oil (N34). The weight of individual fruit was decided by direct and indirect contribution of several component characters. The genotypes were categorised into 12 divergent groups on the basis of 15 fruit characters.

vi) The period for germination from sowing varied from 53 to more than 100 days with a success of germination to the extent of 60.91 per cent. The nutmeg genotypes N43 and N42 showed most promising performance for percent germination. The genotypes with bolder fresh seed can produce the seedlings having longer roots and profuse foliage having long and broad leaves with longer petiole in a short period after sowing.

vii) The survival percentage of grafts varied from 42.5 (N23) to 92.5 per cent (N66). Higher graft sprouting, rapid production of new leaves with less breadth and longer petiole was the basis for successful grafting in nutmeg.

viii) The variability of yield was very low but a great variation for the characters of growth, flowering and yield was noticed. The characters like crown volume, crown surface, fruit set, fruit weight, fresh and dry weight of mace, kernel weight, number of primary branches and spread exhibited a large variability at genotypic as well as at phenotypic level.

ix) Simultaneous consideration of plant height, spread, number of secondary branches, crown volume and crown surface help in precise prediction of yield performance in nutmeg.

x) The prediction of leaf area on the basis of length and breadth of leaf and their product was found to be highly precise.

xi) It is difficult to achieve a goal of selecting a genotype in nutmeg having all merit points in it. On the basis of the rating of genotypes on simultaneous consideration of 39 characters of growth, development, yield and regeneration the genotypes N42, N24, N37, N22 and N26 could be rated as most promising genotypes proposed to be launched for general cultivation as a first step of systematic promotion of this crop which could be continued further by employing the conventional as well as modern techniques of plant breeding in future strategies of improvement process in this crop.



LITERATURE CITED

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- * Allard, R. W. (1960). Principles of plant breeding. John Willey and Sons. Inc. New York, London.
- Anonymous (1989). Tree spices Package of practices. National Research Centre for spices. Calicut 673 012, Kerala pp. 5-10.
- Anonymous (1992). Indonesia is worlds largest nutmeg producer. *Spice India*. 3(11) : 4.
- Bagade, D. S. (1989). Studies on flowering, fruiting and seed germination in clove. A M. S. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) pp. 85-90.
- Baier, W. (1979). Note on the terminology of crop weather models. *Agric Meteorol.* 20 : 137-145.
- * Baker, N. R.; W. J. Davies and C. K. Ong (1985). Control of leaf growth. 1st Ed. Cambridge Univ. Press. Cambridge, U.K.
- Balakrishnan, K.; K. M. Surdaram and N. Natrajarathnan (1987). Leaf area estimation by non-destructive methods in black gram. *Indian J. Agric. Sci.* 57: 286-288.
- Balakrishnan, K.; R. Anadan and S. Nanthakumar (1998). Non destructive method of leaf area estimation in nutmeg and clove. *South Indian Hort.* 46(5 & 6) : 364-365.
- Bhan, V. M. and H. K. Pandey (1966). Measurement of leaf area of rice. *Agron. J.* 58 : 454.
- Bisla, S. S. and B. S. Daulta (1988). Variability and heritability of some growth characters in ber (*Zizyphus mauritiana* LAM). *Indian J. of Hort.* 45(1 & 2) : 29-33.
- Boersma, L. and F. T. Lindstrom (1990). Mathematical model of water stress effects on phloem transport and partitioning of assimilates. In proceedings of the International congress of plant physiology, New Delhi. Ed. Sinha, S. K., Sane, P. V., Bhargava, S. C. and Agarwar, P. K. Vol.1 pp. 521-537.
- * Burton, G. W. and E. H. Devane (1953). Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agron. J.* 45 : 478-481.

- Carr, D. J. (1996). Metabolic and hormonal regulation of growth and development. In Trends of plant morphogenesis. Ed. Gutter E.G. Longmans Green, London pp. 253-283.
- Causton, D. R. and J. C. Venus (1981). The Biometry of Plant Growth. Edward Arnold, London.
- * Chandra, N.; R. B. Mehra and S. P. Singh (1978). Genetic divergense among elite germplasm lines in lentil. LENS. **51** : 20-23.
- * Charles – Edwards, D. A.; D. Doley and G. M. Rimmington (1986). Modelling plant growth and development. Academic Press. London.
- Chezhiyan, N.; M. Ananthan and G. B. Peter Vedamuthu. (1996). Standardization of seed propagation techniques in nutmeg (*Myristica fragrans* Houtt.) and clove (*Syzygium aromaticum* (L.) Merr. & Perry). *Spice India*. **June** : 21-22.
- Dabholkar, A. R. (1992). Elements of Biometrical Genetics. Concept publishing Company, New Delhi – 110 059. pp. 326-365.
- * Deinum, H. (1932). De nootmuskaatcultuur op de Banda cilanden. Landbouw **7** : 467-488.
- * Deinum, H. (1949). Nootmuskaat en foelie. Landh i. D. Ind. Arch. DI 2b. Gravenhage. Van Heve : 655-683.
- Dewey, D. R. and K. H. Lu (1959). A correlation and path coefficient analysis of components of crested wheat grass and seed production. *Agron. J.* **51** : 315-318.
- Dhakal, D. D. (1979). Studies on stone grafting in mango. A M. Sc. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli. pp. 55-59.
- Dwivedi, A. K. and S. K. Mitra (1995). Path coefficient analysis of some fruit characters in litchi (*Litchi chinensis* Sonn.). *South Indian Hort.* **43** (5 & 6) : 125-127.
- Eames J. A. (1961). Morphology of Angiosperms. Mc Graw Hill Company, New York.
- Falconer, D. S. (1960). Introduction to quantitative genetics. Oliver and Boyd. Edinburgh.
- Falconer, D. S. (1981). Introduction to quantitative genetics. Text Book. Longman Group Ltd. Marlow, Essex, U. K. pp. 129-325.

- Farrel, K. T. (1990). Spices, condiments, and seasonings. 2nd Ed. Pub. Van Nostrand Reinhold. New York pp. 126-147.
- * Fisher, R. A. and F. Yates, (1963). Statistical tables for research workers. 14th Ed. Oliver and Boyd. London.
- Flach, M. (1966). Nutmeg cultivation and its sex problem. Pub. Veenman, H. and Zonen, N. V. Wageningen. pp. 1-27.
- * Flach, M. and A. M. Cruickshank (1969). Outline of perennial crop breeding in the tropics. Ed. Ferwerda, F. P. and Wit, F. Pub., Veenam H. and Zones, N. V. Wagenigen. pp 329-330.
- Gamble, J. (1967). Flora of the Presidency of Madras. Botanical Survey of India. Calcutta. 218-224.
- * Garret, G. A. (1933). Bearing of wood anatomy on the relationships of Myristicaceae. *Tropical Woods*. 36 : 20-44.
- Gautam, J. N. (2000). Variability studies in mango (*Mangifera indica* Linn.) for growth, flowering, yield and quality. A Ph.D. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.). pp. 158-190.
- Geetha, C. K.; A. K. Babylatha; K. Lila Mathew and T. George Sarah (1992). Fruit development in jamun (*Syzygium cumini* Skeels). *South Indian Hort.* 40(6) : 350-351.
- George, S. T.; A. K. B. Latha; K. L. Mathew and C. K. Geetha (1992). Pattern of flowering and flower development in Kodampauli. *Indian Cocoa Arecanut and Spice J.* 16(2) : 68-70.
- Ghanta, P. K. and S. K. Mandal (1992). Genotypic variability and correlation coefficients relating to fruit yield and few other quantitative characters in papaya (*Carica papaya* L.) cultivars. *South Indian Hort.* 40(5) : 248-251.
- Ghanta, P. K.; A. K. Dwivedi; Pal Krisan and S. K. Mitra (1994). Genetic variability, heritability and genetic advance relating to some fruit characters in litchi (*Litchi chinensis* Sonn.) *South Indian Hort.* 42(1) : 1-4.
- Gomez, K. A. and A. A. Gomez (1976). Statistical procedures for Agricultural Research Second Ed. John Wiley and Sons. New York. pp. 357-423.
- Gopalkrishnan, M. (1992). Chemical composition of nutmeg and mace. *J. Spices and Aromatic Crops*. 1 : 49-54.

- * Grafius, J. E. (1959). Heterosis in barley. *Agron. J.*, **51** : 551-554.
- * Guenther, E. (1952). The essential oils. D. Van Nostrand Co. INC. New York **5** : 59-81.
- Gutschick, V. P.; J. C. Pushnik, and B. A. Swanton (1990). Optimizing photosynthesis and water use efficiency with the aid of models. In proceedings of the International congress of plant physiology – New Delhi Ed. Sinha, S. K., Sane P.V., Bhargava, S. C. and Agarwar, P. K. Vol.1 pp. 538-546.
- Haldankar, P. M.; D. D., Nagwekar; A. G. Desai, and J. C. Rajput (1999). Factors influencing epicotyl grafting in nutmeg. *J. Medicinal and Aromatic Plant Sci.*, **21**(4) : 940-944.
- Haldankar, P. M.; D.D. Nagwekar and A. G. Desai (1997). Studies on softwood grafting in nutmeg. *Indian Cocoa, Arecanut and Spices J.* **21**(4) : 96-100.
- * Hanson, G. H.; H. F. Robinson and R. E. Comstock (1956). Biometrical studies of yield in segregating populations of Korean Lespedeza. *Agron. J.* **48** : 268-272.
- Hartmann, H. T.; D. E., Kester; F. T. Davis and R. L. Geneve (1997). Plant propagation principles and practices. 6th Ed. Prentice Hall of India. New Delhi – 110 001. pp. 393-436.
- * Haun, J. R. (1974). Prediction of spring wheat yields from temperature and precipitation data. *Agron. J.* **66** : 405-409.
- Hay, R.K.M. and A. J. Walkar (1989). An introduction to the physiology of crop yield. Longman Scientific & Technical, New York. pp. 107-153.
- Hittalmani, S. V.; M. M. Rao and K. M. Bojappa (1977). Studies on parameters of flowering in Kagzi and Tahiti lime in North Karnataka. *Punjab Hort. J.* **17**(324) : 97-103.
- Hunt, R. (1982). Polynomial functions. In Plant growth curves. Edward Arnold, London. pp. 79-120.
- Jain, J. P. (1982). Statistical Techniques in Quantitative Genetics. 1st Ed. Tata McGraw- Hill Publishing Co. Ltd. New Delhi. pp. 42-51.
- Johnson, H. W.; H. F. Robinson and R. E. Comstock (1955). Estimation of genetic and environmental variability in soybean. *Agron. J.* **45** : 314-318.

- Jones, D. B.; M. L. Peterson and S. Geng (1979). Association between grain filling rate and duration and yield component in rice. *Crop Science*. **19** : 641-644.
- Joseph, T. and K. Kumaran (1996). Fruit set, fruit development and fruit drop in hard and soft flaked genotypes of jack (*Artocarpus heterophyllus* Lan.). *J. Trop. Agric.*, **34** : 21-24.
- * Joshi, A. C. (1946). A note on the development of pollen of *Myristica Fragrans* Houtt. And the affinities of the family *Myristicaceae* J. *Indian Bot. Soc.*, **25** : 139-145.
- Josy Joseph (1980). The nutmeg its botany, agronomy, production, composition and uses. *J. Plantation Crops*. **8**(2) : 61-72.
- Jyothi, M. L. (2000). Variability and character association analysis of pickle type mango. A Ph. D. (Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara, Trichur. pp. 85-130.
- Kannan, K. (1971). Some problems of field planting of *nutmeg*. *Arecanut and spices Bull*. **3**(1) : 6-8.
- Karibasappa, G. S. and K. R. Ohiman (1987). Estimation of leaf area in large cardamom (*Amomum subulatum* Roxb.). *J. Plantation Crops*. **15**(1) : 63-65.
- Keating, B. A.; B. M. Wafula and R. L. McLown (1990). Simulation of plant density effects on maize yield as influenced by water and nitrogen limitations. In Proceedings of International congress of plant physiology New Delhi. Ed. Sinha, S. K., Sane, P. V.; Bhargava, S. C. and Agarwar, P. K. Vol. 1 pp. 547-559.
- Khan, A. A. (1960). Relation of growth to fruit bearing in mango. *Punjab Fruit J*. **23** : 117-40.
- Khanna Chopra, R. and S. K. Sinha (1990). What limits the yield of pulses? plant process or plant type. In proceedings of the International Congresses of plant physiology, New Delhi. Ed. Sinha, S. K.; Sane, P. V.; Bhargava, S. C. and Agarwar, P. K. Vol. 1 pp. 268-278.
- Khanvilkar, S. V. (1984). Evaluation of seedling types in Kokum (*Garcinia indica* choisy) A M. Sc. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri pp. 22-51.
- Khuspe, S. S. and S. D. Ugale (1977). Floral biology of *Carica Papaya* L. *J. Maharashtra Agric. Univ*. **2**(2) : 115-118.

- Krishnamoorthy, B.; B. Sasikumar; J. Rema and A. Gopalam (1992). Variability and association studies in cinnamon (*Cinnamomum verum*). *J. of Spices & Aromatic Crops*. 1(2) : 148-150.
- Krishnamoorthy, B.; B. Sasikumar and J. Rema (1996). Genetic variability and segregation of sex in nutmeg (*Myristica fragrans* Houtt.) *J. Plantation Crops*. 24 (Supplement) : 468-472.
- Krishnamurthy, K.; G. S. Randhwa and P. G. Sivaraman Nai (1961). Growth studies in mango (*Mangifera indica* L.) under Delhi (Subtropical conditions). *Indian J. Hort.* 18(2) : 106-118.
- Kulwal, L. U. and G. S. Tayde (1985). Studies on propagation of mango varieties by softwood grafting under Akola conditions. Abstract of paper. Second International symposium on Mango. Bangalore. May 20-24.
- * Lai, H. H. and J. Z. Chen (1984). Translocation of photosynthates in *Mangifera indica* (L.) about bud bursting period. *J. chinese Society of Hort. Sci.* 30 : 180-186.
- * Landes, K. H. (1949). Developments in nutmeg and mace. *Spice Mill*. 72(6) : 53-54.
- Lila Mathew (1979). Propagation studies in nutmeg. A M. Sc. (Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara. Trichur. pp. 55 to 61.
- Lila Mathew; George; T. Sarah; A. K. Babylatha and C. K. Geetha (1993). Flowering and fruit development in bilimbi (*Averrhoa bilimbi* L.) *South Indian Hort.* 41(1) : 41-42.
- Lila Mathew (1992). Viability and germination studies in nutmeg seeds (*Myristica Fragrans*). *Indian J. Cocoa, Arecanut & Spices* 16(1) : 21-23.
- * Linnaeus, C. (1742). *Genera plantarum*. 2nd Ed. Conrad Wishoft Lugdomi. Balavorum : 527.
- Little, T. M. and F. J. Hills (1978). *Agricultural Experimentation Design and Analysis*. John Willy and Sons. New York.
- * Lush, J. L. (1937). *Animal Breeding. Plans*. Iowa State College Press. Ames. Iowa.
- * Lush, J. L. (1949). *Animal breeding* 3rd Ed. Collegiate Press, Ames. Iowa. pp. 853.

- Madhusudhanan, K. N. and V. Babu (1994). Recalcitrancy, Viability and germination of nutmeg seeds. *J. Plantation Crops*. **22**(1) : 25-29.
- Mahalanobis, P. C. (1936). On the generalized distance in statistics. *Proc. Nat. Inst. Sci. (Indian)*, **2** : 49-55.
- Maiti, S. C. and P. Biswas (1980). Effect of scion variety and type of scion shoot on success of epicotyl grafting in mango (*Mangifera Indica* L.) *Punjab Hort. J.* **20** (3 & 4) : 152-155.
- * Mather, K. and J. L. Jink (1971). Biometrical Genetics. The study of continuous variation 2nd Ed. Chapman and Hall, London.
- Mathew, P. A. and J. Joseph (1982). Epicotyl grafting in nutmeg (*Myristica fragrans* Houtt.). *J. Plantn. Crops*. **10** : 61-63.
- McQuigg, J. D. (1976). Modelling the impact of climatic variability for the purpose of establishing grain yield. Proceedings of symposium. Univ. of Gulph. April 20-12 pp. 4-18.
- * Mead, R. (1971). A note on the use and misuse of regression models in ecology. *J. Ecology*. **59** : 215-219.
- Milthorpe, F. L. (1965). Crop responses in relation to the forecasting of yields. In the biological significance of climate changes in Britain Ed. Johnson, C. G. and Simith, L. P. Academic Press. New York. pp. 119-128.
- Montgomery, E. D. (1911). Correlation studies on corn. 24th Ann. Rept. Nebraska, Agril. Expt. Sta. **11** : 59.
- Morgan, J. M. (1984). Modelling environmental effects on crop productivity. In Control of crop productivity Ed. Pearson, C. J. Academic Press, London. pp. 289-303.
- Muthulakshmi, P. (1998). Variability analysis in *Garcinia Cambogia* Desf. (Malabar Tamarind). A M. Sc. (Hort.) thesis submitted to the Kerala Agricultural University. Vellanikkara, Trichur. pp. 71-130.
- Nair, M. K.; T. Premkumar; Y. R. Sarma and M. J. Ratnambal (1977). Prospectus and problems of tree spice cultivation in India. *Indian Spices J.* **14** (2 and 3) : 2-9.
- Narayan, R. K. J. and A. J. Macefield (1976). Adaptive responses and genetic divergence in a world germplasm collection of chickpea (*Cicer arietinum* L.) *Theort. Appl. Genet.* **47** : 179-187.

- Nazeem, P. A. (1979). Studies on growth, flowering, fruit set and fruit development in nutmeg (*Myristica fragrans* Houtt.). A M. Sc. (Hort.) thesis submitted to the Kerla Agricultural University, Vellanikkara, Trichur. pp. 43-106.
- Nazeem, P. A. and S. Nair (1981). Growth and flowering in nutmeg. *Indian Cocoa, Arecanut & Spices J.* 4(3) : 81-83.
- Nazeem, P. A.; P. C. Srivaraman Nair and L. Babu (1981). Flower development, floral characters and pollination in nutmeg. *Indian Cocoa, Arecanut & Spices J.* 5(2) : 29-32.
- Nazeem, P. A.; Rema Menon and V. K. G. Unnithan (1989). Estimation of leaf area in clove [*Syzygium aromaticum* (L.) Merr and Perry] using linear measurements. *J. Plantation Crops.* 17(2) : 125-126.
- Oppenheimer, C. (1960). The relationship between tree size and yield in mango (*Mangifera indica* L.) and avocado (*Persea americana* Mill). *Hort. Adv.* 4 : 6-15.
- Panse, V. G. and P. V. Sukhatme (1995). Statistical methods for Agricultural workers. I.C.A.R. Rev. Ed. by Sukhatme P. V. and Amble, V. N. pp. 145-156.
- Parameswaran, N. K. (1979). Factors affecting yield in cashew (*Anacardium occidentale* L.). A M. Sc. (Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara, Trichur.
- Patil, J. L.; P. M. Haldankar; B. M. Jamadagni, and P. Rethinam, (1998). Foliar attributes in relation nut yield in Coconut. *South Indian Hort.* 46(5 & 6) : 303-308.
- Patil, J. L.; P. M. Haldankar; B. M. Jamadagni and M. J. Salvi (1991). Influence of interplanting with tree spices on yield of coconut (*Cocos nucifera* L.). *Indian Coconut J.* 22 (1) : 15-18.
- Patil, J. L.; P. M. Haldankar; B. M. Jamadagni, and M. J. Salvi, (1993 a). Inflorescence characters and yield in Coconut. *J. Maharashtra Agric. Univ.* 18(3) : 303-304.
- Patil, J. L.; P. M. Haldankar; B. M. Jamadagni and M. J. Salvi (1993 b). Variability and correlation studies for nut characters in Coconut. *J. Maharashtra Agric. Univ.* 18(3) : 361-364.
- Peter, K. V. (1996). Spices research and development in India. *J. Plantation Crops.* 24 (Supplement) : xiv-xxiv.

- Ponnuswami, V.; I. Irulappan and R. Arumugam (1992). Growth and development of sapota fruits. *South Indian Hort.* **40**(4) : 227-228.
- Ponnuswami, V.; I. Irulappan; S. Annadurai and E. Vadivel, (1982). Variability studies in cinnamon (*Cinnamomum verum* Breyn.) *South Indian Hort.* **30**(2) : 159-160.
- Pool, P. A.; S. J. Eden-Green and M. T. Muhammad (1986). Variation in clove (*Zyzygium aromaticum*) germplasm in the Moluccan islands *Euphytica.* **35** : 149-159.
- Prabhu, S. D. (1978). Studies on propagation on nutmeg (*Myristica fragrans* Houtt.). A M. Sc. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.). pp. 58-60.
- Prasada Rao, G. S.L.H.V. and Sebastian Siby (1994). Estimation of leaf area in tree crops. *J. Plantation Crops.* **22**(1) : 44-46.
- Prem Narain; V. K. Bhatia and P. K. Malhotra (1979). Hand book of statistical genetics I. C. A. R. (ISARI) 1st Ed. pp. 52-75.
- Purseglove, J. W.; E. G. Brown; C. L. Green and S. R.J. Robbins (1981). Spices Vol. 1 1st Ed. Pub. Longman group Ltd. pp. 1 to 228.
- Pushpalatha, P. B. (2000). Morphophysiological analysis of growth and yield in cashew (*Anacardium occidentale* L.) A Ph. D. (Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara, Trichur.
- Radhakrishnan, V. V.; K. J. Madhusoodanan and K. M. Kuruvilla (1992). Nutmeg – a persuit in Toto. *Spice India.* **3**(11) : 2-5.
- Radhamony P. S. (1987). Varietal response of scion to stone grafting in mango for commercial propagation. A M.Sc. (Agri.) thesis submitted to the Kerala Agricultural University, Vellanikkara, Trichur. pp. 78-81.
- Radhamony, P. S.; K. Gopikumar and P. K. Valsalakumari (1989). Varietal response of scion to stone grafting in mango for commercial propagation. *South Indian Hort.* **37**(5) : 298-299.
- Rajamony L. and N. Mohanakumaran (1996). Phenology of flowering and fruiting of cocoa (*Theobroma Cacao* L.) in Kerala. *Indian Cocoa, Arecanut & Spices J.* **20**(1) : 1-4.
- Ram, L. M. (1982). Studies on growth, flowering and fruiting in nutmeg (*Myristica fragrans* Houtt.) . A M.Sc. (Agri.) thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli Ratnagiri 415 712 pp. 33-92.

- Ram, R. A. and M. S. Rajput (1999). Fruit growth in mango (*Mangifera indica*). *Indian J. Agric. Sci.* **69**(11) : 802-803.
- Rama Rao, G.; G. V. Hanumantha Rao and T. Sujatha (1990). Rate of fruit development and dry matter accumulation in chilli cultivars (*Capsicum annum* L.). *South Indian Hort.* **38**(4) : 191-192.
- Ramadasan, A and Jacob Mathew (1987). Leaf area and dry matter production in adult coconut palm. *J. Plantation Crops.* **15**(1) : 59-63.
- Ramchander, P. R. and G. S. Prasada Rao (1986). Technical Bulletin No. 1. Indian Institute of Horticultural Research, Bangalore 560 080 pp 9-35.
- Ranpise, S. A. and U. T. Desai (1994 a). Genotypic and phenotypic correlation and path analysis studies in Kagzi lime (*Citrus aurantifolia* Swingle). *South Indian Hort.* **42**(3) : 133-136.
- Ranpise, S. A. and U. T. Desai (1994 b). Genotypic and phenotypic variability in acid lime (*Citrus aurantifolia* Swingle). *South Indian Hort.* **42**(6) : 353-357.
- * Rao, C. R. (1952). Advanced statistical methods in biometric research. John Wiley and Sons, Inc., New York.
- Rao, V.N.M. and M. V. Hassan (1957). Preliminary studies on the floral biology of cashew (*Anacardium occidentale* L.) *Indian J. Agric Sci.* **27** : 277-288.
- Reddy, M.L.N. (1994). Genetic variability and correlation studies in betelwine (*Piper bettle* L.) *J. Plantation Crops.* **22**(2) : 123-125.
- Rekha, A. and M.B.N.V. Prasad (1993). Genetic variability and character association in banana. *Indian J. Hort.* **50**(1) : 36-40.
- Rema Menon; M. R. Shylaja, and K. A. Mercy (1993). Leaf area estimation in cinnamon (*Cinnamomum zeylanicum* L.) *South Indian Hort.* **41**(4) : 239-241.
- Rema, J.; B. Krishnamoorthy and P. M. Mathew (1997). Vegetative propagation of major tree spices – a review *J. of Spices and Aromatic Crops.* **6**(2) : 87-105.
- * Rendle, A. B. (1971). The classification of flowering plants. **11** : 131-135.
- Ridley H. N. (1912). Nutmeg and mace. In. Spices. Macmillan and Co-London. pp : 94-154.

- Rosamma, C. A. and K. M. Narayanan Namboodiri (1990). Genetic analysis of yield in banana. *Agric Res. J. Kerla* **28** : 1-8.
- Sasikumara, B. and P. N. Ravindran (1999). Genetic resources and improvement of major spices through selection and hybridization. In. Improvement of plantation crops. C. P. C. R. I., Kasaragod. Kerala. pp 107-114.
- Sathesan, K. N. (2000). Physiological aspects of berry set and development in black pepper (*Pipper nigrum* L.). A Ph. D. (Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara. Trichur. pp. 166-169.
- Sawke, D. P.; S. B. Deshpande; R. T. Gunjate; P. M. Haldankar; B. B. Sapkal; J. C. Rajput; M. B. Dalvi; A. Y. Munj; M. B. Magdum and R. B. Dumbre (1998). Release proposal of nutmeg var. Konkan Sugandha. Konkan Krishi Vidyapeeth, Dapoli. pp. 1 to 8.
- Shanmugavelu, K.G. and V. N. Madhava Rao (1977). Spices and plantation crops. 1st Ed. Popular Book Depot. Madras – 600 034. pp. 30-39.
- Shelke, V. B.; V. S. Shinde and V. V. Dahiphale (1991). Estimation of leaf area constants for groundnut cultivars. *J. Maharashtra Agric. Univ.* **16**(2) : 297-298.
- Shete, M. B.; A. R. Karale, P. N. Kale and D. D. Kadam (1993). Variation in seedling progeny of cashew. *South Indian Hort.* **41**(2) : 106-107.
- * Sinclair, J. (1958). A review of the Malayan Myristicaceae. *Singapore cogens Bull.* **16** : 205-472.
- Singh, H. P.; S. H. Jalikop; M. T. Subbaiah and C. P. A. Iyer (1980). Genotypic and phenotypic variability in mandarins (*Citrus Reticulata* Blanco). *Indian J. of Hort.* **37**(1&2) : 109-113.
- Singh, N. P. and R. P. Srivastava (1979). Studies on the different aspects involved in veneer grafting in mango. *Prog. Hort.* **11**(1) : 63-67.
- Singh, R. and S. H. Jalikop (1986). Studies on variability in grape. *Indian J. of Hort.* **43**(3 & 4): 207-209.
- Singh, R. K. and B. D. Chaudhari (1995). Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers Rev. Ed. pp. 39-78.
- Singh, R. N. (1990). Mango, ICAR, New Delhi. pp. 49.

- Sivaraman, K. and K. V. Peter (1999). An overview of spices development in India. *Indian J. of Arecanut, Spices and Medicinal Plants*. 1(1) : 1-11.
- * Smith, A. C. and R. F. Woodhouse (1938). American spices of Myristicaceae. *Britonica*. 5 : 40-90.
- Srinivas, K.; D. M. Hedge, and S. D. Doijode (1983). Studies on fruit development in muskmelon (*Cucumis melo* L.). *South Indian Hort.* 31(2) : 82-84.
- Sriram T. A. (1977). Tree spices-retrospect and research needs. *Arecanut and Spices Bull.* 8 : 97-100.
- Sudhadevi, P. K.; Rema Menon; U. K.G. Unithan and R. Menon (1990). Estimation of leaf area in nutmeg using linear measurements. *Indian Cocoa, Arecanut & Spices J.* 14(1) : 37-38.
- Teotia, S. S.; D. R. Bhati and K. P. S. Phogat (1970). Use of tree vigour as a criteria for yield in mango var. Dashehari. *Prog. Hort.* 2(1) : 5-12.
- Tham.buraj, S. and A. Shanmugasubramanian (1977). Association of fruit characters in acid lime. *South Indian Hort.* 25(4) : 159-160.
- Thangaraj, T.; Rajamani, K. and Thamburaj S. (1992). A note on variability in growth of Rangapur lime (*Citrus limonia*) seedlings. *South Indian Hort.* 40(1) : 57.
- Thankamani, C. K.; K. Sivaraman; K. Kandiannan and K. V. Peter (1994). Agronomy of tree spices (clove, nutmeg, cinnamon and allspices) a review. *J. Spices and Aromatic Crops*. 3(2) : 105-123.
- Thaware, B. L. (1996). Genetic diversity and stability analysis in ricebean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi]. A Ph. D. thesis submitted to the Konkan Krishi Vidyapeeth, Dapoli – pp. 30-67.
- Thomas, Priyamal (1997). Characterization of dioecy in nutmeg (*Myristica fragrans* Hatt.). A M.Sc. (Hort.) thesis submitted to the Kerala Agril. University, Vellanikkara, Trichur.
- Usha Rani, P. (1995). Correlation and regression studies in chilli. *South Indian Hort.* 43 (1 & 2) : 14-17.
- Vashistha, B. B. and O. P. Pareek (1989). Identification key for the cultivars of Indian jojoba (*Zizyphus mauritiana* Lamk.). *Indian J. Hort.* 46 : 183-188.

- Venkata Rao, P. and V. S. Chhonkar (1983). Regression analysis in chillies (*Capsicum annum* L.) – II. *South Indian Hort.* 31(3) : 206-209.
- Verma, M. M.; B. R. Murty and H. B. Singh (1973). Adaption and genetic diversity in soybean II. Genetic diversity and relationship with adaption. *Indian J. Genet.* 33(3) : 326-333.
- Vris, P. D.; H. Van Kealen and C. Algos Jaque (1990). Nitrogen redistribution and potential production in rice. In. Proceedings of the International congress of plant physiology. New Delhi Ed. Sinha S. K. Sane, P. V. Bhargava, S. C. and Agarwar, P. K. Vol. 1 pp. 513-520.
- * Yarranton, G. A. (1971). Mathematical representation and models in plant ecology. Response to a note by Mead R. *J. Ecology.* 59 : 221-224.

* Original not seen.

APPENDICES



APPENDIX - I

Weather parameters during experimental period.

Month	Maximum Temp. (°C)		Minimum Temp. (°C)		Relative humidity (%)		Total rainfall (mm)		No. of rainy days	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Jan	31.91	32.15	18.20	19.41	58.50	54.25	-	-	-	-
Feb.	32.30	30.52	19.78	18.51	60.83	64.78	-	-	-	-
March	32.45	31.59	22.05	20.65	68.45	66.80	-	-	-	-
April	31.62	31.83	21.04	25.06	75.38	74.86	-	-	-	-
May	31.90	32.08	25.35	25.53	75.95	76.35	193	159	9	13
June	29.93	29.72	24.58	24.53	85.88	85.20	970	1075	25	22
July	28.70	28.18	24.22	22.28	88.54	89.43	745	1102	25	24
Aug.	28.83	28.80	24.78	24.34	88.25	88.53	188	776	27	24
Sept.	29.38	30.0	23.74	24.00	88.90	86.03	318	105	20	12
Oct.	32.71	31.40	23.05	23.70	75.82	88.03	82	149	10	11
Nov.	33.69	34.20	22.15	21.60	56.96	61.66	-	5	-	1
Dec.	32.97	33.90	20.28	18.80	47.85	46.57	-	-	-	-
Pooled	376.39	374.37	269.22	268.41	871.31	882.49	24.96	3371	116	107
Average	31.36	31.20	22.44	22.37	72.61	73.54	208.00	280.92	9.66	8.92

APPENDIX - II

Polynomials fitted for yield

Sr. No.	Particulars	Polynomial fitted	R ² (%)
1.	Yield in no. of nuts/tree	$y = 1.06513772 + (0.047442284) \frac{1}{1} + (0.025408271) \frac{1}{2} + (-0.003177417) \frac{1}{3} + (-0.026674885) \frac{1}{4}$	81.62
2.	Yield in kg nuts/tree	$y = 1.127685289 + (0.046215599) \frac{1}{1} + (0.02259965) \frac{1}{2} + (-0.001989912) \frac{1}{3}$	77.85
3.	Yield in kg mace/tree	$y = 1.0265625 + (0.029598214) \frac{1}{1} + (0.021149553) \frac{1}{2} + (-0.006675347) \frac{1}{3}$	91.96
4.	Yield in kg kernel/tree	$y = 1.179071809 + (0.065242189) \frac{1}{1} + (0.02969828) \frac{1}{2} + (-0.004387813) \frac{1}{3}$	83.08

APPENDIX - III

Conversion factor and standard error (SE) of conversion factor of nutmeg

Particular	Order of yield	Conversion factor	SE of conversion factor
A) Yield in no. of fruit/ tree	1	1.00000000	0.00000000
	2	1.085687488	0.659401068
	3	0.910022772	1.425332185
	4	1.160750052	2.282175668
	5	0.706666668	0.368325316
	6	0.698509772	0.381273553
B) Yield in kg nuts/ tree	1	1.00000000	0.00000000
	2	1.070388431	0.221664101
	3	1.037069716	0.203305643
	4	0.934118789	0.338643813
	5	0.810675085	0.152552174
	6	0.697444067	0.135408699
C) Yield in kg mace/ tree	1	1.00000000	0.00000000
	2	1.169912179	0.104050981
	3	1.149075882	0.09665156
	4	1.019465835	0.082135962
	5	0.89198413	0.071427048
	6	0.81616477	0.069343209
D) Yield in kg kernel/ tree	1	1.00000000	0.00000000
	2	1.039548144	0.250234927
	3	1.046861148	0.242145776
	4	0.895211511	0.197252688
	5	0.743771137	0.160871088
	6	0.627080111	0.138623199

APPENDIX-IV

Fruit colour development and days required for harvesting in nutmeg

Type	25 days	50 days	75 days	100 days	125 days	150 days	175 days	200 days	225 days	250 days	275 days	300 days	Days required for harvesting
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
N1	Green	Pale green	Pale green	Pale green	Pale green	Pale green	Yellow	Yellow	Yellow	-	-	-	225 days
N4	Brownish green	Brownish green	Pale greenish brownish	Pale greenish brownish	Pale greenish brownish	Pale yellowish brownish	Pale yellowish brownish	Pale yellowish brownish	Pale yellowish brownish	Pale yellowish brownish	Pale yellowish brownish	Yellow	300 days
N7	Green	Pale green	Pale green	Pale green	Pale yellowish greenish	Pale yellowish greenish	Pale yellowish greenish	Yellow	-	-	-	-	212 days
N10	Green	Pale green	Pale green	Pale green	Pale green	Pale green	Pale yellowish greenish	Yellow	Yellow	-	-	-	247 days
N11	Green	Pale green	Pale green	Pale green	Pale greenish yellowish	Pale greenish yellowish	Pale yellowish greenish	Pale yellowish greenish	Yellow	-	-	-	227 days
N22	Brownish green	Brownish green	Pale greenish brown	Pale greenish brown	Pale greenish brownish	Pale greenish brownish	Pale greenish brownish	Pale yellowish gray	Pale yellowish greenish	Pale yellowish greenish	Pale yellowish greenish	-	288 days

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
N23	Brownish green	Brownish green	Pale brownish green	Pale green brownish	Pale green brownish	Pale green brownish	Pale Yellowish green	Pale yellowish brown	Pale Yellow brownish tinge	Pale Yellow	Yellow	-	289 days
N24	Brownish green	Brownish green	Pale brownish green	Pale brownish green	Pale greenish brown	Pale greenish brown	Pale greenish brown	Pale Yellowish green	Pale Yellowish green	Pale Yellow	Yellow	-	291 days
N26	Brownish green	Brownish green	Pale brownish green	Pale greenish brownish	Pale greenish brownish	Pale greenish brown	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Yellow	Yellow	-	294 days
N29	Green	Pale green	Pale green	Pale green Yellowish	Pale greenish yellow	Pale Yellow	Pale Yellow	Yellow	Yellow	-	-	-	231 days
N30	Green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale Yellowish green	Pale Yellowish green tinge	Pale Yellowish green	Pale Yellow	Yellow	-	-	260 days
N33	Green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale greenish Yellow	Pale Yellowish green tinge	Pale yellowish greenish tinge	Pale Yellow	Yellow	-	-	258 days
N34	Green	Pale green	Pale green	Pale green	Pale green Yellowish	Pale greenish Yellowish	Pale yellowish green	Pale Yellowish green	Pale Yellowish greenish tinge	Pale Yellow	Yellow	-	280 days
N36	Brownish green	Pale brownish green	Pale brownish green	Pale greenish brown	Pale greenish brownish	Pale greenish brownish tinge	Pale greenish Yellow	Pale Yellowish green	Pale Yellowish greenish tinge	Pale Yellow	Yellow	Yellow	293 days

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
N37	Green	Pale green	Pale green	Pale green	Pale green	Pale green yellowish	Pale Yellow	Pale Yellow	Yellow	-	-	-	246 days
N41	Green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Yellow	Yellow	-	-	259 days
N42	Green	Pale green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale Yellow	Yellow	-	-	-	-	218 days
N43	Green	Pale green	Pale green	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Pale Yellow	Yellow	-	-	-	-	221 days
N46	Green	Pale green	Pale green	Pale greenish Yellow	Pale greenish Yellow	Pale green Yellowish	Pale Yellow	Yellow	Yellow	-	-	-	238 days
N49	Green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale Yellow	Pale Yellow	Yellow	Yellow	Yellow	-	-	272 days
N51	Green	Pale green	Pale green	Pale green	Pale greenish Yellowish	Pale Yellow greenish tinge	Pale Yellow	Pale Yellow	Yellow	-	-	-	234 days
N55	Brownish green	Brownish green	Pale greenish brownish	Pale greenish brown	Pale greenish brownish	Pale greenish brownish tinge	Pale greenish brownish tinge	Pale Yellowish brownish	Pale Yellowish brownish	Yellow	Yellow	-	275 days

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
N56	Brownish	Brownish green	Pale green brownish	Pale greenish brown	Pale greenish brown	Pale green brownish tinge	Pale green brownish tinge	Pale yellow brownish	Pale Yellow	Pale Yellow	Yellow	-	281 days
N57	Brownish	Brownish green	Pale green brownish	Pale green brownish	Pale greenish brownish Yellowish	Pale greenish brownish Yellowish tinge	Pale Yellow greenish tinge	Pale Yellow	Yellow	Yellow	Yellow	-	289 days
N61	Green	Pale green	Pale green	Pale green	Pale green	Pale green	Pale green	Pale Yellowish green	Pale Yellow	Pale Yellow	Yellow	-	285 days
N63	Green	Pale green	Pale green	Pale green	Pale green Yellowish	Pale green Yellowish	Pale Yellowish green	Yellow	Yellow	-	-	-	238 days
N66	Green	Pale green	Pale green	Pale green	Pale green	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow greenish tinge	Yellow	-	-	-	245 days
N70	Green	Pale green	Pale green	Pale green Yellowish	Pale greenish Yellow	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Yellow	-	-	-	234 days
N72	Green	Pale green	Pale green	Pale green Yellowish	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Yellow	Yellow	-	-	-	246 days
N74	Green	Pale green	Pale green Yellowish	Pale greenish Yellow	Pale greenish Yellow	Pale greenish Yellow	Pale Yellow	Yellow	-	-	-	-	225 days

APPENDIX-V

Mace development in nutmeg genotypes at various stages of fruit development (days after fruit set)

Geno- type	25 days	50 days	75 days	100 days	125 days	150 days	175 days	200 days	225 days	250 days	275 days	300 days
N1	Papery thin white	Thin white	Thick white	Yellowish white	Yellowish white	Started turning red	50 % red	Fully red	Fully red	-	-	-
N4	Papery thin white	Thin white	Yellowish white	Yellowish white	Thick white	Thick white	thick white	Thick white	Turning red	80 % red	Full Pink	Full mature
N7	Papery thin white	Thin white	Yellowish	Turning Red	Turning Red	50 % red	90 % red	Fully red	Fully red	-	-	-
N10	Papery thin white	Thin white	Yellowish	Yellowish	Turning Red	Turning red	50 % red	Fully pink	Fully red	Fully red	-	-
N11	Papery thin white	Thin white	Whitish yellowish	Yellowish	Thick white	Thick white	50 % red	90 % red	Fully red	Fully red	-	-
N22	Papery thin white	Thin white	Thick white	Thick white	Thick white	Thick white	Turning red	10 % red	50 % red	Fully red	Fully red	Fully red
N23	Papery thin white	Thin white	Yellowish	Yellowish	Whitish yellow	Thick white	Thick white	Turning red	60 % red	80 % red	Fully red	Fully red
N24	Papery thin white	Thin white	Thick white	Yellowish	Thick white	Thick white	Thick white	Turning red	80 % red	Fully red	Fully red	Fully red
N26	Papery thin white	Thin white	Yellowish	Yellowish	Yellowish	Thick white	Turning red	25 % red	Pink red	Fully red	Fully red	Fully red

Geno- type	25 days	50 days	75 days	100 days	125 days	150 days	175 days	200 days	225 days	250 days	275 days	300 days
N29	Papery thin white	Thin white	Thin white	Yellowish white	Whitish Yellow	Thick white	Turning red	80 % red	Fully red	-	-	-
N30	Papery thin white	Thin white	Yellowish	Whitish yellowish	Whitish Yellowish	Thick white	Turning Red	Fully Pink	Fully red	Fully red	Fully red	-
N33	Papery thin white	Thin white	Yellowish	Whitish yellowish	Whitish Yellowish	Thick white	Turning red	50 % red	Fully red	Fully red	Fully red	-
N34	Papery thin white	Thin white	Yellowish white	Whitish yellowish	Whitish Yellowish	Thick white	Thick white	Turning red	Fully red	Fully red	Fully red	Fully red
N36	Papery thin white	Thin white	White	White	Thick white	Thick white	Turning red	50 % Red	80 % red	Fully Pink	Fully red	Fully red
N37	Papery thin white	Thin white	White	Thick white	Thick white	Thick white	Turning red	Fully Pink	Fully red	Fully red	-	-
N41	Papery thin white	Thin white	Yellowish	Yellowish	Thick white	Thick white	Turning red	Fully Pink	Fully red	Fully red	Fully red	-
N42	Papery thin white	Thin white	White	Thick white	Thick white	Thick white	Turning red	Fully Pink	Fully red	-	-	-
N43	Papery thin white	Thin white	Thin white	Thick white	Thick white	Thick white	Turning red	Fully red	Fully red	-	-	-
N46	Papery thin white	Thin white	Yellowish	Thick yellowish	Thick white	Thick white	Turning red	Fully red	Fully red	-	-	-
N49	Papery thin white	Thin white	Yellowish	Thick white	Thick white	Thick white	Turning red	25 % red	80 % red	Fully red	Fully red	-

Geno- type	25 days	50 days	75 days	100 days	125 days	150 days	175 days	200 days	225 days	250 days	275 days	300 days
N51	Papery thin white	Thin white	Thick white	Thick white	Turning Red	40 % red	Fully Pink	Fully red	Fully red	-	-	-
N55	Papery thin white	Thin white	Thin white	Thick white	Thick white	Thick white	Thick white	Turning red	40 % red	Fully pink	Fully red	-
N56	Papery thin white	Thin white	Thin white	Thick white	Thick white	Thick white	Turning red	20 % red	80 % red	Fully Pink	Fully red	Fully red
N57	Papery thin white	Thin white	Yellowish	Yellowish	Thick white	Thick white	Turning red	20 % red	80 % red	Fully red	Fully red	Fully red
N61	Papery thin white	Thin white	Thin white	Thin white	Thick white	Thick white	Thick white	Turning red	60 % red	Fully red	Fully red	Fully red
N63	Papery thin white	Thin white	Yellowish	Yellowish	Thick white	Turning red	50 % red	Fully red	Fully red	-	-	-
N66	Papery thin white	Thin white	Thick white	Yellowish	Yellowish white	Turning red	70 % red	Fully red	Fully red	-	-	-
N70	Papery thin white	Thin white	Thin white	Thick white	Thick white	Thick white	Turning red	Fully red	Fully red	Fully red	-	-
N72	Papery thin white	Thin white	Thick white	Thick white	Thick white	Yellowish white	40% red	Fully red	Fully red	Fully red	-	-
N74	Papery thin white	Thin white	Yellowish	Yellowish	Thick white	Turning red	50 % red	Fully red	Fully red	-	-	-

APPENDIX-VI

Relative ranking of nutmeg genotypes for architecture, fruit set, fruit parameters and yield components.

Geno- type	Tree architecture							Period		Fruit parameters					Yield components							
	Height	Spread	Girth at bottom	No. of crotch- es	No. of prima- ries	No. of secon- daries	No. of tertiar- ies	Crown volume	Crown surface area	for anth- esis	Fruit set	Total fruit weight	Dry nut weight	Dry mace weight	Kem- el weight	Reco- very (%)	Nut- meg butter	Mace oil	No. of nuts/ tree	Kg nuts/ tree	Mace yield/ tree	Kem- el yield/ tree
N1	20	5	14	8	8	16	11	9	9	26	15	18	20	12	21	30	29	31	10	11	10	12
N4	18	16	23	28	16	29	33	17	17	21	22	7	11	9	15	33	18	32	33	30	28	30
N5	33	17	23	31	26	31	20	25	25	26	29	15	9	5	13	31	7	11	23	19	13	21
N7	31	12	13	24	21	30	31	20	20	12	26	31	29	28	28	12	16	27	16	21	17	20
N10	22	15	20	8	7	24	18	16	16	8	10	32	28	30	29	25	9	12	9	13	10	15
N11	14	3	1	4	12	20	5	3	4	5	26	24	23	30	19	11	24	34	7	8	16	8
N22	5	1	2	14	32	32	30	2	2	17	23	5	1	4	1	6	14	24	13	7	4	7
N23	32	29	29	33	33	34	34	30	30	32	17	1	2	1	3	19	33	22	34	34	32	34
N24	12	9	21	22	13	5	4	7	7	5	24	9	30	10	18	1	3	9	14	20	4	16
N26	1	19	4	20	16	11	10	11	11	8	24	6	7	3	5	3	34	3	17	16	9	14
N27	8	7	12	14	1	1	1	5	5	34	34	13	13	30	12	17	25	18	28	28	32	28
N29	9	22	21	24	23	14	16	19	18	8	2	12	8	34	8	15	22	33	8	9	14	8
N30	10	9	4	10	5	9	6	8	8	16	14	19	19	19	20	29	12	28	15	15	17	17
N32	17	21	28	24	5	3	2	21	22	19	33	26	33	14	31	24	17	16	30	33	29	33
N33	24	32	31	28	18	22	27	32	31	11	5	28	32	17	30	16	22	15	19	23	20	22
N34	21	23	26	11	19	15	22	23	23	2	12	17	14	18	10	10	25	1	5	5	7	6
N36	11	13	30	7	2	2	3	14	14	13	8	11	22	8	9	5	29	21	6	6	1	5
N37	6	20	10	11	9	7	12	15	15	1	8	16	14	28	16	21	11	26	4	3	7	3

Geno- type	Tree architecture										Fruit parameters										Yield components			
	Height	Spread	Grth at bottom	No. of crotch- es	No. of prima- ries	No. of secon- daries	No. of tertiar- ies	Crown volume	Crown surface area	Period for anth- esis	Fruit set	Total fruit weight	Dry nut weight	Dry mace weight	Kernel weight	Reco- very (%)	Nut- meg butter	Mace oil	No. of nuts/ tree	Kg nuts/ tree	Mace yield/ tree	Kernel yield/ tree		
N38	7	26	18	4	3	13	17	24	24	24	17	20	12	20	11	22	2	7	18	16	22	18		
N41	25	4	8	24	25	5	13	10	10	17	30	21	24	16	22	9	19	28	3	4	3	4		
N42	4	2	11	3	11	4	9	1	1	31	15	23	16	23	17	23	4	2	1	1	2	1		
N43	30	30	32	14	29	25	32	29	29	22	13	34	34	33	33	7	6	10	25	29	31	29		
N46	28	34	27	28	28	26	21	33	34	19	20	37	27	24	27	18	28	7	32	32	32	31		
N49	28	27	23	22	14	10	15	27	27	14	3	25	18	22	14	13	1	20	24	22	26	23		
N51	15	33	33	4	14	12	7	31	32	29	6	22	21	20	34	28	15	30	22	24	22	24		
N55	2	10	7	2	20	27	24	4	3	4	30	8	6	6	7	32	31	13	29	27	25	26		
N56	13	6	2	1	3	8	8	6	6	14	26	4	4	2	4	2	20	17	27	25	22	24		
N57	3	17	6	11	24	19	14	13	12	23	11	3	3	7	2	4	32	6	20	12	12	11		
N61	18	11	8	14	31	28	29	12	13	30	32	14	9	13	23	8	13	13	26	26	26	27		
N63	23	28	15	20	27	23	23	28	28	33	21	10	17	15	24	34	20	4	31	30	29	31		
N66	25	25	18	31	29	21	19	26	26	5	17	2	5	10	6	25	10	18	21	14	14	13		
N70	25	14	15	14	9	17	26	18	19	3	3	30	31	27	32	14	5	23	11	18	20	18		
N72	17	24	15	14	21	18	25	22	21	28	1	33	26	25	25	20	8	25	2	2	4	2		
N74	34	31	33	34	34	33	28	34	33	24	5	28	25	26	26	27	27	5	12	10	19	10		

APPENDIX-VII

Relative ranking of nutmeg genotypes for seedling and grafting parameters.

Geno- type	Seedling parameters										Grafting parameters									Grand total
	Dura- tion for germin- ation	Germi- ation (%)	Shoot height	Tickness at collar	Total leaves	Petiole length	Leaf length	Leaf breadth	Root length	No. of secon- dary roots	Sprou- ting (%)	Survival (%)	Shoot height	Total new leaves	Length of leaf petiole	Leaf Length	Leaf breadth	Total rating	Rating for architecture yield + fruit parameters	
N1	22	7	13	32	30	11	14	19	32	22	6	5	8	1	1	10	18	251	345	596
N4	9	30	26	14	14	28	24	24	5	14	3	2	18	14	4	2	33	264	486	750
N5	19	28	17	5	4	8	6	8	12	21	1	5	5	2	11	6	24	182	447	629
N7	15	15	20	21	19	12	18	30	15	33	1	15	20	30	26	34	1	325	485	810
N10	26	15	33	34	34	29	29	31	34	15	9	17	3	11	11	23	8	362	368	730
N11	9	5	34	25	7	33	30	28	26	25	3	11	7	4	26	33	9	315	301	616
N22	6	8	22	1	23	3	7	1	24	26	19	27	13	23	11	12	22	248	246	494
N23	4	22	16	21	7	5	19	5	13	20	34	34	20	33	11	24	15	303	548	851
N24	5	25	1	1	7	8	11	3	25	17	3	2	6	20	26	8	34	202	263	465
N26	2	31	18	25	14	3	1	12	20	5	28	17	19	3	26	15	11	250	252	502
N27	19	26	12	21	23	15	20	25	18	12	17	22	23	24	11	13	6	307	366	673
N29	26	3	11	1	19	20	13	4	20	17	9	5	10	20	4	5	22	209	347	556
N30	18	19	24	25	23	29	34	34	27	23	28	29	34	17	26	20	4	414	309	723
N32	31	34	29	31	33	31	27	27	14	32	19	11	28	20	34	32	32	465	481	946
N33	33	24	28	5	23	12	5	22	7	8	9	15	31	24	26	26	12	310	505	815
N34	15	12	5	21	14	2	3	9	23	24	32	32	4	8	4	29	13	250	315	565
N36	12	27	27	25	23	12	32	32	33	11	26	29	32	24	26	4	21	396	240	636
N37	21	19	14	5	3	18	2	15	2	1	19	11	33	24	4	7	19	217	263	480

Geno- type	Seedling parameters										Grafting parameters								Grand total	
	Dura- tion for germin- ation	Germi- ation (%)	Shoot height	Tickness at collar	Total leaves	Petiole length	Leaf length	Leaf breadth	Root length	No. of secun- dary roots	Sprou- ting (%)	Survival (%)	Shoot height	Total new leaves	Length of leaf petiole	Leaf Length	Leaf breadth	Total rating		Rating for architecture yield + fruit parameters
N38	7	17	7	9	1	20	8	9	3	15	9	5	16	4	11	30	15	186	345	531
N41	22	33	32	25	19	25	24	23	31	27	28	22	25	24	1	1	29	391	324	715
N42	22	1	3	5	2	25	17	18	4	9	18	17	27	17	11	11	27	234	205	439
N43	9	1	2	14	18	25	4	13	8	33	32	33	30	31	4	31	5	293	556	849
N46	34	29	8	9	23	24	21	17	28	19	19	11	24	31	26	28	2	353	593	946
N49	30	8	22	9	14	31	33	29	29	28	9	5	29	34	11	14	14	319	418	737
N51	31	8	25	14	30	18	9	21	17	2	31	22	20	24	11	25	3	311	478	789
N55	26	23	4	14	4	8	26	19	19	10	19	17	26	14	11	19	26	285	343	628
N56	2	19	9	25	30	5	30	9	30	29	9	10	12	4	4	9	31	267	244	511
N57	22	31	15	14	7	15	12	13	11	7	19	17	16	11	4	16	30	260	265	525
N61	15	18	30	9	7	15	22	16	6	6	6	2	1	4	11	21	25	214	424	638
N63	14	14	10	9	7	20	23	25	10	3	9	29	13	17	11	17	20	251	514	765
N66	13	12	31	14	7	23	16	6	16	13	6	1	9	10	11	27	17	232	380	612
N70	1	6	19	33	23	34	28	32	9	29	26	27	1	8	1	3	28	308	392	700
N72	7	8	6	1	4	1	15	2	1	29	19	22	15	14	11	17	6	178	378	556
N74	29	4	20	14	19	5	10	6	22	4	9	22	10	11	11	22	10	228	538	766

APPENDIX - XIII

ABBREVIATION USED

Anon.	Anonymous
°C	Degree centigrade
C.D.	Critical difference
Cm	Centimeter (s)
Cm ²	Centimeter square
e.g.	Example given
<i>et al.</i>	And others
Fig.	Figure
g	Gram
GA	Genetic Advance
GAM	Genetic Advance on percent mean basis
GCV	Genotypic Coefficient of variation
i.e.	That is
Kg	Kilogram
M	Meter
m ²	Meter square
m ³	Meter cube
M.S.	Maharashtra State
MSL	Mean Sea Level
Mt	Metric tonns
No.	Number
N.S.	Non significant
%	Per cent
PCV	Phenotypic Coefficient of Variation
lb	Pound
R. H.	Relative humidity
S.E.M. ±	Standard error of mean
Viz.,	namely