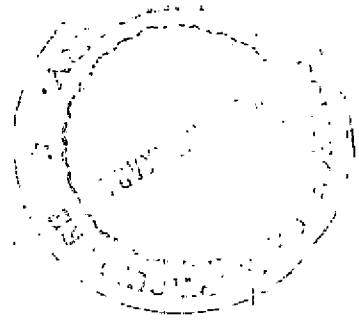
GENETIC ANALYSIS OF SEED DORMANCY AND PRODUCTIVITY IN GROUNDNUT (*Arachis hypogaea* L.)



By

TESSY JOSEPH

THESIS

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Faculty of Agriculture
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DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 654

1997

DECLARATION

I hereby declare that this thesis entitled "**GENETIC ANALYSIS OF SEED DORMANCY AND PRODUCTIVITY IN GROUNDNUT (*Arachis hypogaea* L.)**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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TESSY JOSEPH

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Introduction

INTRODUCTION

Groundnut, the `unpredictable legume', occupies the prime position in the oil seed economy of India. This crop accounts for 45 per cent of the total cropped area (15 million hectares) under edible oil seeds and 55 per cent of the total production (8.26 million tons in 1995-96). Though India leads the world in area and production of groundnut, the country ranks only eighth in productivity (1042 kg ha^{-1}). The low yield levels are attributed to the cultivation of the crop mostly in rainfed marginal areas, poor plant populations, lack of adoption of scientific cultivation methods and frequent occurrence of pest and disease attacks.

Groundnut is grown mostly in the semi-arid tropics and the tropics. The major groundnut producing countries are India, China, USA, Senegal, Indonesia, Nigeria, Myanmar, Brazil and Argentina. The groundnut growers in most parts of this country as well as in aforesaid countries now prefer to grow, early maturing cultivars because of the ease in harvesting the crop and mainly because they can fit into the short rainy seasons, crop rotation systems and availability of water in the irrigation sources. Unfortunately early maturing varieties currently popular among farmers have non-dormant seeds. When caught in untimely rains at the time of maturity, considerable yield losses occur due to viviparous germination inside the subterranean pods.

Groundnut is a non traditional oil seed crop of Kerala which is now gaining popularity in the state. It is widely cultivated in Palakkad district in an area of roughly 13,000 ha as a *kharif* crop, which comes to maturity in mid September. A few early north east monsoon showers are likely to occur during this month. The recommended varieties TG-3, TG-14, Spanish Improved and TMV-2 are all non-dormant by nature. If there is any delay in the harvest or drying, heavy crop loss can occur. Groundnut cultivation is also spreading to newer areas like summer rice fallows, where also there is the threat of a few early summer rains in the month of April-May. The possibility of growing the crop under partially shaded conditions in coconut gardens and as an inter crop in tapioca, have been explored and found feasible Seed dormancy is a desirable attribute for inclusion of a groundnut variety as a component of any cropping system especially in Kerala. Prolonged dormancy is also undesirable when seed from *kharif* crop is used for seed purpose in the succeeding *rabi* crop. Thus a high yielding groundnut variety with 20 to 30 days dormancy, maturing in around 100 days seems to be the ideal one under our conditions.

In groundnut, the two characters earliness and dormancy, happen to be present in two different subspecies. The subspecies *fastigiata* Waldron. is characterised by short life cycle and non-dormant seeds, while subspecies *hypogaea* Linn. generally mature later, possess seed dormancy and have a

very high yield potential. Recombination breeding through inter-subspecific crosses holds promise to incorporate the dormancy and high yield potential of *hypogaea* (Virginia bunch and runners) into early maturing *fastigiata* (Spanish and Valencia bunches) cultivars.

In groundnut many inherent factors are posing problems to breeders preventing any major break through in the improvement of this crop. The unpredictability of the productivity of a genotype from the aerial vegetative parts, allopolyploid nature of the species, governed mostly by non-additive genetic effects in many of the economic traits, cumbersome hybridisation procedure involving small tender flowers at ground level, the indeterminate plant type of *hypogaea* genotypes retaining a large number of immature pods and pegs at harvest, are a few factors that limit substantial progress in the breeding of the crop.

Before planning any long term breeding programme for evolving high yielding dormant bunch varieties, an understanding of the inheritance and gene action for these desirable characters and other yield contributing traits is essential. The reports on inheritance and gene actions of seed dormancy are very few and contradictory. The general combining ability of parents and specific combining ability of crosses and study of heterosis will be a prerequisite for choice of parents for hybridisation programme for evolving high yielding, dormant, early maturing varieties.

With this background the present investigations were undertaken to fulfil the following objectives:

1. To evaluate twenty eight groundnut genotypes for their economic traits and seed dormancy

2. To select three short duration, high yielding, non-dormant, female parents and five divergent, dormant, male parents

3. To assess the general combining ability of selected genotypes and specific combining ability of crosses for different characters

4. To find out the heterotic effect for different characters in different crosses

5. To estimate heritability in different characters

6. To study the inheritance of seed dormancy from different generations

7. To estimate the various genetic parameters for seed dormancy using the three parameter/six parameter model.

Review of Literature

REVIEW OF LITERATURE

The genus *Arachis* belongs to the family *Leguminosae* [*Tribe Aeschynomeneae*, sub tribe *Stylosanthinae* (Gregory *et al.*, 1973)]. The genus is subdivided into seven sections according to Gregory *et al.* (1973) and to nine sections according to Simpson *et al.* (1994). The cultivated species, *Arachis hypogaea*, 2n = 4x = 40, first described by Linnaeus (1753) belongs to section *Arachis* and series *Amphiploides* (Gregory *et al.*, 1973). The primary centre of origin is the Bolivian region in South America. Krapovickas (1968, 1973) identified five centres of variability apart from Bolivian region, which Gregory and Gregory (1976) recognised as secondary centres of diversity. Gibbons *et al.* (1972) regarded African continent also as a secondary centre of diversity.

The subspecific classification and nomenclature of *Arachis hypogaea* have been attempted extensively by several workers on the basis of plant habit, branching pattern, kernel size, colour, number and pod characteristics (Bunting, 1955; Krapovickas, 1968; Gibbons *et al.*, 1972 and Simpson *et al.*, 1994).

The subspecific divisions are as follows and the key characteristics of these subspecific groups are given in Table 1 and 2, after Gibbons *et al.* (1972).

Table 1 Description of the subspecies of groundnut (*Arachis hypogaea* L.)

Character	Subsp. *hypogaea*	Subsp. *fastigiata*
1. Habit	Procumbent, decumbent or erect	Erect to decumbent
2. Branching	Alternate	Sequential
3. Inflorescence	Simple and absent on main axis	Simple or compound, always present on main axis
4. First node on cotyledonary branch	Always vegetative	Reproductive
5. Foliage colour	Dark green	Lighter green
6. Seed dormancy	Present	Absent

Table 2 Description of botanical varieties in groundnut (*Arachis hypogaea* L.)

Subsp. *hypogaea*		Subsp. *fastigiata*	
Var. *hypogaea* Virginia bunch	Var. *hirsuta* Virginia runner	Var. *fastigiata* Valencia	Var. *vulgaris* Spanish
Procumbent decumbent or erect habit	Procumbent habit	Vegetative branches on primaries absent or regularly placed at distal nodes	Occasional and irregularly placed
Stem not very hairy	Stem fairly hairy	Inflorescence simple	Inflorescence compound
Medium late maturing	Very late maturing		

Arachis hypogaea L.

Subspecies *hypogaea*

Variety *hypogaea* (Virginia bunch)

Variety *hirsuta* Kohler (Virginia runner)

Subspecies *fastigiata* Waldron

Variety *fastigiata* (The Valencia types)

Variety *Vulgaris* Harz. (The Spanish types)

Among the different botanical varieties *hypogaea* and *hirsuta* are reported to possess marked and long lasting seed dormancy unlike other two types (Krapovickas, 1968).

The latest classification by Simpson *et al.* (1994) proposes four botanical varieties under subspecies *fastigiata* viz., *fastigiata* (valencia types) *peruviana aequatoriana* and *vulgare* (Spanish types).

In this chapter the important literature on different aspects of breeding and genetics, related to seed dormancy and yield attributes in groundnut like divergence of genotypes, inheritance of characters, heterosis, combining ability and gene action have been reviewed briefly.

2.1 Dormancy

Seed dormancy is the failure of otherwise viable seeds to recommence development immediately when provided with

all the favourable conditions for germination. Koller *et al.* (1962) termed `dormancy' as the period during which seed regains its ability to germinate. It was termed as `rest period' by Mayer and Anderson (1963). Vegis (1964) defined it as a condition in which growth could not be resumed what ever the external conditions might be.

Vleeshouwers *et al.* (1995) has presented the concept of seed dormancy in which physiology and ecology are integrated. They defined seed dormancy as a characteristic, the degree of which determines the range of conditions in which a seed is able to germinate.

Lang (1996) states that the term dormancy embraces the processes that bring about a programmed inability within a plant to grow and develop inspite of suitable environmental conditions.

2.1.1 Seed dormancy as a breeding objective in groundnut

Lack of dormancy in bunch types of groundnut (subspecies *fastigiata*) is a major problem in the cultivation of this group, because it causes *in situ* germination and spoilage of the produce. The need for incorporating the dormancy of spreading types (subspecies *hypogaea*) into bunch types has been recognised by several workers in India and elsewhere.

Stokes and Hull (1930) were the first to point out that seed dormancy was essential in bunch varieties when frequent rains occurred during harvest period. John *et al.* (1948) gave a true picture of the bunch groundnut cultivation prevalent in the Pollachi tract of Madras state where south-west and north-east monsoons were prevalent. He mentioned about 80 per cent loss to the produce due to sprouting in the field in certain years due to heavy rains. He also pointed out that prolonged dormancy in spreading varieties needed to be shortened, so as to get a uniform germination in next crop. Gregory *et al.* (1951) reported about an extensive breeding programme in Georgia which included the objective of combining high yield with non sprouting nature in the bunch variety. Ramachandran *et al.* (1967) conducted elaborate breeding work with the objective of evolving dormant bunch groundnut strains by hybridization and they isolated several such lines.

Besides India, lack of dormancy was reported to be a major problem limiting groundnut production in Argentina, Indonesia and Zimbabwe (Cummins and Jackson, 1982). Breeding for short duration dormant groundnut varieties suited to *kharif* season has been a strategy for breeding at ICRISAT (ICRISAT, 1981). Programmes are under way to select dormant, short duration cultures from crosses between early non-dormant and late dormant types.

Reddy *et al.* (1985) developed a Spanish cultigen CGC-7, from a cross between J-11 (Spanish) and Robut-33-1 (Virginia bunch) possessing a fresh seed dormancy period of five weeks. This was released for general cultivation after All India Co-ordinated trials.

Bhapkar *et al.* (1986) emphasized the need for a variety having very short dormancy period so that seeds produced in one season could be utilized for seed purposes in the succeeding season. Dormancy for a longer period is disadvantageous. Maiti *et al.*, (1988) pointed out that lack of dormancy not only caused yield loss but also produced volunteer plants immediately after harvest, which served as reservoirs for pests and diseases.

Manoharan *et al.* (1994) isolated sixteen dormant cultures with bunch growth habit from Spanish x virginia crosses.

Huang (1982), Weiss (1983), Khalfaoui (1991) and Nautiyal *et al.* (1993) have also suggested the need for breeding dormant bunch varieties in groundnut.

2.1.2 Dormancy in relation to plant characters in groundnut

Groundnut varieties are classified into bunch, semi-spreading and spreading types according to their growth habit. Barring a few exceptions the bunch types are essentially non-dormant (Stokes and Hull, 1930; John *et al.* 1948).

Ramachandran *et al.* (1967) reported that dormant nature of seed was associated with dark green leaves.Zade *et al.* (1986) observed that dormancy in various genotypes ranged from 40 to 70 days. His study revealed that dormancy breaking was gradual in some genotypes, while in others it was sudden. The rapidity of dormancy breakage and duration of dormancy were not related. The virginia types are indeterminate in nature and so even the pods of the same plants highly vary in maturity.

The dormancy of seed also appears to be dependent upon its position in the pod. Toole *et al.* (1964) and Patil (1967) reported that in two seeded groundnut pods the basal seed always had more dormancy than apical seed.

The maturity status, variation among seeds within and between plants of same genotype and length of storage on dormancy in groundnut were examined by Nautiyal *et al.* (1993). They observed that aging of seeds in storage broke dormancy faster than aging in plants and there was substantial range in germination percentage among the plants of each genotype.

2.1.3 Screening of groundnut cultivars for dormancy

Screening of groundnut cultivars for dormancy in different botanical groups has been attempted by several workers.

Patil (1967) studied 16 groundnut varieties and reported that the four varieties found to be dormant belonged to spreading types and the rest, the non dormant ones, belonged to bunch type.

Varisai Muhammed and Dorairaj (1968) screened 206 bunch groundnut genotypes for dormancy and only six varieties recorded 90 per cent or more dormancy over a period of 15 to 20 days after pod maturity.

Lin and Chen (1970) examined dormancy in 56 varieties and concluded that significant difference existed in the length of dormancy period among the varieties. They classified the varieties into three groups according to length of dormancy period and the fourth group having no dormancy.

Sengupta *et al.* (1977) studied the germination and seed dormancy of nine varieties of ground nut. Bunch types were non-dormant while spreading and semi spreading types had prolonged seed dormancy and period of dormancy varied among the varieties.

Variability in dormancy in groundnut varieties within subsp. *fastigiata* has also been reported by Pandya and Patel (1986). He identified four genotypes CGC-7, Dh-8,

ICGS-30 and ICG-357 as dormant among bunch cultivars. Vindhiyavarman and Arjunan (1990) screened twenty bunch types and three genotypes TG-9, TG-17 and EC-119704 recorded seed dormancy between 20 to 30 days. Asok Kumar *et al.* (1991) studied intensity and duration of dormancy with selected dormant bunch varieties and selected out three bunch varieties having more than three weeks dormancy.

Presannakumari (1992) screened 419 genotypes for dormancy. She observed wide variability for dormancy from 20 to 110 days among the different botanical groups.

2.1.4 Mechanism of dormancy

The mechanism of dormancy in groundnut seed is not fully known and the views about the same are contradictory.

Stokes and Hull (1930) mentioned that dormancy in runner type groundnut varieties was not due to impervious seed coat, where as Toole *et al.* (1964) demonstrated that the removal of the outer layer of the seed coat helped in the loss of dormancy. Sengupta *et al.* (1977) also reported that tightly attached seed coat was one of the factors that delayed the germination in dormant groundnut varieties and its removal enhanced germination.

Patil (1967) studied dormancy in relation to maturity of groundnut pods and observed that excised embryo irrespective of stage of development, had very high percentage of germination and concluded that dormancy was not associated with embryo. In contrast, Vaithialingam and Rao (1973) observed that presence of germination inhibitors were more near the embryo region.

Ketring and Morgan (1972) and Ketring and Pattee (1985) have brought out the role of endogenous ethylene production in seed dormancy. According to them, seed dormancy in groundnut resulted from the hormonal balance between a germination inhibitor abscisic acid, produced in the aerial part of the plant which then accumulated in the cotyledons and the seed coat, and a germination activator, ethylene, produced by the embryo through the action of the cytokinin during seed imbibition. During storage of dormant seed, oxidation of the inhibitor occurred which tilted the hormonal balance in favour of germination activator. They also associated lipoxygenase activity with ethylene production indicating that the metabolites from the lipoxygenase activity might serve as a substrate for ethylene production. Studies by Presannakumari (1992) indicated that the groundnut embryonic axis did not require any rest period for commencement of growth. The dormancy in groundnut was primarily caused by the cotyledons with

the support of testa. There was no indication of the presence of any water soluble inhibitor in the freshly harvested dormant groundnut genotypes tested. Same was the case with reference to presence of water soluble promoters in the freshly harvested seeds of non-dormant groundnut genotypes tested.

2.1.5 Inheritance of seed dormancy

The few reports on the inheritance of seed dormancy in groundnut are found to be contradictory.

Stokes and Hull (1930) reported that dormancy was incompletely dominant over non-dormancy.

Hull (1937) also suggested that rest period behaviour agreed closely with the theory of multigenic inheritance.

John *et al.* (1948) observed that F_1 progenies were intermediate in behaviour between the two parents while the F_2 segregation showed great variability which indicated that multiple factors were responsible.

Ramachandran *et al.* (1967) observed dormancy to be partially dominant over non-dormancy from the F_1 and F_2 generations of two crosses they studied.

Lin and Lin (1971) determined dormancy of seeds two weeks after harvesting from reciprocal crosses between virginia cultivars with different dormancy intensities. Based on F_2 and F_3 individuals, they suggested monogenic control with dormancy being dominant.

Cheng (1972) reported that from preliminary studies in transferring seed dormancy (virginia to Spanish type) indicated that the character was controlled by a single pair of recessive genes.

Studies by Presannakumari (1992) also indicated polygenic inheritance of seed dormancy. Seeds of F_1 embryonic generation behaved like the dormant parents indicating the dominant nature of dormancy. A study of F_2 families revealed significant differences between individual families in their initial sprouting values. F_3 generation showed a continuous variation.

2.2 Yield

Yield is a complex character the expression of which depends on a number of component characters. Variability, heritability and genetic advance of these component characters in groundnut and also heterosis, combining ability and gene action for these characters in various crosses are reviewed here under.

2.2.1 Coefficient of variation, heritability and genetic advance

The success of selection depends upon variability present and also on the magnitude of heritable variation present in relation to observed variation. The reports on coefficient of variation, heritability and genetic advance in groundnut for important characters are tabulated below:

Character	Coefficient of variation		Herita-bility (%)	genetic advance (%)	Reported by
	Geno-typic	Pheno-typic			
Height of main stem	21.40	-	73.70	11.3	Kulkarni and Albuquerque (1967)
	11.76	-	36.44	14.62	Basu and Asoka Raj (1969)
	24.20	-	71.90	20.85	Dixit *et al.* (1970)
	13.86	23.84	33.70	16.55	Patra (1975)
	17.64	19.28	69.24	8.39	Deshmukh *et al.* (1986)
	-	-	70.66	-	Basu *et al.* (1986a)
Number of primary branches		50.80	88.90	6.10	Kulkarni and Albuquerque (1967)
		45.18	94.50	38.16	Majumdar *et al.* (1969)
		31.30	84.50	3.11	Dixit *et al.* (1970)
	28.11	15.28	23.70	175.28	Patra (1975)

Character	Coefficient of variation		Heritability (%)	genetic advance (%)	Reported by
	Genotypic	Phenotypic			
Number of secondary branches		10.5	-	10.24	Dixit *et al.* (1970)
			89.92	-	Sangha (1973b)
Number of mature pods		44.22	81.30	8.50	Kulkarni and Albuquerque (1967)
		14.08	60.94	10.95	Majumdar *et al.* (1969)
		61.90	77.80	23.90	Dixit *et al.* (1970)
	17.76	16.25	84.00	-	Sangha (1973b)
	-	-	87.10	-	Balaiah and Reddy (1975)
	-	-	31 to 43	-	Coffelt and Hammons (1974)
		7.89	4.80	-	Patra (1975)
	24.10	38.08	-	3.54	Deshmukh *et al.* (1986)
			31.68% (Narrow sense heritability)	-	Basu *et al.* (1986a) (in F_1 and parents)

Character	Coefficient of variation		Herita-bility (%)	genetic advance (%)	Reported by
	Geno-typic	Pheno-typic			
100 kernel weight			87.40	71.00	Dixit *et al.* (1970)
			99.60	54.00	Sangha and Sandhu (1975)
			64.00		Rao 1979)
			99.40		Singh *et al.* (1982)
			77.46	14.34	Deshmukh *et al.* (1986)
			51.33 (Narrow sense heritabi lity)		Basu *et al.* (1986a) (in F_1 generation)
Pod yield		21.06	36.44	3.88	Basu and Asoka Raj (1969)
		13.33	49.60	8.61	Majumdar *et al.* (1969)
		62.30	84.00	3.75	Dixit *et al.* (1970)
	13.19	10.70	66.00	17.77	Sangha (1973b)
	58.66	58.66	88.50	108.41	Patra (1975)
			59.75		Basu *et al.* (1986a) (in F_1 generation)
	12.09				Deshmukh *et al.* (1986)

2.2.2 Genetic divergence

Estimation of divergence among genotypes would help the breeder in the choice of parents for hybridisation. The success in obtaining highly heterotic hybrids and occurrence of desirable recombinants in advanced generations depends to a large extent on the degree of divergence between parents chosen. In groundnut the following studies have been reported on genetic diversity.

Sangha (1971) studied 27 spreading varieties for divergence with regard to six characters. Divergence analysis revealed that hundred grain weight and pod number contributed most to the diversity.

Shew *et al.* (1972) studied divergence among 24 elite groundnut varieties consisting of six bunch, six semi-spreading and 12 spreading types, using 17 characters. The varieties were grouped into three clusters with 7, 13 and 4 varieties respectively. The first cluster consisted of mostly bunch varieties. There was overlapping in clusters II and III which had semi-spreading and spreading varieties. No relationship could be established between geographic diversity and genetic diversity.

Sangha (1973a) reported genetic diversity in another set of 27 spreading groundnut varieties. The varieties were arranged into six clusters and spatial patterns of clusters were not corresponding to geographical diversity.

Sandhu and Sagha (1974) examined a collection of 27 bunch groundnut varieties for genetic divergence. The varieties were classified into seven clusters with respect to six characters. The divergence between the populations could not be related to their geographical distribution.

Durgaprasad *et al.* (1985) studied a representative sample of 160 varieties, equally divided among Spanish bunch, Valencia bunch, virginia bunch and Virginia runner varieties. In each group substantial diversity was found within and between the four botanical groups. Overlapping of Spanish and Valencia types within clusters was common. But they did not group with virginia bunch or runner in any of the three experiments. Indian and exotic cultivars were found together in many clusters. No relationship was found between geographic diversity and genetic diversity of the varieties and their origin in each cluster.

Sigamani (1981) studied 144 groundnut genotypes and classified them into 16 clusters. The characters, days to maturity and days to flowering were important in differentiating the genotypes in all the studies.

Reddy *et al.* (1989) subjected 31 Virginia varieties to D^2 analysis and grouped them under 10 clusters. Plant height, number of mature pods, number of secondary

branches and 100 kernel weight were found to be the potent factors for identifying genetically diverse genotypes in groundnut.

Nadaf *et al.* (1986) analysed 83 bunch genotypes for their D^2 values and grouped them under nine clusters irrespective of geographic isolation.

2.2.3 Combining ability and gene action

Combining ability is one of the powerful tools available to breeder for predicting the performance of parents and crosses for further use in heterosis breeding or combination breeding. General combining ability is associated with genes which are additive in effects and specific combining ability is attributed primarily to deviations from the additive scheme caused by dominance and epistasis (Rojas and Sprague, 1952).

Parker *et al.* (1970) estimated combining ability for 17 characters in F_1 hybrids from a six parent diallel under controlled conditions. In his study significant variance were found for GCA in 11 out of 17 characters. Estimates of SCA variance were significant for five characters. Wynne *et al.* (1970) estimated combining ability in the same set of hybrids used by Parker *et al* (1970) under field conditions. Specific combining ability effects were

significant for 16 out of 17 characters and gca for eight. The SCA variance component was 12 times greater than GCA component for yield of fruit.

Sadhu and Kehra (1976) report that non-additive effect were more important than additive effects for pod yield per plant and number of mature pods per plant where as for 100 kernel weight, additive gene effects were more important.

In a five parent diallel Raju *et al.* (1979) observed that both gca and sca effects were significant for 12 characters. The magnitude of SCA variance was greater than GCA variance, for all the characters indicating the predominance of non-additive gene effects.

Singh and Labana (1980) in a six parent diallel cross studied combining ability for nine vegetative and fruit characters. The gca and sca estimates were significant for all traits. Additive gene effects were found to play a major role in all the traits except in leaflet breadth and kernel weight.

Habib *et al.* (1985) conducted a 12 parent diallel and studied six quantitative traits. Variances due to GCA were highly significant for all the six characters and were higher in magnitude than SCA variances which were

significant for all characters. Both additive and non-additive gene effects were important for plant height, pod yield and days to maturity and only additive gene effects were important for number of branches and number of developed and under-developed pods.

Manoharan *et al.* (1985) in a line x tester analysis involving seven female and three male reported additive gene action for plant height, 100 pod weight, shelling percentage and pod yield and non-additive gene effects for pod number.

Bhagat *et al.* (1986) conducted line x tester analysis (8x5) with parents belonging to different sub-species and studied seven pod and seed characters. Combining ability analysis indicated that lines as well as testers were highly significant. General combining ability effects were significant for pod length, pod width, seed length, seed width and 100 seed weight and non significant for percentage of sound mature kernels. Majority of the crosses exhibited significant sca effects also and gene action was largely non additive.

Basu *et al.* (1987) in a 8x8 diallel cross reported that both GCA and SCA variances were substantial for days to 50 per cent flowering, days to maturity, mature pods per plant, pod yield per plant, 100 kernel weight and shelling percentage.

Nadaf *et al.* (1988) in a 5x5 diallel observed GCA variance estimates three to four times greater in magnitude than SCA for several characters. JL-24 and ICG-7899 were best general combiners.

Dwivedi *et al.* (1989) in an 8x8 diallel observed high gca for fruit and seed traits. He observed significant maternal inheritance for more than 6 traits in six crosses.

Vindhiyavarman and Ravindran (1994) studied 22 F_1 hybrids from crosses between 11 lines and two testers. The estimate of SCA/GCA variance indicated the predominance of non-additive gene action for number of pods and pod yield. Additive and non-additive gene action appeared to be important for harvest index, shelling out turn and sound mature kernels. Line VG-78 was a good general combiner for all characters and the best specific combination for pod yield was ACR-1/CG-2187.

2.2.4 Heterosis

Heterosis is the superiority of a F_1 hybrid over its parents. It is expressed in relation to better parent, mid parent or standard variety. F_1 heterosis is of direct interest for developing hybrids. But in groundnut where flower structure is not suited for outcrossing, the chances for exploiting heterosis on a commercial scale are remote. Arunachalam (1993) has suggested that heterotic crosses may produce desirable transgressive segregants in advanced generations.

The manifestation of heterosis in different economic traits of groundnut was first observed by Stokes and Hull (1930) in 11 groundnut crosses. Higgins (1941) in a diallel cross of 16 cultivars observed marked heterosis, for vegetative traits and pod yield. Hassan and Srivastava (1966) observed F_1 superiority for yield, number of branches and leaflet length in crosses involving three parents. Lin (1966) noted significant hybrid vigour for length of main stem and branches. He reported that virginia x valencia crosses gave greater magnitude of heterosis. Parker *et al.* (1970) conducted a 6x6 diallel in controlled environment. The F_1s exceeded the midparent by 20-40 per cent for several seedling characters. Wynne *et al.* (1970) using same parents of Parker *et al.* (1970) reported that F_1 hybrids from virginia x valencia parents gave greater heterosis for vegetative characters. Crosses of Valencia x Spanish gave greater heterosis for yield and fruit characters. Hammons (1973) reported heterotic responses for pod yield for F_1 hybrids resulting from crosses made between the subspecific groundnut groups.

Arunachalam *et al.* (1980) conducted two sets of diallel crosses involving 10 and 15 parents. They classified the parents as high or low based on combining ability computed for 15 characters. They observed that

high x low crosses produced greater heterosis than high x high or low x low crosses. In the first 15 x 15 diallel set, positive heterosis was estimated for nine characters and in the 10 x 10 set, for thirteen characters.

Sridharan and Marappan (1980) studied nine characters in nine hybrids. They reported positive heterosis over the mid parent in all the nine characters.

Arunachalam *et al.* (1982) studied two sets of diallel crosses involving 15 and 10 parents respectively for 15 characters. In the first set, 6 crosses showed heterosis for four or more characters and 8 crosses in the second. The highest proportion of crosses showing heterosis occurred in crosses between high gca and low gca parents. Crosses within variety groups as well as those between them, had a high proportion of crosses showing heterosis.

Isleib and Wynne (1983) crossed 28 diverse lines from different countries with elite virginia breeding lines. Positive heterosis was observed for number, size and yield of pods.

Arunachalam *et al.* (1984) examined the frequency and magnitude of heterosis in relation to genetic divergence

among parents in the two sets of diallel cross experiments. He defined four divergence classes. The frequency of heterotic crosses and the magnitude of heterosis for yield and its components were found to be higher in crosses between the parents in intermediate divergence classes than extreme ones. The study showed that there was an optimum level of genetic divergence between parents to obtain heterosis in F_1 generation.

Deshmukh *et al.* (1986) studied 12 morphological characters in 4 crosses of groundnut with JL-24 as pollen parent. The number of secondaries, mature and immature nuts, number of unproductive pegs and pod yield recorded positive heterobeltiosis in all crosses. Basu *et al.* (1986b) studied vegetative and reproductive characters, through a half diallel involving 8 genotypes belonging to sub-species *hypogaea* and *fastigiata*. Spanish x Spanish crosses recorded high desirable negative heterosis for days to 50 per cent flowering and high positive heterosis for number of mature pods and pod yield. Dwivedi *et al.* (1989) observed significant negative heterosis for fruit/seed weight and fruit/seed length and width.

High frequency of heterotic hybrids and high magnitude of heterosis for number of nodes, 100 pod weight, 100 kernel weight, shelling percentage and pod yield were

observed in Spanish x virginia crosses than in Spanish x Valencia crosses by Manoharan *et al.* (1990). In another study involving crosses between six Spanish bunch varieties (as females) and two Valencia and one virginia genotypes (as male parents), in a line x tester mating design, Manoharan and Thangavelu (1992) noticed that Spanish x virgina crosses expressed greater average heterobeltiosis for pod yield and its attributes than other crosses.

Vindhiyavarman and Raveendran (1994) observed heterosis over better parent for pod yield in *hypogaea* x *fastigiata* crosses.

Material and Methods

MATERIALS AND METHODS

Investigations were carried out in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, during the period 1992-1995. Field experiments were conducted in the fields of the Department (22.5 m above MSL) and that of Agricultural Research Station, Mannuthy (1.5 m above MSL) situated between 10°32' N latitude and 76° 10'E longitude. Geographically it falls in the warm humid tropical climatic zone.

3.1 Materials

Fourteen non-dormant and 14 dormant groundnut genotypes belonging to different botanical groups, as identified by Presannakumari (1992) in a previous study, were chosen as the experimental material for the study. The details of genotypes, their origin and duration of dormancy are presented in Table 3.

The 14 dormant and 14 non-dormant genotypes were evaluated for two seasons viz., *kharif* '92 and *rabi* '92-93. Based on yield, duration of dormancy and divergence, three genotypes from non-dormant group and five genotypes from dormant group (Plates 1 to 8) were selected as lines and testers respectively to give 15 hybrids. In 10 crosses F_1, F_2 and back cross generations were obtained, for the study of gene action of seed dormancy based on generation

Plate 1 Nondormant parent JL-24


JL 24

Plate 2 Nondormant parent VRI-3


VRI - 3

Plate 3 Nondormant parent Co-2


CO-2

Plate 4 Dormant parent ICG--7269


ICG - 7269

Plate 5 Dormant parent TG-17


TG-17

Plate 6 Dormant parent TMV-10


TMV -10

Plate 7 Dormant parent ICG-4861


ICG - 4861

Plate 8 Dormant parent ICG-1037


ICG - 1037

Table 3 Details of genotypes and their duration of seed dormancy

Sl. No.	Identity		Subspecies	Botanical variety	Origin	Duration* of seed dormancy
	ICRISAT	Other				
NONDORMANT						
1	ICG-5461	AH-816	*fastigiata*	*fastigiata*	Unknown	10
2	ICG-128	AH-7398	"	"	Unknown	10
3	-	VRI-3	"	*vulgaris*	Tamilnadu	10
4	ICG-3501	TMV-9	"	"	Tamilnadu	10
5	-	CO-2	"	"	Tamilnadu	10
6	ICG-5340	TG-14	"	"	Maharashtra	10
7	ICG-1528	TG-3	"	"	Maharashtra	10
8	-	JL-24	"	"	Jalgaon	10
9	ICG-7512	Hung Mein Chao	"	"	China	10
10	ICG-1994	TG-6	"	"	Maharashtra	10
11	ICG-154	Pol-2	"	"	Tamilnadu	10
12	ICG-459	Barberton	"	"	S. Africa	10
13	ICG-1231	AH-4218	"	"	India	10
14	-	TMV-2	"	"	Tamilnadu	10
DORMANT						
15	ICG-1883	EC-289622	"	*fastigiata*	Unknown	30
16	ICG-7269	BMP-16/52	"	*vulgaris*	Zimbabwe	20

Contd....

Table 3 contd.....

17	ICG-5341	TG-15	*fastigiata*	*vulgaris*	Maharashtra	30
18	ICG-5343	TG-17	"	"	Maharashtra	30
19	-	TMV-10	*hypogaea*	*hypogaea*	Tamilnadu	50
20	-	Robut-33-1	"	"	Andhra Pradesh	30
21	ICG-6301	NCAC-17649	"	"	USA	50
22	ICG-8281	NC-10468	"	"	USA	50
23	ICG-4861	AH-7652	"	*hirsuta*	India	60
24	ICG-1002	AH-84	"	"	India	70
25	ICG-1037	AH-7224	"	"	Nigeria	80
26	ICG-6193	43-G-44	"	"	India	40
27	ICG-1063	#648-4(GWALIOR)	"	"	India	50
28	ICG-861	C-118	"	"	India	40

*Measured as number of days to attain 80% germination after harvest

mean analysis. The pedigree of the lines and testers are presented in Table 4.

3.2 Methods

The experimental methods employed can be considered broadly under following heads.

1. Methods for analysis of productivity traits
2. Methods for analysis of seed dormancy

3.2.1 Analysis of productivity traits

The experimental methods for the analysis of productivity traits consisted of three parts:

1. Analysis of variance of 28 genotypes
2. D^2 analysis of 28 genotypes
3. Line x tester analysis

3.2.1.1 Analysis of variance of 28 genotypes

3.2.1.1.1 Field plot technique

The experiment was conducted in the *kharif* and *rabi* seasons of 1992-93. The experiment was laid out with 28 genotypes, in RBD with two replications adopting a spacing of 20 x 20 cm, in 2 m x 1 m plots. The other operations were done as per the package of practice recommendations of Kerala Agricultural University (KAU, 1993). Need based plant protection measures were adopted to control pest and diseases.

Table 4 Pedigree of parents selected for LxT analysis

Sl. No.	Identity	Parentage	Source	Seed dormancy*
Non-dormant female parents				
1	JL-24	Selection from EC-94943	Jalgaon	-
2	VRI-3	J-11/Robut 33-1	Virudhachalam	-
3	CO-2	EMS mutant from POL-1	TNAU, Coimbatore	-
Dormant male parents				
4	ICG-7269	Unknown	ICRISAT	20
5	TG-17	Dark Green Mutant/TG1	BARC Trombay	26
6	TMV-10	Natural mutant from Argentina	Tindivanam	47
7	ICG-4861	Unknown	ICRISAT	57
8	ICG-1037	Unknown	ICRISAT	76

* Measured as number of days required to attain 80 per cent germination after harvest

3.2.1.1.2 Observations

The following observations were recorded on five random plants per plot.

a) Days to 50 per cent flowering

Number of days taken from sowing, to 50 per cent of the plants in a plot to start flowering.

b) Height of the plant

Height of the plants at harvest was measured from the ground level to the tip of plant and expressed in cm.

c) Total number of branches per plant

All primary and secondary branches in each plant were counted and recorded at the time of harvest.

d) Number of mature pods per plant

Fully matured pods were counted from each plant at harvest.

e) Mean pod yield per plant

The pod yield of five plants after drying for two days was weighed and expressed as mean, in grams.

f) Hundred seed weight

A random sample of 100 seed was taken, weighed and expressed in grams.

g) Shelling percentage

The weight of kernels after shelling was expressed as percentage over weight of whole pods.

h) Oil content

Duplicate seed samples from each plot were analysed for oil content using percolation method and expressed in percentage.

i) Per hectare pod yield

The pod yield obtained from net plot area after excluding two border rows was converted to one hectare.

3.2.1.1.3 Statistical procedure

Measures like mean, variance and standard error were calculated for above characters as per Panse and Sukhatme (1978).

Mean values of five plants per plot, for all the nine characters, were subjected to analysis of variance technique. The analysis of variance table was constructed as follows:

Source	df	Mean square	Expected mean square
Replication	r-1		σ_e^2
Genotypes	t-1	M_1	$\sigma_e^2 + r\sigma_g^2$
Error	(r-1)(t-1)	M_2	σ_e^2
Total	rt-1		

σ_e^2 = error variance

σ_g^2 = Genotypic variance

The significance test was carried out by referring to the 'F' table . Pooled analysis was conducted for the *kharif* and *rabi* seasons.

Genotypic, phenotypic and environmental variances and their coefficients of variation, heritability (broad sense) and genetic advance were calculated by the methods suggested by Burton (1952) and Johnson *et al.* (1955).

3.2.1.2 Mahalonobis D^2 analysis

The genetic divergence among the 28 genotypes was calculated adopting the method suggested by Mahalonobis (1936). All possible $n(n-1)/_2$ D^2 values between 28 genotypes were calculated utilizing the varietal means.

Variance with respect of nine characters and co-variance between character pairs were calculated as per the method outlined by Rao (1952). The clustering of the varieties was done by the iterative method suggested by Suresh and Unnithan (1996).

3.2.1.3 Line x tester analysis

Three non-dormant genotypes were selected as lines (females) based on yield and five dormant genotypes were selected as testers (males) based on their divergence and duration of dormancy (Table 2; Plates 1 to 8). The three lines and five testers were crossed to give fifteen hybrids.

The conventional hybridization technique described by Norden (1973) with modifications given by Nigam *et al.* (1990) was employed for crossing. At a node a single well developed bud was selected and all other buds were removed. The emasculation was carried out between 3 and 5 pm. Using forceps the single sepal opposite to standard petal was pulled down. The standard petal was then gently opened with forceps and held back by the thumb and index finger. The wing petals were pulled down locking them with the standard. The keel was pulled outwards to expose anthers. All the eight fertile anthers were removed with the filaments. The standard, wing and keel petals were

returned to their normal positions after emasculation. The internode just above the emasculated bud was then marked with a date coded coloured nylon thread. Next day between 6.30 am and 7.30 am, pollination was carried out. The female parent plant was harvested 60 days after last pollination.

The eight parents and fifteen hybrids were raised during summer 1994 in RBD replicated twice, each treatment (parent or F_1) represented by 12 plants in a row. There was a spacing of 45 cm between rows and 30 cm between plants, within rows. Five plants were selected at random for recording details of observations for the following seven metric characters.

1. Days to 50 per cent flowering
2. Plant height
3. Total number of branches
4. Number of mature pods
5. Pod yield per plant
6. Shelling percentage
7. Hundred seed weight

The data collected for the seven metric traits from the parents and hybrids were subjected to critical analysis for *per se* performance, heterosis and combining ability.

3.2.1.3.1 Analysis of variance.

The variation among genotypes including parents and hybrids were first tested and were found significant. The treatment sum of squares were further partitioned into components like parents, parents vs. crosses, lines, testers, lines vs. testers and significance test carried out referring to `F' table.

3.2.1.3.2 Combining ability analysis

Analysis of combining ability (GCA and SCA) was carried out following the method suggested by Kempthorne (1957). Mean squares due to different sources of variation and their genetic expectations were estimated as indicated in the following ANOVA Table.

Source	df	Mean square	Expected mean square
Replication	(r-1)		
Hybrids	(lt-1)	-	
Lines	(l-1)	M_l	Ems+r [(Cov.(F.S)-2 Cov.(H.S)]+rt[Cov.(H.S.)]
Testers	(t-1)	M_t	Ems+r [(Cov.(F.S)-2 Cov.(H.S)]+rl[Cov.(H.S.)]
Lines x Testers	(l-1) (t-1)	M_{lt}	Ems+r [Cov.(F.S)-2 Cov.(H.S)]
Error	(r-1) (lt-1)	M_e	Ems
Total	(rlt-1)		

Where,

r = number of replications

l = number of lines

t = number of testers

Estimates of covariance of full sibs and half sibs were made from the genetic expectations of mean squares as,

$$\text{Cov.(F.S)} = \frac{M_l + M_t + M_{lt} - 3M_e + 6r\,\text{Cov.(H.S)} - r(l+t)\,\text{Cov.(H.S.)}}{3r}$$

$$\text{Cov.(H.S)} = \frac{M_l + M_t - 2M_{lt}}{r\,(l+t)}$$

From the covariance of full sibs and half sibs, variances due to general combining ability (σ^2_{gca}) and specific combining ability (σ^2_{sca}) were calculated as follows:

$$\sigma^2_{gca} = \text{Cov. H.S.}$$

$$\sigma^2_{sca} = \text{Cov. F.S.} - 2\ \text{Cov. H.S.}$$

The additive component A and non-additive component D were computed as follows as in Singh and Chaudhary (1985):

$$\sigma^2_A\ (F = 1) = 2\,\sigma^2_{gca}$$

$$\sigma^2_D\ (F = 1) = \sigma^2_{sca}$$

Proportional contribution by lines, testers and their interaction to total variance was calculated as per Singh and Chaudhary (1985).

$$\text{Contribution of lines} = \frac{ss(l) \times 100}{ss\ (crosses)}$$

$$\text{Contribution of testers} = \frac{ss\ (t) \times 100}{ss\ (crosses)}$$

$$\text{Contribution of hybrids} = \frac{ss\ (l \times t) \times 100}{ss\ (crosses)}$$

3.2.1.3.3 Estimation of gca and sca effects

The gca and sca effects of parents and hybrids were estimated based on the following model.

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

where,

X_{ijk} = Value of the ijk^{th} observation,

μ = Population mean

g_i = gca effect of the i^{th} line,

g_j = gca effect of the j^{th} tester,

s_{ij} = sca effect of the ij^{th} hybrid

e_{ijk} = error effect associated with ijk^{th} observation,

i = 1, 2,....., l

j = 1, 2,....., t

k = 1, 2,....., r

The individual effects of gca and sca were obtained from the two way table of lines vs. testers, in which each figure was a total over replications.

$$\mu = \frac{x...}{rlt}$$

$$g_i = \frac{xi....}{rt} - \frac{x....}{rlt}$$

$$g_j = \frac{xj..}{rl} - \frac{x....}{rlt}$$

$$s_{ij} = \frac{xij}{r} - \frac{xi...}{rt} - \frac{xj..}{rl} + \frac{x...}{rlt}$$

where,

x....	=	total of all hybrid combinations
xi...	=	total of i^{th} line over t testers and r replications,
xj.	=	total of j^{th} tester over l lines and r replications,
xij	=	total of the hybrid between i^{th} line and j^{th} tester over r replications

The standard errors pertaining to gca and sca effects were calculated from the square root of variance effects as given below:

i) Standard error for testing the gca effects of lines

$$SE\ (g_i) = \left[\frac{EMS}{rt}\right]^{1/2}$$

ii) Standard error for testing the significance of difference between gca effects of two lines

$$SE\ (g_i - g_j) = \left[\frac{2\ EMS}{rt}\right]^{1/2}$$

iii) Standard error for testing the gca effect of testers

$$SE\ (g_i) = \left[\frac{EMS}{rl}\right]^{1/2}$$

iv) Standard error for testing the significance of difference between gca effects of two testers

$$SE\ (g_i - g_j) = \left[\frac{2\ EMS}{rl}\right]^{1/2}$$

v) Standard error for testing sca effect of a cross

$$SE\ (S_{ij}) = \left[\frac{EMS}{r}\right]^{1/2}$$

vi) Standard error for testing the significance of difference between sca effects of two hybrids

$$SE\ (s_{ij} - s_{kl}) = \left[\frac{2\ EMS}{r}\right]^{1/2}$$

3.2.1.3.4 Heterosis

Heterosis was worked out as follows:

a) Based on mid parent value (MP):

$$\text{Relative heterosis (di)} = \frac{\overline{F_1} - \overline{MP} \times 100}{\overline{MP}}$$

b) Based on better parent value (BP):

$$\text{Heterobeltiosis (dii)} = \frac{\overline{F_1} - \overline{BP} \times 100}{\overline{BP}}$$

c) Based on standard variety (JL-24)

$$\text{Standard heterosis (diii)} = \frac{\overline{F_1} - \overline{SV} \times 100}{\overline{SV}}$$

where,

$\overline{F_1}$ = Mean of hybrid

$\overline{MP}$ = Mean of two corresponding parental values

$\overline{BP}$ = Mean of better parent value

$\overline{SV}$ = Mean of standard variety

The significance of heterosis was tested using the following formula:

a) for mid parent value:

$$\frac{\overline{MP} - \overline{F_1}}{\frac{3\ EMS}{2\ r}} \sim t_{(r-1)\ (lt-1)}$$

b) For better parent value

$$\frac{\overline{BP} - \overline{F_1}}{\frac{2\ EMS}{r}} \sim t_{(r-1)\ (lt-1)}$$

c) For standard variety value

$$\frac{\overline{SV} - \overline{F}_1}{\frac{2\ EMS}{r}} \sim t_{(r-1)\ (lt-1)}$$

3.2.2 Analysis of seed dormancy

Methods for the genetic analysis of seed dormancy consisted of following parts:

1. Dormancy studies in 28 groundnut genotypes
2. Dormancy studies in early generations
3. Generation mean analysis

3.2.2.1 Dormancy studies in 28 groundnut genotypes

The duration of dormancy was studied in 28 groundnut genotypes by periodical germination tests. The tests were conducted both for *kharif* and *rabi* seasons. The pods harvested from the experimental plots (laid out in RBD) were cured for three days in shade. For each genotype two replicates of 50 seeds each were sown in soil in trays, with embryo pointing upwards. The germinated seeds were counted and removed on the 10^{th} day. A seed was considered to have germinated if the radicle was visible out of the seed coat. The test for each genotype was continued till 80 per cent germination was attained.

The test was repeated in petridishes lined with germination paper using seeds from *rabi* crop.

3.2.2.2 Dormancy studies in early generations

In groundnut seed dormancy is a result of interaction between maternal genotype which determines inhibitor production in the aerial part of the plant and embryonic genotype which determines activator production by embryo (Ketring and Morgan, 1972). In each generation the embryonic genotype is different and one generation advanced from maternal genotype. For instance the seeds borne on F_1 plants possess F_2 embryos. To include the effect of embryo and maternal genotypes, the dormancy studies were conducted in following seeds from different generations.

1) F_1 seed (represents F_1 embryonic generation)
2) F_2 seed (represents F_2 embryonic generation and F_1 mature plant generation)
3) F_3 seed (represents F_3 embryonic generation and F_2 mature plant generation)
4) $BC_{1(ND)}$ seed (represents $BC_{1(ND)}$ embryonic generation)
5) $BC_{1(D)}$ seed (represents $BC_{1(D)}$ embryonic generation)
6) $BC_{1(ND)}$ F_2 seed (represents $BC_{1(ND)}$ mature plant generation)
7) $BC_{1(D)}$ F_2 seed (represents $BC_{1(D)}$ mature plant generation)

Since the number of seeds borne on a plant was few, and periodic observations on a per plant basis was necessary, the standard germination tests in petri dishes could not be followed. The seeds were found to get attacked by fungus within 10 days in petri dishes. Hence the media used for germination test was soil, where dormant seeds could be retained for several weeks.

3.2.2.2.1 Study of dormancy in F_1 seeds and back cross seeds

The crossed F_1 seeds were harvested 60 days after last pollination. The seeds were dried in shade for three days and sown in sterilised soil in germination trays, one seed in one hole. For each cross twenty seeds each of the parents and hybrids were sown and watered daily for 30 days (Plate 9a). Germination counts were taken at 10 days interval after sowing. The germination observed on 10^{th} day after sowing was designated as 10 D germination and on 20^{th} day as 20 D germination and so on. The germinated seeds were counted and eliminated from the test. After thirtieth day the remaining ungerminated seeds were treated with 500 ppm ethrel solution(Wadia *et al.*, 1987) and trays kept covered for 24 hours (Plate 9b). The seeds start germinating by 24 hours. The ungerminated seeds after ethrel treatment were noted as nonviable or diseased. The germinated seedlings were transplanted to raise F_2 plants.

Plate 9a Germination test in F_1 seeds

Plate 9b Ethrel treatment for dormant F_1 seeds 30 days after sowing


ICG 1037
VRI 3


VRI - 3
ICG - 1037

Similarly back cross seeds were also tested for dormancy and generation advancement done by ethrel treatment.

3.2.2.2.2 Dormancy studies in F_1 generation (F_2 seed), F_2 generation (F_3 seed) and backcross generations (BC_1F_2 seeds)

The dormancy of F_1, F_2, $BC_{1\,(ND)}$ and $BC_{1\,(D)}$ generations was observed on per plant basis by raising the plants in the field. For each cross 20 F_1 seeds, 40 F_2 seeds (bulked), 20 $BC_{1(ND)}$ seeds and 20 $BC_{1\,(D)}$ seeds were sown along with 20 P_1 and 20 P_2 seeds. At harvest five pods (containing 10 seeds) showing uniform maturity were randomly selected from each plant and seeds sown in the same layout. The maturity was assessed by slightly breaking the pods and examining the browning pattern inside the pod. The pods were allowed to cure for two days and irrigation started on the third day. Measures were taken to keep away ants and rodents. The number of seedlings emerged on per plant basis was noted at 10 days interval upto 30 days.

For comparison of crosses or generations the germination percentage on tenth day was taken, since at this point the parents were showing maximum difference in germination (Paterson *et al.* 1989).

Comparison of mean germination of F_1, F_2 and backcross generations with non dormant parents was done by `t' test. Arcsine square root transformation was applied to proportion of germination percentage to improve normality and error homogeneity (Snedecor and Cochran, 1980).

3.2.2.3 Generation mean analysis

The number of F_1 seeds obtained from a single female plant was very few, and hence the dormancy test for F_1 embryonic generation could not be obtained on per plant basis. Because of this reason generation mean analysis could not be carried out with embryonic generations.

In this study the generation mean analysis was carried out with the assumption that maternal genotype determined dormancy.Transformed proportion of germination percentage of six generations F_1, F_2, $BC_{1\,(ND)}$, $BC_{1\,(D)}$, P_1 and P_2 obtained from ten crosses for 10th day and 20th day was fitted into full six parameter model. Scaling tests were done according to Mather (1949) to examine whether simple additive-dominance model was adequate. The adequacy of model was further tested by joint scaling test proposed by Cavalli (1952).

3.2.2.3.1 Scaling tests

Scaling tests suggested by Mather (1949) were employed, based on the assumption that epistasis was absent. The following formulae were adopted for estimation of scales.

$$A = 2\overline{BC_{1(ND)}} - \overline{P_1} - \overline{F_1} \text{ (for back cross to } P_1)$$

$$B = 2\overline{BC_{1(D)}} - \overline{P_2} - \overline{F_1} \text{ (for back cross to } P_2)$$

$$C = 4\overline{F_2} - \overline{2F_1} - \overline{P_1} - \overline{P_2} \text{ (for } F_2 \text{ generation) and}$$

$$V_A = 4\overline{VBC_{1(ND)}} + \overline{VP_1} + \overline{VF_1}$$

$$V_B = 4\overline{VBC_{1(D)}} + \overline{VP_1} + \overline{VF_1}$$

$$V_C = 16\overline{VF_2} + \overline{VF_1} + \overline{VP_1} + \overline{VP_2}$$

where,

V_A, V_B and V_C are the variances of A, B and C respectively. $\overline{VP_1}$, $\overline{VP_2}$, $\overline{VF_1}$, $\overline{VF_2}$, $\overline{VBC_{1(ND)}}$ and $\overline{VBC_{1(D)}}$ are the variances of the generation means.

The standard errors of A, B and C were then calculated by estimating the square root of the variance concerned.

$$\text{S.E. of A} = \sqrt{\overline{V_A}}$$

$$\text{S.E. of B} = \sqrt{\overline{V_B}}$$

$$\text{S.E. of C} = \sqrt{\overline{V_C}}$$

The significance of the scales A, B and C was determined by comparing the observed and expected 't' values.

$$\text{`t' for A} = \frac{A}{\sqrt{V_A}}$$

$$\text{'t' for B} = \frac{A}{\sqrt{V_B}}$$

$$\text{'t' for C} = \frac{A}{\sqrt{V_C}}$$

3.2.2.3.2 Joint scaling tests

Weighted least square method proposed by Cavalli (1952) was adopted for joint scaling tests. The genetic parameters m, d, h were estimated and their significance tested. The expected means of six generations were computed using estimates of m, d and h. The significance of gene effects was verified at each step by chi-square goodness of fit test.

3.2.2.3.3 Estimation of genetic components

Using the six generation means, estimates of mean (m), additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) effects obtained following the equations formulated by Hayman (1958).

$$m = \bar{F}_2$$

$$d = \overline{BC}_{1(ND)} - \overline{BC}_{1(D)}$$

$$h = \bar{F}_1 - 4\bar{F}_2 - \tfrac{1}{2}\bar{P}_1 - \tfrac{1}{2}\bar{P}_2 + 2\overline{BC}_{1(ND)} + 2\overline{BC}_{1(D)}$$

$$i = 2\overline{BC}_{1(ND)} + 2\overline{BC}_{1(D)} - 4\bar{F}_2$$

$$j = \overline{BC}_{1(ND)} + \tfrac{1}{2}\bar{P}_1 - \overline{BC}_{1(D)} + \tfrac{1}{2}\bar{P}_2$$

$$l = \overline{P_1} + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\overline{BC}_{1(ND)} - 4\overline{BC}_{1(D)}$$

The variances for various parameters were calculated by utilizing the following equations.

$$V_m = V(\bar{F}_2)$$

$$V_d = \overline{VBC}_{1(ND)} + \overline{VBC}_{1(D)}$$

$$V_h = \overline{VF_1} + 16\overline{VF_2} + \tfrac{1}{4}\overline{VP_1} + \tfrac{1}{4}\overline{VP_2} + 4\overline{VBC}_{1(ND)} + 4\overline{VBC}_{1(D)}$$

$$V_i = 4\overline{VBC}_{1(ND)} + 4\overline{VBC}_{1(D)} + 16\overline{VF}_2$$

$$V_j = \overline{VBC}_{1(ND)} + \tfrac{1}{4}\overline{VP}_1 + \overline{VBC}_{1(D)} + \tfrac{1}{4}\overline{VP}_2$$

$$V_l = \overline{VP_1} + \overline{VP_2} + 4\overline{VF_1} + 16\overline{VF_2} + 16\overline{VBC}_{1(ND)} + 16\overline{VBC}_{1(D)}$$

The standard errors of the estimates of various components were obtained by the square root of the respective variances. The significance of these parameters were tested by calculating the `t' values as for scaling test.

Results

RESULTS

The results of the statistical analysis of the data on nine productivity traits and seed dormancy, in groundnut genotypes and crosses, are presented hereunder.

4.1 Analysis of productivity traits

The variability in twenty eight genotypes for nine biometric characters was analysed for two seasons. The divergence among 28 genotypes was studied by D^2 analysis. The combining ability of parents selected from 28 genotypes was assessed by Line x tester analysis.

4.1.1 Variability analysis

4.1.1.1 Mean performance of twenty eight genotypes of groundnut

The mean performance of twenty eight groundnut genotypes for *kharif* and *rabi* seasons and the pooled mean are given in Table 5.

4.1.1.1.1 Days to 50 per cent flowering

The number of days to 50 per cent flowering ranged from 26.5 to 41.5 days with a mean of 33.05 during *kharif* season. ICG-128 recorded the minimum and ICG-4861, the maximum flowering duration.

Table 5 Mean performance of fourteen non-dormant and fourteen dormant genotypes for kharif and rabi seasons

Genotypes	Days to 50% flowering			Plant height (cm)			Total number of branches		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
I Non-Dormant									
ICG-5461	27.50	27.50	27.50	75.70	50.30	63.00	4.30	4.10	4.20
ICG-128	26.50	27.00	26.75	85.80	41.50	63.65	3.10	3.80	3.45
VRI-3	28.50	27.50	28.00	78.50	39.70	59.10	4.60	4.30	4.45
TMV-9	33.00	29.50	31.25	70.50	40.35	55.43	5.65	4.50	5.08
CO-2	33.00	29.50	31.25	70.30	39.00	54.65	5.50	4.20	4.85
TG-14	33.00	28.00	30.50	69.90	48.60	59.25	4.40	2.40	4.35
TG-3	28.50	27.50	28.00	72.70	51.30	62.00	6.10	4.20	5.15
JL-24	30.50	28.00	29.25	74.63	50.90	62.76	4.80	4.20	4.50
ICG-7512	34.50	31.50	33.00	76.05	48.20	62.13	4.40	4.00	4.20
TG-6	33.00	27.50	30.25	76.50	50.80	63.65	5.20	4.50	4.85
POL-2	33.00	29.50	31.25	81.65	50.40	66.03	6.30	4.20	5.25
ICG-459	32.50	32.50	32.50	82.10	46.60	64.35	4.80	4.30	4.35
ICG-1231	27.00	27.50	27.25	79.40	46.60	63.00	5.10	4.50	4.80
TMV-2	29.00	28.00	28.50	71.75	51.75	61.75	5.50	4.10	4.80

Contd....

Table 5 contd.....

Genotypes	Days to 50% flowering			Plant height (cm)			Total number of branches		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
II Dormant									
ICG-1883	33.00	27.50	30.25	55.30	58.70	57.00	4.80	4.00	4.40
ICG-7269	28.50	25.50	27.00	74.65	49.65	62.15	5.10	4.20	4.65
TG-15	32.50	31.50	32.00	67.40	47.90	57.65	6.20	4.20	5.20
TG-17	32.50	29.50	31.00	61.45	36.15	48.80	4.00	4.30	4.15
TMV-10	33.00	34.50	33.75	53.50	43.10	48.30	12.40	13.75	13.08
ROBUT-33-1	33.50	33.00	33.25	56.50	39.40	47.95	15.35	14.55	14.95
ICG-6301	33.00	33.50	33.25	43.30	55.50	49.40	13.50	13.70	13.60
ICG-8281	40.00	37.00	28.50	76.20	47.80	62.00	9.50	11.00	10.25
ICG-4861	41.50	42.50	42.00	94.90	103.70	99.30	15.90	11.50	13.70
ICG-1002	38.00	39.00	38.50	85.40	64.10	74.75	11.10	10.50	10.80
ICG-1037	38.00	37.00	37.50	104.20	49.80	77.00	13.30	10.10	11.70
ICG-6193	39.00	37.00	38.00	93.80	56.40	75.10	12.30	10.30	11.30
ICG-1063	40.50	38.00	39.25	87.40	60.55	73.98	10.10	11.70	10.90
ICG-861	33.00	34.50	33.75	71.96	54.30	63.13	12.70	16.00	14.35
Mean	33.05	31.46	32.26	74.69	50.82	62.76	7.71	7.11	7.41
SED	1.06	0.92	1.04	6.17	2.89	6.04	0.78	0.53	0.54
CD (0.05)	2.18	1.89	4.26	12.65	5.92	24.75	1.60	1.09	2.21
CD (0.01)	2.94	2.55	5.76	17.09	8.01	33.45	2.16	1.47	2.98

Contd.....

Table 5 contd....

Genotypes	Number of mature pods			Pod yield per plant (g)			Hundred seed weight (g)		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
I Non-Dormant									
ICG-5461	9.20	9.10	9.15	5.60	5.97	5.79	27.52	26.63	27.07
ICG-128	10.20	9.30	9.75	5.33	4.33	4.83	23.35	18.58	20.96
VRI-3	10.90	11.20	11.05	9.19	9.68	9.44	36.03	35.57	35.80
TMV-9	12.00	10.00	11.00	7.20	6.37	6.79	27.99	25.29	26.64
CO-2	12.10	11.70	11.90	9.89	10.21	10.05	31.01	39.24	35.12
TG-14	13.40	12.00	12.70	8.95	10.31	9.58	44.00	44.41	44.23
TG-3	14.50	11.30	12.90	8.61	7.04	7.85	31.00	30.50	30.75
JL-24	12.90	9.80	11.35	13.59	9.79	11.69	49.94	46.91	48.42
ICG-7512	10.10	7.30	8.70	7.63	5.66	6.65	33.74	31.83	32.78
TG-6	12.90	9.30	11.10	6.79	4.73	5.76	35.67	31.40	33.53
POL-2	14.40	10.30	12.35	9.60	7.80	8.70	31.85	30.06	30.96
ICG-459	4.40	5.50	4.95	5.43	4.23	4.83	27.02	25.07	26.04
ICG-1231	5.00	5.50	5.25	6.79	7.83	7.31	24.95	26.16	25.55
TMV-2	9.50	8.90	9.20	6.48	5.71	6.09	31.90	27.90	29.90

Contd....

Table 5 contd.....

Genotypes	Number of mature pods			Pod yield per plant (g)			Hundred seed weight (g)		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
II Dormant									
ICG-1883	7.10	10.80	8.95	9.12	7.11	8.11	34.60	38.00	36.30
ICG-7269	11.70	12.40	12.05	11.06	12.65	11.85	43.85	38.63	41.24
TG-15	10.70	9.60	10.15	5.55	4.94	5.25	50.04	50.54	50.29
T5-17	11.20	9.45	10.33	11.57	11.11	11.34	52.00	47.27	49.64
TMV-10	14.70	11.70	13.20	14.39	10.92	12.65	47.17	43.85	45.51
ROBUT-33-1	14.35	10.80	12.58	14.66	11.05	12.85	35.80	39.07	37.43
ICG-6301	6.75	14.90	10.83	5.77	6.64	6.20	24.59	25.90	25.25
ICG-8281	8.50	6.53	7.52	11.00	7.56	9.28	73.40	70.29	71.84
ICG-4861	15.50	13.20	14.35	11.28	9.34	10.31	31.37	31.55	21.46
ICG-1002	7.60	8.20	7.90	8.09	5.40	6.75	50.40	48.80	49.60
ICG-1037	14.00	8.90	11.45	13.53	9.23	11.38	48.90	50.16	49.53
ICG-6193	5.60	4.30	4.95	6.96	4.72	5.84	34.09	37.33	35.71
ICG-1063	7.90	6.10	7.00	6.44	5.30	5.87	38.61	37.04	37.83
ICG-861	7.30	7.80	7.55	5.37	5.66	5.52	30.17	29.74	29.95
Mean	10.51	9.50	10.01	8.78	7.55	8.17	37.53	36.70	37.12
SED	2.01	1.78	1.31	1.73	1.83	0.77	2.77	2.40	1.37
CD (0.05)	4.12	3.65	5.36	3.55	3.83	3.02	5.68	4.90	5.37
CD (0.01)	5.55	4.93	7.24	4.79	5.18	3.98	7.67	6.70	7.07

Contd...

Table 5 contd....

Genotypes	Shelling percentage			Oil content (%)			Yield (kg ha^{-1})		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
I Non-Dormant									
ICG-5461	68.05 (55.52)	62.31 (52.69)	65.65 (54.10)	37.39 (37.67)	38.37 (38.20)	37.88 (38.93)	1900	1573	1736
ICG-128	64.40 (53.36)	68.71 (50.51)	61.98 (51.93)	43.00 (40.97)	42.22 (40.48)	42.61 (40.73)	1640	1570	1605
VRI-3	71.16 (57.52)	64.74 (55.49)	69.54 (56.50)	45.08 (42.19)	45.61 (42.48)	45.34 (42.33)	2265	1815	2040
TMV-9	67.07 (54.99)	67.38 (56.47)	67.52 (55.73)	52.30 (46.32)	47.21 (43.47)	49.75 (44.86)	1915	1685	1800
CO-2	70.86 (57.44)	67.97 (57.55)	71.12 (57.50)	48.75 (44.27)	47.82 (43.74)	48.28 (44.01)	2063	1815	1939
TG-14	63.67 (52.93)	65.87 (56.57)	66.67 (54.75)	43.39 (41.21)	45.68 (42.33)	44.53 (41.77)	2115	1735	1925
TG-3	73.05 (58.73)	69.73 (56.70)	71.45 (57.71)	45.05 (42.10)	46.85 (43.15)	45.95 (42.62)	1788	1485	1636
JL-24	69.24 (56.79)	71.25 (58.76)	71.32 (57.62)	46.97 (43.28)	50.30 (45.18)	48.63 (44.23)	2165	1850	2008
ICG-7512	68.91 (56.14)	69.05 (53.00)	67.00 (54.77)	38.47 (38.29)	38.87 (38.56)	38.67 (38.43)	1188	1138	1163
TG-6	66.86 (54.86)	70.15 (55.67)	67.43 (55.26)	49.06 (44.48)	51.68 (45.86)	50.37 (45.17)	2068	1700	1884
POL-2	70.15 (56.86)	67.26 (56.65)	70.00 (56.76)	44.95 (42.11)	40.65 (39.61)	42.80 (40.86)	1765	1653	1709
ICG-459	72.94 (58.69)	66.52 (57.14)	71.74 (57.90)	44.71 (41.99)	42.18 (40.28)	43.44 (41.13)	1628	1480	1554
ICG-1231	67.91 (55.40)	62.80 (54.76)	67.32 (55.08)	44.94 (42.10)	39.45 (38.91)	42.20 (40.50)	1790	1620	1705
TMV-2	69.98 (56.75)	64.13 (56.33)	69.61 (55.54)	50.77 (45.43)	41.44 (40.04)	46.10 (42.74)	1990	1590	1790

Table 5 contd.....

Genotypes	Shelling percentage			Oil content (%)			Yield (kg ha^{-1})		
	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean	Kharif	Rabi	Pooled mean
II Dormant									
ICG-1883	65.45 (54.00)	62.41 (52.10)	63.93 (53.05)	39.93 (39.21	39.74 (39.09)	39.84 (39.15)	1855	1790	1823
ICG-7269	74.07 (59.39)	68.71 (55.98)	71.39 (57.69)	46.70 (43.08)	43.15 (41.06)	44.93 (42.07)	1950	1795	1873
TG-15	66.29 (54.52)	64.74 (53.59)	65.52 (54.06)	35.95 (36.82)	39.28 (38.79)	37.62 (37.81)	1938	1838	1888
T5-17	67.50 (55.25)	67.38 (55.21)	67.44 (55.23)	50.58 (45.32)	49.73 (44.83)	50.16 (45.07)	1970	1820	1895
TMV-10	73.43 (59.31)	67.97 (55.53)	70.70 (57.42)	50.89 (45.52)	53.79 (47.18)	52.34 (46.35)	2100	1363	1731
ROBUT-33-1	63.71 (52.93)	65.74 (54.16)	64.73 (53.54)	43.42 (41.21)	44.12 (41.61)	43.77 (41.41)	1970	1290	1630
ICG-6301	70.01 (56.77)	69.73 (56.60)	69.87 (56.68)	38.55 (38.38)	39.82 (39.08)	39.19 (38.73)	1325	1450	1388
ICG-8281	69.00 (56.17)	71.25 (57.62)	70.13 (56.89)	44.50 (41.81)	38.30 (38.24)	41.40 (40.02)	1600	1588	1594
ICG-4861	68.40 (55.81)	69.05 (56.20)	68.73 (56.00)	39.88 (39.15)	44.85 (42.05)	42.37 (40.60)	1700	1775	1738
ICG-1002	71.61 (57.80)	70.15 (56.89)	70.88 (57.35)	44.41 (41.99)	50.50 (45.26)	47.46 (43.53)	1250	1070	1160
ICG-1037	63.50 (52.84)	67.26 (55.10)	65.38 (53.97)	44.23 (41.70)	41.39 (40.04)	42.81 (40.87)	2088	1390	1739

Contd....

Table 5 contd....

ICG-6193	66.73 (54.75)	66.52 (54.64)	67.63 (54.70)	48.69 (44.26)	46.95 (43.25)	47.82 (43.75)	1500	1070	1285
ICG-1063	62.80 (52.42)	62.80 (52.42)	62.80 (52.42)	44.74 (41.98)	43.43 (41.18)	44.09 (41.58)	1060	1165	1113
ICG-861	64.93 (53.66)	64.13 (53.20)	64.53 (53.43)	44.11 (41.61)	45.01 (42.13)	44.56 (41.87)	1050	1250	1150
Mean	68.26 (55.75)	67.60 (55.30)	67.93 (55.53)	44.69 (41.94)	44.23 (41.64)	44.56 (41.79)	1773	1549	1661
SED	1.32	1.38	0.92	1.85	1.40	0.89	173.44	96.60	177.94
CD (0.05)	2.71	2.82	3.76	3.79	2.90	3.50	355.47	198.03	348.76
CD (0.01)	3.66	3.82	5.08	5.13	3.89	4.61	480.43	267.58	471.26

Values after angular transformation are given in parenthesis

In the *rabi* season the range was from 25.50 to 42.50 days, recorded by ICG-7269 and ICG-4861 respectively. The mean duration recorded was 31.46 days.

The pooled mean recorded was the lowest in ICG-128 (26.75 days) and the highest in ICG-4861 (42 days). The general pooled mean was 32.26 days.

4.1.1.1.2 Plant height

In the *kharif* season minimum plant height was recorded by ICG-6301 (43.3 cm) and maximum by ICG-1037 (104.2 cm). The general mean was 74.69 cm.

The plant height ranged from 36.15 in TG-17 to 103.7 cm in ICG-4861 during *rabi* season. The general mean for the trait was 50.82 cm.

The pooled mean height for the two seasons was 62.76 cm. ICG-4861 recorded the maximum height of 99.3 cm while the minimum was recorded by Robut-33-1 (47.95 cm).

4.1.1.1.3 Total number of branches

The range was between 3.1 in ICG-128 to 15.90 in ICG-4861 for *Kharif* season. The general mean was 7.71.

During *rabi* season the maximum number of branches was registered by Robut-33-1 (14.55) and minimum by ICG-128 (3.8). The general mean was 7.11.

When the data for two seasons were pooled Robut-33-1 recorded the highest pooled mean for total number of branches (14.95) and the least by ICG-128 (3.45) and the pooled general mean was 7.41.

4.1.1.1.4 Number of mature pods

The mean number of mature pods for *kharif* season ranged from 4.4 in ICG-459 to 15.5 in ICG-4861 with a general mean of 10.51.

The range was found to be between 4.3 to 14.9, during *rabi* season, ICG-6301 recorded the maximum number of mature pods, while ICG-6193 recorded the minimum value for the trait. The general mean was 9.5.

The pooled mean was the highest for ICG-4861 and the least for ICG-6193 and ICG-459 the values being 14.35 and 4.95 respectively. The pooled general mean was 10.01.

4.1.1.1.5 Pod yield per plant

For *kharif* season genotypes ICG-128 recorded the minimum per plant pod yield of 5.33, while Robut-33-1 registered maximum yield of 14.66 g. The general mean for the character was 8.78 g.

The range was found to be between 4.23 g (ICG-459) to 12.65 g (ICG-7269) during *rabi* season. The general mean was 7.55 g.

The two seasons' pooled mean was highest for Robut-33-1 (12.85 g) and least for ICG-128 and ICG-459 (4.83 g). The pooled general mean was 8.17 g.

4.1.1.1.6 Hundred seed weight

The general mean for hundred seed weight for *kharif* season was found to be 37.53 g, while the range was from 23.35 g to 73.4 g. ICG-8281 recorded the highest value and ICG-128 recorded the least.

The range for *rabi* season was from 18.58 g in ICG-128 to 70.29 g in ICG-8281. The general mean registered was 36.7 g.

The pooled mean recorded for the character was the maximum in ICG-8281 (71.84 g) and the minimum in ICG-128 (20.96 g). The general pooled mean for the trait was 37.12 g.

4.1.1.1.7 Shelling percentage

For the *kharif* season the range was found to be between 62.8 per cent in ICG-1063 and 74.07 per cent in ICG-7269. The general mean was 68.26 per cent.

The mean shelling percentage for twenty eight genotypes for *rabi* season was 67.6 per cent. The range recorded for the trait was from 62.3 per cent in ICG-5461 to 71.25 per cent in ICG-8281 and JL-24.

The pooled general mean was 67.93 per cent, the maximum value recorded was 71.74 per cent for ICG-459 and the minimum by ICG-128 (61.98 per cent).

4.1.1.1.8 Oil content

The genotype TMV-9 recorded the maximum oil content (52.3 per cent) while TG-15 recorded the minimum (35.95 per cent) for *kharif* season. The general mean for the trait was 44.69 per cent.

The range was found to be between 38.3 per cent and 53.79 per cent, ICG-8281 recording the minimum value and TMV-10, the maximum value during *rabi* season. The general mean for oil content was 44.23 per cent.

The pooled mean recorded for both the seasons was the highest for TMV-10 (52.34 per cent) and the lowest in TG-15 (37.62 per cent). The pooled general mean was 44.56 per cent.

4.1.1.1.9 Yield (kg ha^{-1})

The per hectare yield recorded for *kharif* season was the highest for VRI-3 (2265 kg ha^{-1}) and the least for ICG-861 (1050 kg ha^{-1}). The general mean for the character was 1773 kg ha^{-1}.

For the *rabi* season, the range was between 1070 kg ha^{-1} in ICG-1602 to 1850 kg ha^{-1} in JL-24. The general mean was 1773 kg ha^{-1}.

The general pooled mean recorded for pod yield was 1661 kg ha^{-1}. The highest pooled yield was recorded by VRI-3 (2040 kg ha^{-1})and the least by ICG-1063 (1113 kg ha^{-1}).

4.1.1.2 Analysis of variance

Data on nine biometric characters recorded on twenty eight genotypes for two seasons was subjected to statistical analysis. The ANOVA is presented in Table 6 and 7. Variance due to genotypes for individual season for all the traits were significant at one per cent level.

In the pooled analysis also the genotypes recorded significant differences in all the traits except plant height (Table 8). The X^2 test revealed that error mean squares for the two seasons, were homogenous and interaction significant in the case of days to 50 per cent flowering, number of mature pods per plant, shelling percentage and pod yield, whereas interaction was not significant in the case of pod yield per plant, hundred seed weight and oil content. For plant height and total number of branches, the error mean squares were heterogenous and interaction was significant.

Table 6 Analysis of variance for nine plant characters in twenty eight groundnut genotypes during *kharif* season

Sl. No.	Character/source	Mean sum of squares	
		Varieties df = 27	Error df = 27
1	Days to 50% flowering	33.94**	1.11
2	Plant height	343.86**	38.10
3	Total number of branches	31.34**	0.61
4	Number of mature pods	20.54**	4.05
5	Pod yield per plant	16.94**	3.00
6	Hundred seed weight	251.18**	7.66
7	Shelling percentage	8.18**	1.74
8	Oil content	12.16**	3.43
9	Pod yield (kg ha^{-1})	230558.82**	30081.11

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

Table 7 Analysis of variance for nine plant characters in twenty eight groundnut genotypes during *rabi* season

Sl. No.	Character/source	Mean sum of squares	
		Varieties df = 27	Error df = 27
1	Days to 50% flowering	40.03**	0.84
2	Plant height	305.83**	8.36
3	Total number of branches	34.02**	0.28
4	Number of mature pods	13.80**	3.16
5	Pod yield per plant	12.93**	3.48
6	Hundred seed weight	237.34**	5.75
7	Shelling percentage	7.26**	1.92
8	Oil content	12.79**	1.96
9	Pod yield (kg ha^{-1})	123342.82**	9331.06

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

Table 8 Pooled analysis of variance for nine plant characters in twenty eight groundnut genotypes during *kharif* and *rabi* seasons

Sl. No.	Character/source	Mean sum of squares for varieties (MSSV) df = 27	MSSV tested against		
				df	MSS
1	Days to 50% flowering♧	69.66**	Interaction mean square	27	4.32
2	Plant height♡	179.06^{NS}	Interaction mean square	27	145.78
3	Total number of branches♡	31.52**	Interaction mean square	27	1.16
4	Number of mature pods per plant♧	26.11**	Interaction mean square	27	6.83
5	Pod yield per plant✣	26.22**	Pooled error mean square of interaction and pooled error	81	2.38
6	Hundred seed weight✣	479.3**	Pooled error mean square of interaction and pooled error	81	7.51
7	Shelling percentage♧	12.28**	Interaction mean squares	27	3.37
8	Oil content✣	20.77**	Pooled error mean square of interaction and pooled error	81	3.18
9	Pod yield (kg ha^{-1})♧	148006.5**	Interaction mean squares	27	28944.00

♧ Error mean squares homogenous, interaction significant
✣ Error mean squares homogenous, interaction not significant
♡ Error mean squares heterogenous interaction significant
* Significant at 5% level ** Significant at 1% level

4.1.1.3 Genetic parameters of variation

The genetic parameters of variation for *kharif* and *rabi* seasons in nine biometric characters are presented in Table 9 and 10.

The phenotypic and genotypic variances were almost equal in magnitude in most of the characters except for number of mature pods, pod yield per plant and oil content, where the phenotypic variance was considerably higher. The phenotypic coefficient of variation was higher than genotypic coefficient of variation in all the traits but the differences were small, except in the case of number of mature pods per plant and pod yield per plant.

The broad sense heritability estimates were high for all the traits except for oil content in *kharif* season and pod yield per plant and shelling percentage in *rabi* season. Heritability ranged from 56.03 per cent for oil content to 96.18 per cent for total number of branches in *kharif* season. The range was from 57.61 per cent for pod yield per plant to 98.57 per cent for total number of branches in *rabi* season.

The genetic advance expressed as percentage over mean was highest for total number of branches (102.46) followed by hundred seed weight (58.70) during *kharif* season. In the *rabi* season also same characters recorded the highest, values, 118.0 and 58.97 respectively.

Table 9 Genetic parameters for nine characters for *kharif* season

Parameter	Days to 50% flowering	Plant height	Total number of branches	Number of mature pods	Pod yield per plant	Hundred seed weight	Shelling percentage	Oil content	Pod yield kg ha^{-1}
Genotypic variance σg^2	16.42	152.88	15.35	8.25	6.97	121.76	3.22	4.37	100238.85
Phenotypic variance σp^2	17.53	190.98	15.96	12.30	9.97	129.42	4.96	7.80	130319.96
Environmental variance σe^2	1.11	38.10	0.61	4.05	3.00	7.66	1.74	3.43	30081.11
Genotypic coefficient of variation (GCV) %	12.26	16.55	50.82	27.33	30.07	29.40	3.22	4.98	17.86
Phenotypic coefficient of variation (PCV) %	12.67	18.50	51.82	34.70	35.96	30.31	3.99	6.66	20.36
Heritability (Broad sense) %	93.67	80.05	96.18	67.07	69.91	94.08	67.14	56.03	76.92
Genetic advance	8.11	22.78	7.90	4.84	4.55	22.03	3.07	3.22	571.87
Genetic advance as % of mean	24.54	30.50	102.46	46.05	51.82	58.70	5.51	7.21	32.25

Table 10 Genetic parameters for nine characters in groundnut for *rabi* season

Parameter	Days to 50% flowering	Plant height	Total number of branches	Number of mature pods	Pod yield per plant	Hundred seed weight	Shelling percentage	Oil content	Pod yield kg ha^{-1}
Genotypic variance $\sigma^2 g$	19.60	148.74	16.87	5.32	4.73	115.80	2.67	5.42	57005.88
Phenotypic variance $\sigma^2 p$	2044	157.10	17.15	8.48	8.21	121.55	4.59	7.38	66336.94
Environmental variance $\sigma^2 e$	0.84	8.36	0.28	3.16	3.48	5.75	1.92	1.96	9331.06
Genotypic coefficient of variation (GCV) %	14.07	24.00	57.77	24.28	28.80	29.32	2.96	5.59	15.41
Phenotypic coefficient of variation (PCV) %	14.37	24.66	58.25	30.65	37.95	30.04	3.87	6.52	16.63
Heritability (Broad sense) %	95.89	94.68	98.37	62.74	57.61	95.27	58.17	73.44	85.93
Genetic advance	8.93	24.45	8.39	3.76	3.40	21.64	2.57	4.11	455.92
Genetic advance as % of mean	28.39	48.11	118.00	39.58	45.03	58.97	4.65	9.80	29.43

4.1.2 Genetic divergence

The divergence within the genotypes and the characters were tested by Wilk's criterion and was found to be significant. Thus the analysis of genetic divergence among the genotypes taken for study was considered to be relevant.

4.1.2.1 D^2 analysis

The data on nine characters in twenty eight genotypes, for *kharif* and *rabi* seasons were analysed for genetic divergence. The plot means of twenty eight genotypes were transformed into standardised uncorrelated mean values. The D^2 values were computed for all possible 28 (28-1)/2 = 378 pairs of genotypes. By the application of clustering technique the 28 genotypes could be grouped into four clusters, both in *kharif* and *rabi* season. The constituents of different clusters with their sources are presented in Table 11 and 12.

Among the four clusters identified for *kharif* season, cluster-I was the largest with fourteen genotypes, followed by cluster-II with six genotypes. Cluster-III and IV were represented by four genotypes each. In the *rabi* season also the 28 genotypes could be grouped into four clusters. Cluster-I had the maximum number of genotypes (sixteen) followed by cluster-II with six genotypes and cluster-III and IV with three genotypes each.

Table 11 Composition of D^2 clusters for *Kharif* season

Cluster No.	Total number of genotypes in each cluster	Identity	Botanical variety	Origin/source
I	14	ICG-5461	Valencia	ICRISAT, Hyderabad
		ICG-128	Valencia	ICRISAT, Hyderabad
		VRI-3	Spanish	Virudhachalam Tamilnadu
		TMV-9	Spanish	Tindivanam Tamilnadu
		CO-2	Spanish	Coimbatore, Tamilnadu
		TG-14	Spanish	BARC, Trombay
		JL-24	Spanish	Jalgaon, Maharashtra
		TG-6	Spanish	BARC, Trombay
		POL-2	Spanish	Coimbatore, Tamilnadu
		ICG-459	Spanish	ICRISAT, Hyderabad
		ICG-1231	Spanish	ICRISAT, Hyderabad
		TMV-2	Spanish	Tindivanam, Tamilnadu
		ICG-1883	Valencia	ICRISAT, Hyderabad
		ICG-7269	Spanish	ICRISAT, Hyderabad
II	6	ICG-8281	Virginia bunch	ICRISAT, Hyderabad
		ICG-4861	Virginia runner	ICRISAT, Hyderabad

Contd.....

Table 11 contd....

		ICG-1002	Virginia runner	ICRISAT, Hyderabad
		ICG-1037	Virginia runner	ICRISAT, Hyderabad
		ICG-6193	Virginia runner	ICRISAT, Hyderabad
		ICG-1063	Virginia runner	ICRISAT, Hyderabad
III	4	TMV-10	Virginia bunch	Tindivanam, Tamilnadu
		Robut-33-1	Virginia bunch	ICRISAT, Hyderabad
		ICG-6301	Virginia bunch	ICRISAT, Hyderabad
		ICG-861	Virginia runner	ICRISAT, Hyderabad
IV	4	TG-3	Spanish	BARC, Trombay
		ICG-7512	Spanish	ICRISAT, Hyderabad
		TG-15	Spanish	BARC, Trombay
		TG-17	Spanish	BARC, Trombay

Table 12 Composition of D^2 clusters for Rabi season

Cluster No.	Total number of genotypes in each cluster	Identity	Botanical variety	Origin/source
I	16	ICG-5461	Valencia	ICRISAT, Hyderabad
		ICG-128	Valencia	ICRISAT, Hyderabad
		VRI-3	Spanish	Virudhachalam Tamilnadu
		TMV-9	Spanish	Tindivanam, Tamilnadu
		CO-2	Spanish	Coimbatore, Tamilnadu
		TG-14	Spanish	BARC, Trombay
		TG-3	Spanish	BARC, Trombay
		JL-24	Spanish	Jalgaon, Maharashtra
		ICG-7512	Spanish	ICRISAT, Hyderabad
		TG-6	Spanish	BARC, Trombay
		POL-2	Spanish	Coimbatore, Tamilnadu
		ICG-459	Spanish	ICRISAT, Hyderabad
		ICG-1231	Spanish	ICRISAT, Hyderabad
		TMV-2	Spanish	Tindivanam, Tamilnadu
		ICG-1883	Valencia	ICRISAT, Hyderabad
		ICG-7269	Spanish	ICRISAT, Hyderabad

Contd....

Table 12 contd.....

II	6	TMV-10	Virginia bunch	Tindivanam, Tamilnadu
		Robut-33-1	Virginia runner	ICRISAT, Hyderabad
		ICG-1002	Virginia runner	ICRISAT, Hyderabad
		ICG-1037	Virginia runner	ICRISAT, Hyderabad
		ICG-6193	Virginia runner	ICRISAT, Hyderabad
		ICG-1063	Virginia runner	ICRISAT, Hyderabad
III	3	TG-15	Spanish	BARC, Trombay
		TG-17	Spanish	BARC, Trombay
		ICG-8281	Virginia bunch	ICRISAT, Hyderabad
IV	3	ICG-6301	Virginia bunch	ICRISAT Hyderabad
		ICG-861	Virginia runner	ICRISAT, Hyderabad
		ICG-4861	Virginia runner	ICRISAT, Hyderabad

The clustering pattern of genotypes for *kharif* season was in general, based on their subspecific status. The clusters I and IV comprised of genotypes belonging to subsp. *fastigiata* and clusters-II and III were constituted by subsp. *hypogaea* genotypes. All the three Valencia genotypes and eleven Spanish genotypes were grouped into cluster-I. Cluster-IV comprised of only Spanish genotypes. Cluster-III included Virginia bunch genotypes with the exception of ICG-861 which was a Virginia runner. Similarly, cluster-II was constituted by Virginia runners with the exception of ICG-8281 which was a Virginia bunch.

For the *rabi* season, however the clustering pattern was found to be at random. All the three Valencia genotypes and thirteen other Spanish genotypes were grouped in cluster-I. Cluster-II was formed with two Virginia bunch and four Virginia runner genotypes. Cluster-III included two Spanish and one Virginia bunch genotype. Two Virginia runner and one Virginia bunch were grouped in cluster-IV.

4.1.2.2 Intra and inter cluster average distance

The intra and inter cluster D^2 and D values among the four clusters for *kharif* and *rabi* seasons are presented in Table 13 and 14 respectively.

Table 13 Inter and intra (diagonal) cluster average of D^2 values for *Kharif* season

Clusters	I	II	III	IV
I	**73.51** (8.57)	539.61 (23.23)	360.86 (19.00)	123.58 (11.12)
II	-	**163.40** (12.78)	276.30 (16.62)	393.42 (19.83)
III	-	-	**93.23** (9.66)	292.7 (17.11)
IV	-	-	-	**131.58** (11.47)

Table 14 Inter and intra (diagonal) cluster average of D^2 values for *Rabi* season

Clusters	I	II	III	IV
I	**91.30** (9.56)	638.81 (25.27)	550.64 (23.47)	748.37 (27.36)
II	-	**150.61** (12.27)	497.53 (22.31)	434.00 (20.83)
III	-	-	**478.27** (21.87)	981.17 (31.32)
IV	-	-	-	**583.98** (24.17)

For the *kharif* season, the highest inter-cluster distance was observed between cluster-I and II (23.23) and the least was between cluster-I and IV (11.12). Among the *rabi* season clusters, the inter-cluster distance was maximum between cluster-III and IV (31.32). The closest clusters were II and IV (20.83).

The intra-cluster distance for *kharif* season was the highest in cluster-II (12.78) and the least in cluster-I (8.57). In the *rabi* season maximum intra-cluster distance was recorded by cluster-IV (24.17) and minimum by cluster-I (9.56).

4.1.2.3 Cluster mean value of characters

The mean values for nine characters in each cluster for *kharif* and *rabi* seasons are presented in Table 15.

In the *kharif* season wide differences were observed among clusters for most of the characters except for number of mature pods per plant and shelling out turn. Higher values than general mean were observed in cluster-II and III for days to 50 per cent flowering, plant height and total number of branches, clusters-III and IV for number of mature pods per plant, clusters-II and III for pod yield per plant, clusters-II and IV for hundred seed weight, cluster-I and IV for shelling percentage, cluster-I for oil content and per hectare yield. Cluster-I recorded maximum

Table 15 Cluster means for nine characters

Sl. No.	Character	General mean	Clusters			
			I	II	III	IV
A. KHARIF SEASON						
1	Days to 50% flowering	33.05	30.57	39.50	33.13	32.00
2	Plant height (cm)	74.69	74.76	90.27	56.32	55.84
3	Total number of branches	7.71	4.90	12.03	13.49	5.18
4	Number of mature pods per plant	10.51	10.41	9.85	10.78	11.63
5	Pod yield per plant (g)	8.78	8.44	9.55	10.05	7.55
6	Hundred weed weight (g)	37.53	33.55	46.13	34.43	41.70
7	Shelling percentage	68.35	68.71	67.03	68.20	69.00
8	Oil content (%)	44.70	45.52	44.40	44.20	42.40
9	Pod yield (kg ha^{-1})	1773	1936	1533	1289	1721
B. RABI SEASON						
1	Days to 50% flowering	31.46	28.38	36.42	32.67	36.83
2	Plant height (cm)	49.13	47.77	52.23	43.95	55.33
3	Total number of branches	7.10	4.21	11.82	6.50	13.73
4	Number of mature pods per plant	9.50	9.65	8.33	8.53	11.97
5	Pod yield per plant (g)	7.55	7.46	7.77	7.87	7.21
6	Hundred seed weight (g)	36.87	32.26	42.71	56.03	30.65
7	Shelling percentage	67.60	67.85	66.75	67.84	67.70
8	Oil content (%)	44.15	43.72	46.65	42.40	43.20
9	Pod yield (kg ha^{-1})	1549	1643	1225	1811	1429

cluster mean for oil content, per hectare pod yield, while cluster-II registered maximum values for days to 50 per cent flowering and hundred seed weight. Cluster-III registered highest mean values for total number of branches and pod yield per plant. Cluster-IV recorded maximum values for number of mature pods per plant and shelling percentage.

For the *rabi* season also, the differences in the cluster means were very evident except in the case of pod yield per plant and shelling percentage. Higher value than the general mean was observed in the cluster-II, III and IV for days to 50 per cent flowering, II and IV for plant height and total number of branches. Cluster-I and II for number of mature pods per plant, cluster-II and III for pod yield per plant and hundred seed weight, cluster-I, III, IV for shelling percentage, cluster-II for oil content, cluster-I and III for per hectare yield. Cluster-I recorded maximum cluster mean for shelling percentage, cluster-II for oil content, cluster-III for pod yield peer plant, hundred seed weight and per hectare yield. Cluster-IV registered highest mean value for days to 50 per cent flowering, plant height, total number of branches and number of mature pods per plant.

4.1.3 Line x Tester analysis

Out of the twenty eight genotypes, eight genotypes three non-dormant and five dormant were selected as parents, based on *per se* performance, dormancy range and divergence. To avoid cytoplasmic effect if any, the dormant genotypes were taken as male parents. Another reason for selecting dormant genotypes as male parents was that, the subspecies *hypogaea* branching habit being dominant over subspecies *fastigiata* habit, it would serve as a marker character for selecting true hybrids in many of the crosses. Three out of five dormant male parents belonged to subsp. *hypogaea*.

While fixing the non-dormant parents from fourteen non-dormant genotypes, short duration and high pooled mean yield were given priority and JL-24, VRI-3 and CO-2 were selected from cluster I. While selecting dormant parents stress was given to divergence as well as range in duration of dormancy. Inclusion of different botanical groups as far as possible was also taken care of in the choice of dormant parents. Though selection was based on *kharif* season clusters, their divergence was further confirmed in *rabi* season also. Thus, ICG-7269 with 20 days dormancy from cluster I, TG-17 with 30 days dormancy from cluster IV (both belonging to subsp. *fastigiata*), TMV-10 a virginia bunch with 50 days dormancy from cluster III and ICG-4861 (Virginia runner) with 60 days dormancy and ICG-1037

(Virginia runner) with 80 days dormancy from cluster II (the latter three from subsp. *hypogaea*) were selected as dormant parents.

Each of the three non-dormant genotypes was crossed with each of the five dormant ones and the resultant fifteen hybrids were raised for the study in summer 1994. Data on seven yield contributing characters were subjected to analysis of variance (Table 17). The treatment differences between genotypes (parents and hybrids) were highly significant for all the characters.

4.1.3.1 Mean performance of the parents and hybrids

The data on mean performance of the parents and hybrids for the seven characters under study are presented in Table 16.

4.1.3.1.1 Days to 50 per cent flowering

Earliness is considered as a desirable character for yield in groundnut where the cropping seasons are short. The shortest duration for 50 per cent flowering among the parents was recorded by ICG-7269 (26.5 days) while maximum duration was taken by ICG-4861. The mean duration for parents was 31.13 days. All the five *fastigiata* parents, JL-24, VRI-3, CO-2, ICG-7269 and TG-17 recorded significantly lower duration for flowering.

Among the hybrids JL-24/ICG-7269, VRI-3/ICG-7269 and CO-2/ICG-7269 recorded the lowest duration for 50 per cent flowering. The mean value recorded for hybrids was 32 days. Six hybrids recorded significantly lower values than hybrid mean.

4.1.3.1.2 Plant height

Among the parents, ICG-1037 was found to have the maximum plant height (85.25 cm) while TG-17 was having the least height of 34.25 cm. The mean height of parents was 51.82 cm. Two parents, ICG-4861 and ICG-1037 significantly exceeded this value.

Among the hybrids the plant height ranged from 37.55 cm in JL-24/TMV-10 to 59.15 cm in CO-2/ICG-1037. Only one hybrid CO-2/ICG-1037 recorded significantly higher values than the hybrid mean, 50.87 cm.

4.1.3.1.3 Total number of branches per plant

The highest value for total number of branches among parents, 13.2, was observed for TMV-10 which is a virginia bunch variety. The minimum value 4.0 was recorded by VRI-3 and ICG-7269. The mean of eight parents was 6.92 which was significantly exceeded by the three virginia types TMV-10, ICG-4861 and ICG-1037.

Table 16 Mean performance of parents and hybrids

Sl. No.	Parent/hybrid	Days to 50% flower-ing	Plant height (cm)	Total number of branches	Number of mature pods per plant	Pod yield per plant (g)	Shelling percentage	Hundre see weigh (g
1	JL-24	28.0	45.3	4.1	10.5	9.84	70.18(56.89)	49.5
2	VRI-3	27.5	37.95	4.0	11.4	7.82	70.07(56.73)	33.0
3	CO-2	28.5	42.95	4.1	9.2	7.97	69.13(56.23)	31.5
4	ICG-7269	26.5	50.95	4	7.9	7.23	69.38(56.35)	40.5
5	TG-17	28.0	34.25	4.1	9.0	8.77	70.81(57.30)	51.4
6	TMV-10	34.5	37.25	13.2	11.3	9.87	70.07(56.78)	49.2
7	ICG-4861	40.0	80.7	11.0	8.2	5.96	66.87(54.88)	31.6
8	ICG-1037	36.0	85.25	10.85	10.7	7.04	68.57(55.89)	45.7
9	JL-24/ICG-7269	28.0	50.2	4.5	12.9	14.7	72.97(58.67)	48.7
10	JL-24/TG-17	27.5	41.3	7.5	10.2	8.10	71.88(57.96)	37.9
11	JL-24/TMV-10	33.5	37.55	16.45	13.4	9.84	71.9(57.96)	43.1
12	JL-24/ICG-4861	32.0	51.65	10.6	9.55	15.39	64.43(53.28)	49.0
13	JL-24/ICG-1037	33.5	54.7	10.35	11.9	14.23	60.46(54.69	50.6
14	VRI-3/ICG-7269	27.5	57.45	4.3	16.6	11.66	67.95(55.55)	38.7

Contd.

Table 16 contd....

15	VRI-3/TG-17	28.5	46.55	5.8	10.8	10.00	71.51(57.71)	45.10
16	VRI-3/TMV-10	34.5	47.15	15.4	10.6	7.41	66.85(54.85)	44.77
17	VRI-3/ICG-4861	35.5	53.4	9.8	7.3	5.14	57.45(49.25)	33.79
18	VRI-3/ICG-1037	35.0	51.45	10.0	7.0	8.80	59.40(50.46)	37.81
19	CO-2/ICG-7269	27.5	55.8	6.1	13.8	14.14	71.88(57.96)	33.95
20	CO-2/TG-17	29.5	54.4	9.0	9.63	8.89	69.37(56.39)	36.55
21	CO-2/TMV-10	35.0	48.0	12.2	12.7	7.73	73.96(59.31)	30.67
22	CO-2/ICG-4861	34.5	54.3	11.0	7.6	7.98	66.04(54.37)	29.87
23	CO-2/ICG-1037	38.0	59.15	10.6	8.0	8.59	70.77(57.27)	30.77
Mean of parents		31.13	51.82	6.92	9.77	8.06	69.39 (56.38)	41.6
Mean of hybrids		32.0	50.87	9.57	10.8	10.17	67.79 (55.71)	39.44
CD (0.05)		2.53	6.46	2.07	2.20	1.86	0.19 (2.49)	3.69
CD (0.01)		3.44	8.76	2.82	3.01	2.51	0.35 (3.38)	5.02

Values after angular transformation are given in parenthesis

Among the hybrids total number of branches ranged between 4.3 in VRI-3/ICG-7269 to 16.45 in JL-24/TMV-10 with a mean of 9.57. Three hybrids have recorded significantly higher values than hybrid mean.

4.1.3.1.4 Number of mature pods per plant

The parental mean for the trait was 9.77 which was not significantly exceeded by any of the parents. Among the eight parents VRI-3 recorded the maximum number of mature pods (11.4) while ICG-4861 recorded the minimum (8.2).

Among the fifteen hybrids VRI-3/ICG-7269 recorded the maximum number of mature pods per plant (16.6), while VRI-3/ICG-1037 registered the minimum of 7.0 pods. The hybrid mean for this character was 10.8 and three hybrids significantly exceeded this value.

4.1.3.1.5 Pod yield per plant

The parental performance for pod yield per plant ranged between 5.96 g in ICG-4861 to 9.87 g in TMV-10 with a mean of 8.06 g. None of the parents registered significant increase in pod yield over parental mean.

Out of the 15 hybrids studied, five hybrids gave significantly superior pod yield than the hybrid mean 10.17 g. The range was between 5.14 g in VRI-3/ICG-4861 to 15.39 g in JL-24/ICG-4861.

4.1.3.1.6 Shelling percentage

The shelling percentage in the parents ranged between 66.87 per cent in ICG-4861 to 70.81 per cent in TG-17. The parental mean for the trait was 69.39 per cent. None of the parents recorded significantly higher values than the parental mean (69.39 percentage).

Three hybrids registered significantly higher values for shelling percentage than the hybrid mean 72.65 per cent, the range being 57.45 per cent in VRI-3/ICG-4861 to 73.96 per cent in CO-2/TMV-10.

4.1.3.1.7 Hundred seed weight

The range for hundred seed weight for parents was from 31.52 g in CO-2 to 51.45 g in TG-17 with a mean of 41.6 g. Four parents registered significantly higher values than parental mean.

Among the hybrids, the range was between 29.87 g in CO-2/ICG-4861 to 50.63 g in JL-24/ICG-1037. Eight hybrids recorded significantly superior values than the hybrid mean 39.44 g.

4.1.3.2 Analysis of variance

4.1.3.2.1 Analysis of variance of parents and hybrids

The analysis of variance for parents and hybrids is presented in Table 17. The analysis of the data revealed that the variances due to parents, hybrids and

Table 17 Analysis of variance for parents and hybrids

Source	df	Mean squares						
		Days to 50% flowering	Plant height (cm)	Total No. of branches	No. of mature pods per plant	Pod yield per plant (g)	Shelling percentage	Hundred seed weight
Replication	1	2.17	22.12	0.29	11.54	0.02	2.31	0.30
Treatments	22	32.49**	298.57**	29.71**	11.41**	15.69**	11.72**	112.07**
Parents	7	49.96**	796.27**	32.13**	3.79**	3.75**	1.12	146.04**
Hybrids	14	25.5**	70.37*	25.37**	15.25**	19.48**	17.53**	99.59**
Parents vs. Hybrids	1	7.99**	9.52**	73.53**	10.94**	46.22**	4.69*	48.92**
Females	2	0.50*	28.18**	0.01	2.45*	2.53	0.23	199.92**
Males	4	63.75**	1150.83**	36.69**	4.57**	4.75*	1.71	125.35**
Females vs. Males	8	93.75**	914.16**	78.09**	3.36*	2.18	0.53	121.06**
Error	22	1.49	9.69	1.00	1.13	0.80	1.44	3.17
Total	45	16.66	151.2	15.02	6.39	8.06	6.49	56.34

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

parents vs. hybrids were highly significant for all the characters except shelling percentage. For shelling percentage the variance due to parents was not significant. The variance due to females, males and females vs. males were significant for plant height, number of mature pods and hundred seed weight but not for shelling percentage. The variance due to females was not significant for total number of branches, pod yield and shelling percentage. Variance due to females vs. males was not significant for pod yield per plant and shelling percentage. The variance due to males was not significant for shelling per centage.

4.1.3.2.2 Analysis of variance of combining ability

The analysis of variance for combining ability is presented in Table 18. The differences in the combining ability effects of males, females and the interaction were highly significant for most of the characters. For total number of branches variances due to combining ability effects of females was not significant. Interaction effect was not significant for days to 50 percentage flowering.

4.1.3.2.3 GCA and SCA variances

The general (GCA) and specific combining ability (SCA) variances for seven characters are presented in Table 19. The magnitude of GCA variance was more than the SCA variance for days to 50% flowering, plant height and shelling percentage, whereas SCA variance was more for number of mature pods, pod yield per plant and hundred seed weight.

Table 18 Analysis of variance for combining ability

Source	df	Mean squares						
		Days to 50% flower-ing	Plant height (cm)	Total No. of branches	No. of mature pods per plant	Pod yield per plant (g)	Shelling percentage	Hundred seed weight
Females	2	10.3*	132.22**	2.00	4.12*	40.78**	35.20**	461.33*
Males	4	79.08**	137.95**	79.90**	38.98**	24.70**	33.48**	7.30**
Females/Male	8	2.51	21.12**	3.95*	6.01**	11.55**	5.00**	55.30**
Error	14	1.49	10.5	1.37	1.27	0.96	2.10	2.62

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

Table 19 Estimation of combining ability variances genetic components and heritability (narrow sense) for seven characters

Character	σ^2_{gca}	σ^2_{sca}	σ^2_A (F=1)	σ^2_D (F=1)	$\frac{\sigma^2_A}{\sigma^2_D}$	Heritability in narrow sense
Days to 50% flowering	5.40	0.51	10.8	0.51	21.18	87.37
Plant height	14.25	5.7	28.493	5.72	4.99	72.96
Total number of branches	4.62	1.48	9.25	1.48	6.27	82.4
Number of mature pods	1.98	2.44	3.96	2.44	1.62	56.86
Pod yield per plant	2.65	5.37	5.3	5.34	0.99	47.84
Shelling percentage	3.68	1.79	7.37	1.79	4.11	74.59
100 seed weight	22.38	26.06	44.75	26.06	1.72	61.81

4.1.3.2.4. Genetic components of variation

The additive component of variance A and non additive component D.for seven characters are presented in Table 19. The magnitude of additive component was higher than non additive component in all the characters except in pod yield where both the components were of equal magnitude.

4.1.3.2.5 Proportional contribution of males, females and hybrids to total genetic variance

The proportional contribution to total variance by males, females and hybrids are presented in Table 20.

The proportional contribution by males was substantial for all the characters except hundred seed weight for which the contribution was mostly by females. For hundred seed weight, plant height and shelling percentage, the females contributed more than hybrids. Total number of branches and pod yield per plant were the characters for which females vs. males interaction recorded a higher contribution than females.

4.1.3.3 Heritability in narrow sense

Narrow sense heritability estimates for seven characters is presented in Table 19. Maximum heritability was recorded for days to 50% flowering (87.37%) followed by total number of branches (82.4%) and shelling percentage (74.59%). The least value for heritability was recorded by pod yield per plant (47.84%).

Table 20 Proportional contribution to total variance by parents and hybrids

Characters	Proportional contribution (%)			
	Females	Males	Females vs. Males	Total
Days to 50% flowering	5.77	88.61	5.62	100
Plant height	26.84	56.01	17.15	100
Total number of branches	1.13	89.98	8.90	100
Number of mature pods per plant	4.43	73.05	22.52	100
Pod yield per plant	29.90	36.22	33.88	100
Shelling percentage	28.83	54.80	16.37	100
100 seed weight	66.18	2.09	31.73	100

4.1.3.4 Combining ability effects

The combining ability effects for seven biometric characters are presented individually in Tables 21 to 27 and compiled together in Tables 28 and 29.

4.1.3.4.1 Days to 50 per cent flowering

The gca effects for days to 50 per cent flowering in females ranged from -1.10 in JL-24 to 0.9 in CO-2 and that for males, the range was between -4.33 (ICG-7269) to 3.5 (ICG-1037). Among females JL-24 recorded desirable significant negative effects for the character and among males, ICG-7269 and TG-17.

The sca effect were not significant for any of the crosses (Table 21).

4.1.3.4.2 Plant height

The gca effects of females ranged from -3.79 in JL-24 to 3.46 in CO-2 and from -6.64 (TMV-10) to 4.23 (ICG-1037) in males. The female CO-2 and males ICG-7269 and ICG-1037 recorded significant positive effects, whereas female JL-24 and males TG-17 and TMV-10 recorded significant negative effects.

The sca effects of hybrids ranged from -3.98 in VRI-3/ICG-1037 to 3.52 in CO-2/TG-17. None of the crosses recorded significant positive or negative effects (Table 22).

Table 21 Combining ability effects of parents and hybrids - days to 50 per cent flowering

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	1.43	-0.37	-1.07	-4.33**
TG-17	0.10	-0.20	0.10	-3.50**
TMV-10	0.27	-0.03	-0.23	2.33**
ICG-4861	-0.90	1.30	-0.40	2.00**
ICG-1037	-0.90	-0.70	1.60	3.50**
gca of females	-1.10*	0.20	0.90*	
SE (g_i) of females		0.39		
SE (g_i) of males		0.50		
SE (S_{ij}) of hybrids		0.86		
			P = 0.05	P = 0.01
CD $G_i - G_j$ (female)			1.13	1.54
CD $G_i - G_j$ (male)			1.46	1.99
CD $S_{ij} - S_{kl}$			2.53	3.45

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

Table 22 Combining ability effects of parents and hybrids - plant height

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	-0.49	2.64	-2.14	3.61**
TG-17	-2.33	-1.20	3.52	-3.45
TMV-10	-2.89	2.59	0.31	-6.64**
ICG-4861	2.32	-0.05	-2.28	2.25
ICG-1037	3.39	-3.98	0.59	4.23**
gca of females	-3.79**	0.33	3.46**	
SE (gi) of females	0.98			
SE (gi) of males	1.27			
SE (Sij) hybrids	2.20			
			P = 0.05	P = 0.01
CD Gi-Gj (female)			2.88	3.93
CD Gi-Gj (male)			3.73	5.07
CD Sij-Skl			6.46	8.78

* Significant at 5 per cent level
** Significant at 1 per cent level

4.1.3.4.3 Total number of branches

The gca effects of females ranged from -0.51 (VRI-3) to 0.31 (JL-24). Among males TMV-10 and ICG-4861 recorded significant positive effects and ICG-7269 and TG-17 recorded significant negative effects. The gca effect for females were not significant.

The sca effects ranged from -2.69 for CO-2/TMV-10 to 1.46 in JL-24/TMV-10. Cross CO-2/TMV-10 alone recorded significant but negative effect. None of the crosses showed significant positive sca effects (Table 23).

4.1.3.4.4 Number of mature pods

The gca effects of females for number of mature pods varied from -0.45 (CO-2) to 0.79 (JL-24) and from -2.65 (ICG-4861) to 3.64 (ICG-7269). Among females significant positive gca effects were recorded by JL-24 (0.79). The males ICG-7269 and TMV-10 recorded significant positive effect whereas ICG-4861 and ICG-1037 recorded significant negative gca effect.

The range of sca effects was from -2.33 in the cross JL-24/ICG-7269 to 2.5 in the cross VRI-3/ICG-7269. Crosses VRI-3/ICG-7269 and JL-24/ICG-1037 recorded significant positive sca effects where as JL-24/ICG-7269 and VRI-3/ICG-1037 recorded significant negative sca effects (Table 24).

Table 23 Combining ability effects of parents and hybrids - total number of branches

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	-0.77	-0.15	0.93	-4.61**
TG-17	-0.24	-1.12	1.36	-2.14**
TMV-10	1.46	1.23	-2.69**	5.11**
ICG-4861	-0.17	-0.15	0.33	0.89*
ICG-1037	-0.24	0.20	0.08	0.74
gca of females	0.31	-0.51	0.21	

		P = 0.05	P = 0.01
SE (gi) of females	0.32		
SE (gi) of males	0.41		
SE (Sij) hybrids	0.70		
CD Gi-Gj (female)		0.93	1.26
CD Gi-Gj (male)		1.20	1.63
CD Sij-Skl		2.07	2.82

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 24 Combining ability effects of parents and hybrids - number of mature pods

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	-2.33**	2.5**	-0.18	3.64**
TG-17	-0.80	0.93	-0.13	-0.59
TMV-10	0.38	-1.3	0.92	1.44**
ICG-4861	0.61	-0.51	-0.10	-2.65**
ICG-1037	2.14**	-1.63*	-0.51	-1.83**
gca of females	0.79*	-0.34	-0.45	
SE (gi) of females	0.35			
SE (gi) of males	0.43			
SE (Sij) hybrids	0.75			
			P = 0.05	P = 0.01
CD Gi-Gj (female)			0.99	1.34
CD Gi-Gj (male)			1.27	1.73
CD Sij-Skl			2.21	3.0

* Significant at 5 per cent level
** Significant at 1 per cent level

4.1.3.4.5 Pod yield per plant

The range of gca effects for pod yield was from -1.57 in VRI-3 to 2.28 in JL-24. All the females registered significant gca effects. JL-24 recorded highly significant positive effect where as VRI-3 and CO-2 recorded significant but negative gca effect. Among the males the range was between -1.85 in TMV-10 to 3.33 in ICG-7269. ICG-7269 recorded significant positive effect where as TMV-10 and TG-17 recorded significant negative effect.

Six hybrids registered significant sca effects for pod yield per plant. Among the crosses significant positive sca effects were recorded by JL-24/ICG-4861, VRI-3/TG-17, JL-24/ICG-1037, CO-2/ICG-7269 while JL-24/TG-17 and VRI-3/ICG-4861 registered highly significant negative effect (Table 25).

4.1.3.4.6 Shelling percentage

All the parents except ICG-1037 recorded significant gca effect for shelling percentage. The females recorded between -2.15 (VRI-3) to 1.35 (CO-2). Among the males the range was between -3.41 in ICG-4861 and 1.68 in ICG-7269. The magnitude of the effect was positive for JL-24 and CO-2 among females and in ICG-7269, TG-17 and TMV-10 among males. The negative significant effects were recorded by VRI-3 among females and ICG-4861 and ICG-1037 among males.

Table 25 Combining ability effects of parents and hybrids - Pod yield per plant

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	-1.08	-0.27	1.35*	3.33**
TG-17	-3.18**	2.58**	0.60	-1.18**
TMV-10	-0.76	0.67	0.11	-1.85**
ICG-4861	3.61**	-2.79**	-0.82	-0.67
ICG-1037	1.41*	-0.17	-1.24	0.37
GCA of females	2.28**	-1.57**	-0.71*	
SE (gi) of females	0.28			
SE (gi) of males	0.37			
SE (Sij) hybrids	0.63			
			P = 0.05	P = 0.01
CD Gi-Gj (female)			0.83	1.13
CD Gi-Gj (male)			1.07	1.46
CD Sij-Skl			1.86	2.53

* Significant at 5 per cent level
** Significant at 1 per cent level

The magnitude of sca effects ranged from -2.31 in CO-2/TG-17 to 2.51 in VRI-3/TG-17. Significant positive effects were recorded by VRI-3/TG-17 while CO-2/TG-17 recorded significant negative sca effect (Table 26).

4.1.3.4.7 Hundred seed weight

Maximum gca effect recorded for hundred seed weight among the females was 6.47 by JL-24 and the minimum, -7.08 by CO-2. JL-24 recorded significant positive effect and CO-2 recorded significant negative effect. Among the males the gca effect varied from -1.87 (ICG-4861) to 1.05 (ICG-7269). None of the males recorded significant positive effect for the trait. ICG-4861 recorded significant negative effect.

Among the hybrids JL-24/ICG-4861, VRI-3/TMV-10, VRI-3/TG-17 and JL-24/ICG-1037, recorded significant positive sca effect. Significant negative sca effect was observed for JL-24/TG-17, VRI-3/ICG-4861 and JL-24/TMV-10. The range of hybrids for sca effects was from -8.35 in JL-24/TG-17 to 5.02 in JL-24/ICG-4861 (Table 27).

4.1.3.5 Heterosis

Heterosis, calculated as percentage deviation of hybrids from the parental mean (di) better parent mean (dii) and the standard variety (JL-24) mean (diii) for the fifteen hybrids are presented in Table 30.

Table 26 Combining ability effects of parents and hybrids - shelling percentage

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	0.48	0.31	-0.78	1.68*
TG-17	-0.20	2.51**	-2.31*	1.64*
TMV-10	-0.21	-0.38	0.59	1.66*
ICG-4861	0.18	-0.90	0.72	-3.41**
ICG-1037	-0.25	-1.53	1.78*	-1.57
gca of females	0.80*	-2.15**	1.35*	
SE (gi) of females	0.38			
SE (gi) of males	0.49			
SE (Sij) hybrids	0.85			
			P = 0.05	P = 0.01
CD Gi-Gj (female)			1.11	1.51
CD Gi-Gj (male)			1.44	1.96

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 27 Combining ability effects of parents and hybrids - hundred seed weight

Male parents	sca of hybrids with each female parent			gca of males
	JL-24	VRI-3	CO-2	
ICG-7269	1.77	-2.32	0.55	1.05
TG-17	-8.35**	4.61**	3.75**	0.44
TMV-10	-2.87*	4.64**	-1.77	0.08
ICG-4861	5.02**	-4.39**	-0.63	-1.87*
ICG-1037	4.43**	-2.54	-1.89	0.3
gca of females	6.47**	0.61	-7.08**	
SE (gi) of females	0.56			
SE (gi) of males	0.73			
SE (Sij) hybrids	1.26			
			P = 0.05	P = 0.01
CD Gi-Gj (female)			1.65	2.25
CD Gi-Gj (male)			2.13	2.90

* Significant at 5 per cent level
** Significant at 1 per cent level

Table 28 General combining ability effects of parents for 7 characters♧

Parents	Days to 50% flowering	Plant height (cm)	Total number of branches	Number of mature pods per plant	Pod yield per plant (g)	Shelling percentage	Hundred seed weight (g)
Non-dormant females							
1. JL-24	-1.10	-3.79**	0.31	0.79*	2.28**	0.80*	6.47**
2. VRI-3	0.20	0.33	-0.51	-0.34	-1.57**	-2.15**	0.61
3. CO-2	0.90*	3.46**	0.21	-0.45	-0.71*	1.35*	-7.08**
Dormant males							
1. ICG-7269	-4.33**	3.61**	-4.61**	3.64**	3.33**	1.68*	1.05
2. TG-17	-3.50**	-3.45	-2.14**	-0.59	-1.18**	1.64*	0.44
3. TMV-10	2.33**	-6.64**	5.11**	1.44**	-1.85**	1.66*	0.08
4. ICG-4861	2.00**	2.25	0.89*	-2.65**	-0.67	-3.41**	-1.87
5. ICG-1037	3.50**	4.23**	0.74	-1.83**	0.37	-1.57	0.3
SE (g_i) of females	0.39	0.98	0.32	0.35	0.28	0.38	0.56
SE (g_i) of males	0.50	1.27	0.41	0.43	0.37	0.49	0.73

♧ Compiled from previous tables 21 to 27
* Significant at 5% level ** Significant at 1% level

Table 29 Specific combining ability effects for seven characters in fifteen groundnut hybrids♧

Crosses	Days to 50% flower-ing	Plant height	Total number of branches	Number of mature pods	Pod yield per plant	Shelling out turn	Hundred seed weight
JL-24/ICG-7269	1.43	-0.49	-0.77	-2.33**	-1.08	0.48	1.77
JL-24/TG-17	0.10	-2.33	-0.24	-0.80	-3.18**	-0.20	-8.35**
JL-24/TMV-10	0.27	-2.89	1.46	0.38	-0.76	-0.21	-2.87*
JL-24/ICG-4861	-0.90	2.32	-0.17	0.61	3.61**	0.18	5.02**
JL-24/ICG-1037	-0.9	3.39	-0.24	2.14**	1.41*	-0.25	4.43**
VRI-3/ICG-7269	-0.37	2.64	-0.15	2.50**	-0.27	0.31	-2.32
VRI-3/TG-17	-0.20	-1.20	-1.12	0.93	2.58**	2.51**	4.61**
VRI-3/TMV-10	-0.03	2.59	1.23	-1.3	0.67	-0.38	4.64**
VRI-3/ICG-4861	1.3	-0.05	-0.15	-0.51	-2.79**	-0.9	-4.39**
VRI-3/ICG-1037	-0.7	-3.98	0.20	-1.63	-0.17	-1.53	-2.54
CO-2/ICG-7269	-1.0	-2.14	0.93	-0.18	1.35*	-0.78	0.55
CO-2/TG-17	0.10	3.52	1.36	-0.13	0.60	-2.31*	3.74**
CO-2/TMV-10	-0.23	0.31	-2.69**	0.92	0.11	0.59	-1.77
CO-2/ICG-4861	-0.4	-2.28	0.33	-0.10	-0.82	0.72	-0.63
CO-2/ICG-1037	1.60	0.59	0.08	-0.51	-1.24	1.78*	-1.89
SE(S_{ij})	0.86	2.20	0.70	0.75	0.63	0.85	1.26

♧ Compiled from previous tables 21 to 27
* Significant at 5% level ** Significant at 1% level

4.1.3.5.1 Days to 50 per cent flowering

Relative heterosis ranged from -5.88 in JL-24/ICG-4861 to 19.83 in CO-2/ICG-1037. Desirable significant negative heterosis was not observed in any of the crosses.

Heterosis over better parent ranged from -20.0 in JL-24/ICG-4861 to 5.56 in CO-2/ICG-1037. Significant negative heterosis was observed for three crosses JL-24/ICG-1037, CO-2/ICG-4861 and VRI-3/ICG-4861.

Standard heterosis ranged from -1.79 to 35.71. None of the hybrids recorded significantly negative heterosis over the standard variety JL-24.

4.1.3.5.2 Plant height

Significant relative heterosis was observed in the positive direction in six hybrids and in negative direction in five hybrids. Hybrid vigour ranged from -16.48 in VRI-3/ICG-1037 to 40.93 per cent in CO-2/TG-17.

Heterobeltiosis for this trait ranged between -39.65 per cent in VRI-3/ICG-1037 to 26.66 per cent in CO-2/TG-17. Out of fifteen, four hybrids recorded significance in the positive direction and seven in the negative direction.

Table 30 Estimates of heterosis (expressed as percentage) over the mid parent (di), better parent (dii) and standard check (diii)

Hybrid	Days to 50% flowering			Plant height			Total number of branches		
	(di)	(dii)	(diii)	(di)	(dii)	(diii)	(di)	(dii)	(diii)
JL-24 / ICG-7269	2.75	0.0	0.0	4.31	-1.47	10.82	11.11	9.76	9.76
JL-24 / TG-17	-1.79	-1.79	-1.79	3.83	-8.83	-8.83	82.93**	82.93**	82.93**
JL-24 / TMV-10	7.20*	-2.9	19.6**	-9.02	-17.11*	-17.11*	90.17**	24.62**	301.22**
JL-24 / ICG-4861	-5.88	-20**	14.3**	-18.02**	-36.00**	14.02	40.40**	-3.64	158.54**
JL-24 / ICG-1037	4.69	-6.94	19.6**	-16.2**	-35.84**	20.75**	38.46**	-4.61	152.44**
VRI-3 / ICG-7269	1.85	0.0	-1.79	29.25**	12.76*	26.82**	7.5	7.5	4.88
VRI-3 / TG-17	2.7	1.79	1.79	28.95**	22.66*	2.76	43.21	41.46*	41.46
VRI-3 / TMV-10	11.3**	0.0	23.2**	25.40**	24.24**	4.08	79.07**	16.67*	275.6*
VRI-3 / ICG-4861	5.19	-11.3**	26.8**	-9.99*	-33.83**	17.88*	30.67*	-10.91	139.02*
VRI-3 / ICG-1037	10.2**	-2.78	25**	-16.48**	-39.65**	13.58	34.68**	-7.83	143.90*
CO-2 / ICG-7269	0	-3.51	-1.79	18.85**	9.52	23.18**	50.62*	48.78*	48.78
CO-2 / TG-17	4.42	3.51	5.38	40.93**	26.66**	20.09**	119.51**	119.51**	119.51*
CO-2 / TMV-10	11.1**	1.45	25**	19.70**	11.76	5.96	41.04**	-7.58	197.56*
CO-2 / ICG-4861	0.73	-13.8**	23.2**	-12.17*	-32.71**	19.87	45.70**	0.0	168.29*
CO-2 / ICG-1037	17.8**	5.56	35.7**	-7.72	-30.62**	30.57	41.81**	-2.3	158.54*
SE for comparison of F_1 with mid parent	1.06			2.69			0.87		
" Male/female parent	1.22			3.11			1.0		
" Selected parent	1.22			3.11			1.0		

Contd.....

Table 30 contd.....

Sl. No.	Hybrid	Number of mature pods			Mean pod yield per plant		
		(di)	(dii)	(diii)	(di)	(dii)	(diii)
1	JL-24 / ICG-7269	40.22**	22.86	22.86*	72.23**	49.39**	49.39**
2	JL-24 / TG-17	4.62	-2.86	-2.86	-13.00	-17.73	-17.73
3	JL-24 / TMV-10	22.94*	18.58	27.62*	-0.18	-0.35	0.00
4	JL-24 / ICG-4861	2.14	-9.05	-9.05	94.75**	56.35**	56.35**
5	JL-24 / ICG-1037	12.26	11.21	13.33	68.29**	44.56**	44.56**
6	VRI-3 / ICG-7269	72.02**	45.61**	58.10**	54.95**	49.10**	18.50
7	VRI-3 / TG-17	5.88	-5.26	2.86	20.55*	14.03	1.63
8	VRI-3 / TMV-10	-6.61	-7.02	0.95	-16.25	-24.06*	-24.7*
9	VRI-3 / ICG-4861	-25.51*	-35.96**	-30.48**	-25.47*	-13.84	-47.82**
10	VRI-3 / ICG-1037	-36.65**	-38.6**	-33.33**	18.24	12.53	-10.57
11	CO-2 / ICG-7269	61.04**	50.00**	31.43**	86.05**	77.42**	43.70**
12	CO-2 / TG-17	5.82	4.67	-8.29	6.15	1.31	-9.71
13	CO-2 / TMV-10	23.90*	12.39	20.96	-13.42	-21.77*	*21.49**
14	CO-2 / ICG-4861	-12.64	-17.39	-27.62*	14.5	0.06	-18.95*
15	CO-2 / ICG-1037	-19.6*	-25.23*	-23.81*	14.26	7.78	-12.7
SE for comparison of F_1 with mid parent		0.92			0.78		
" Male/female parent		1.06			0.90		
" Selected parent		1.06			0.90		

Contd....

Table 30 contd.....

Sl. No.	Hybrid	Shelling percentage			100 seed weight		
		(di)	(dii)	(diii)	(di)	(dii)	(diii)
1	JL-24 / ICG-7269	3.63	3.14	3.14	8.09*	-1.69	-1.69
2	JL-24 / TG-17	1.51	1.14	1.88	-24.78**	-26.16**	-23.35**
3	JL-24 / TMV-10	1.98	1.89	1.89	-12.74**	-13.00**	-13.00**
4	JL-24 / ICG-4861	-4.66*	-6.35**	-6.35**	20.85**	-1.02	-1.02
5	JL-24 / ICG-1037	-3.01	-3.86	-3.86	6.25	2.16	2.16
6	VRI-3 / ICG-7269	-1.75	-2.07	-2.35	5.28	-4.47	-21.76**
7	VRI-3 / TG-17	1.21	0.71	1.44	6.71	-12.35**	-9.01*
8	VRI-3 / TMV-10	-3.36	-3.41	-3.59	8.75	-9.12*	-9.68*
9	VRI-3 / ICG-4861	-11.75**	-13.9**	-13.43**	4.47	2.18	-31.82**
10	VRI-3 / ICG-1037	-10.39**	-11.05**	-11.3**	-4.05	14.33*	-23.71**
11	CO-2 / ICG-7269	2.96	2.86	1.88	-5.84	-16.36**	-31.50**
12	CO-2 / TG-17	-0.67	-1.6	-0.88	11.91**	-28.97**	-26.26**
13	CO-2 / TMV-10	4.96*	4.46*	4.26	-24.06**	-37.73**	-38.12**
14	CO-2 / ICG-4861	-2.14	-3.32	-4.43*	-5.40	-5.55	-39.74**
15	CO-2 / ICG-1037	2.15	1.84	0.67	-20.36**	-32.75**	-37.92**
SE for comparison of F_1 with mid parent		1.04			1.54		
"	Male/female parent	1.20			1.78		
"	Selected parent	1.20			1.78		

* significant at 5% level ** Significant at 1% level

Seven hybrids significantly surpassed the variety JL-24 in the positive direction and one in the negative direction. Standard heterosis ranged from -8.83 per cent to 30.57 per cent.

4.1.3.5.3 Total number of branches

Heterosis over mid parent ranged from 7.5 per cent to 119.51 per cent in VRI-3/TG-17 and CO-2/TG-17 respectively. All the hybrids registered positive heterosis for the trait. Twelve out of fifteen hybrids recorded significant positive relative heterosis.

Range of heterobeltiosis was from -10.91 per cent in VRI-3/ICG-4861 to 119.51 per cent in CO-2/TG-17. Four hybrids registered high heterobeltiosis in the positive direction. None of hybrids showed heterosis in negative direction.

Standard heterosis observed was minimum in VRI-3/TG-17 (4.88 per cent) and maximum in JL-24/TMV-10 (301.22 per cent). Significant positive heterosis was observed in eleven hybrids.

4.1.3.5.4 Number of mature pods

Relative heterosis for number of mature pods was minimum for VRI-3/ICG-1037, with a deviation of -36.65 per cent and maximum for VRI-3/ICG-7269 with a deviation

of 72.02 per cent. Five hybrids recorded significant positive heterosis and three recorded significant negative heterosis.

Two hybrids registered significant positive heterosis, while three recorded significant negative heterosis over the better parent. Heterobeltiosis ranged from -38.6 per cent in VRI-3/ICG-1037 to 50.00 per cent in CO-2/ICG-7269.

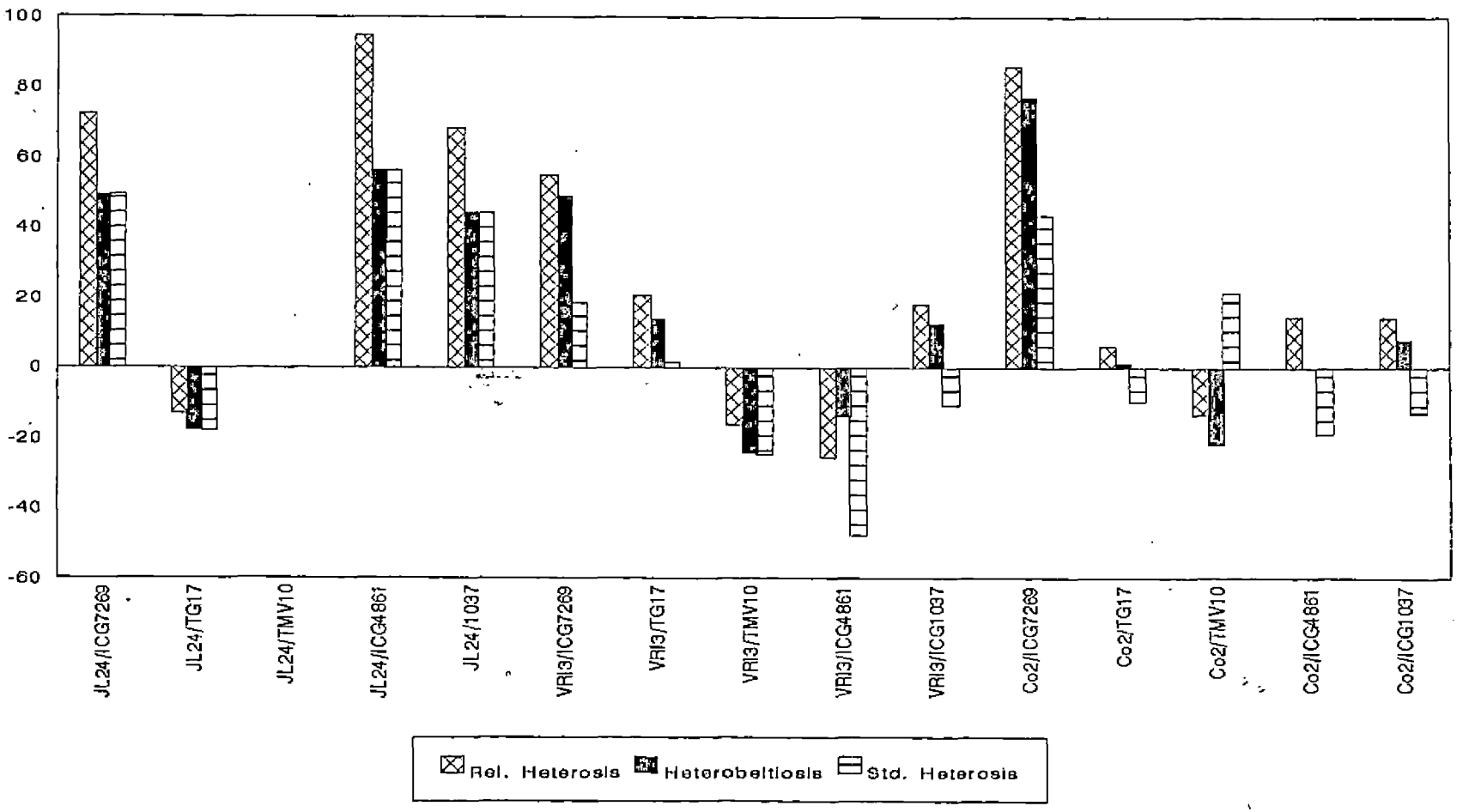
Four hybrids each registered significant positive and negative heterosis over the standard variety. Standard heterosis ranged from -33.33 per cent in VRI-3/ICG-1037 to 58.10 per cent in VRI-3/ICG-769.

4.1.3.5.5 Mean pod yield per plant

The hybrid vigour calculated over parental mean was the minimum for VRI-3/ICG-4861 (25.47 per cent) and maximum for JL-24/ICG-4861 (94.75 per cent). While five hybrids registered significant positive heterosis, only one recorded significant negative heterosis.

Maximum decrease (24.06 per cent) in pod yield over better parent was observed in the hybrid VRI-3/TMV-10 and maximum increase in CO-2/ICG-7269 (77.42 per cent). Five hybrids registered significantly positive heterosis, and two hybrids negative heterosis.

Fig.1 Heterosis for pod yield per plant in 15 groundnut hybrids



Heterosis over standard variety ranged from -47.82 per cent in VRI-3/ICG-4861 to 56.35 per cent in JL-24/ICG-4861. Four hybrids registered significantly higher yield over standard variety JL-24, while another four hybrids recorded significant lower values.

4.1.3.5.6 Shelling percentage

Significant relative heterosis was observed in positive direction for shelling percentage only in one hybrid (CO-2/TMV-10), while three hybrids registered significant negative relative heterosis. The range was from -11.75 per cent in VRI-3/ICG-4861 to 4.96 in CO-2/TMV-10.

None of the hybrids registered significantly positive relative heterosis. Three hybrids registered negative heterosis over better parent. The range of heterosis was between -13.9 per cent in VRI-3/ICG-4861 to 4.46 per cent in CO-2/TMV-10.

The deviation over standard check was also not significant in the positive direction. Four hybrids recorded significant negative heterosis. The range was between -13.43 in VRI-3/ICG-4861 to 4.26 in CO-2/TMV-10.

4.1.3.5.7 Hundred seed weight

Significant relative heterosis for hundred seed weight was observed in the positive direction only in one hybrid,

VRI-3/ICG-1037. Hybrid vigour over parental mean ranged from -24.78 per cent in JL-24/TG-17 to 11.91 per cent in CO-2/TG-17.

Heterosis over better parent was also positively significant only in a single hybrid VRI-3/ICG-1037 whereas it was negatively significant in eight hybrids. The percentage of heterobeltiosis ranged between -37.73 in CO-2/TMV-10 and 14.33 in VRI-3/ICG-1037.

Standard heterosis varied from -39.74 in CO-2/ICG-4861 to 2.16 in JL-24/ICG-1037. None of the hybrids showed positive significant heterosis over the standard variety JL-24. A total of ten hybrids showed significant negative heterosis.

4.2 Analysis of seed dormancy

4.2.1 Duration of seed dormancy in twenty eight genotypes

The cured seeds of twenty eight groundnut genotypes were tested for their germinability after harvest, at ten days interval, until germination reached 80 per cent. The germination test was conducted in soil for two seasons and also in petridishes for *rabi* season. Data are presented in Table 31,32 and 33.

The germination percentage at each interval varied between genotypes, between seasons or media but ultimately in the duration of dormancy there was not much appreciable

Table 31 Mean germination of twenty eight groundnut genotypes at ten days interval after harvest (*Kharif* crop) in soil and their duration of dormancy

Sl. No.	Identity of genotypes	Germination percentage in soil after harvest								Duration of dormancy days
		10 D	20 D	30 D	40 D	50 D	60 D	70 D	80 D	
1	ICG-5461	95	-	-	-	-	-	-	-	10
2	ICG-128	100	-	-	-	-	-	-	-	10
3	VRI-3	97.5	-	-	-	-	-	-	-	10
4	TMV-9	90	-	-	-	-	-	-	-	10
5	CO-2	100	-	-	-	-	-	-	-	10
6	TG-14	90	-	-	-	-	-	-	-	10
7	TG-3	90	-	-	-	-	-	-	-	10
8	JL-24	100	-	-	-	-	-	-	-	10
9	ICG-7512	95	-	-	-	-	-	-	-	10
10	TG-6	92.5	-	-	-	-	-	-	-	10
11	POL-2	92.5	-	-	-	-	-	-	-	10
12	ICG-459	90.0	-	-	-	-	-	-	-	10
13	ICG-1231	90.0	-	-	-	-	-	-	-	10
14	TMV-2	100	-	-	-	-	-	-	-	10
15	ICG-1883	7.5	95	-	-	-	-	-	-	20
16	ICG-7269	5	80	97.5	-	-	-	-	-	20
17	TG-15	5	27.5	90	-	-	-	-	-	30
18	TG-17	7.5	15	95	-	-	-	-	-	30
19	TMV-10	0	0	50	65	87.5	-	-	-	50
20	Robut-33-1	0	0	40	97.5	-	-	-	-	40
21	ICG-6301	0	0	25	85	-	-	-	-	40
22	ICG-8281	0	0	45	67.5	100	-	-	-	50
23	ICG-4861	0	0	32.5	60	87.5	-	-	-	50
24	ICG-1002	0	0	0	32.5	50	70	100	-	70
25	ICG-1037	0	0	0	20	62.5	75	82.5	-	70
26	ICG-6193	12.5	45	100	-	-	-	-	-	30
27	ICG-1063	7.5	37.5	45	72.5	100	-	-	-	50
28	ICG-861	0	0	37.5	100	-	-	-	-	40

Table 32 Mean germination of twenty eight groundnut genotypes at ten days interval after harvest (*rabi* crop) in soil and their duration of dormancy

Sl. No.	Identity of genotypes	Germination percentage in soil after harvest								Duration of dormancy days
		10 D	20 D	30 D	40 D	50 D	60 D	70 D	80 D	
1	ICG-5461	91.25	-	-	-	-	-	-	-	10
2	ICG-128	100	-	-	-	-	-	-	-	10
3	VRI-3	90	-	-	-	-	-	-	-	10
4	TMV-9	90	-	-	-	-	-	-	-	10
5	CO-2	100	-	-	-	-	-	-	-	10
6	TG-14	85	-	-	-	-	-	-	-	10
7	TG-3	85	-	-	-	-	-	-	-	10
8	JL-24	95	-	-	-	-	-	-	-	10
9	ICG-7512	92.5	-	-	-	-	-	-	-	10
10	TG-6	100	-	-	-	-	-	-	-	10
11	POL-2	100	-	-	-	-	-	-	-	10
12	ICG-459	87.5	-	-	-	-	-	-	-	10
13	ICG-1231	87.5	-	-	-	-	-	-	-	10
14	TMV-2	92.5	-	-	-	-	-	-	-	10
15	ICG-1883	0	100	-	-	-	-	-	-	20
16	ICG-7269	0	70	100	-	-	-	-	-	30
17	TG-15	0	42.5	100	-	-	-	-	-	30
18	TG-17	10	32.5	97.5	-	-	-	-	-	30
19	TMV-10	0	20	47.5	92.5	-	-	-	-	40
20	Robut-33-1	0	0	40	87.5	-	-	-	-	40
21	ICG-6301	0	7.5	60	97.5	-	-	-	-	40
22	ICG-8281	0	0	67.5	72.5	100	-	-	-	50
23	ICG-4861	0	0	42.5	52.5	82.5	-		-	50
24	ICG-1002	0	0	22.5	45	67.5	100	-	-	60
25	ICG-1037	0	0	25	42.5	62.5	75	97.5	-	70
26	ICG-6193	0	25	65	95	-	-	-	-	40
27	ICG-1063	0	22.5	50	70	100	-	-	-	50
28	ICG-861	0	0	20	100	-	-	-	-	40

Table 33 Mean germination of twenty eight groundnut genotypes at ten days interval after harvest in pertidishes and their duration of dormancy.

Sl. No.	Identity of genotypes	Germination percentage								Duration of dormancy days
		10 D	20 D	30 D	40 D	50 D	60 D	70 D	80 D	
1	ICG-5461	95	-	-	-	-	-	-	-	10
2	ICG-128	100	-	-	-	-	-	-	-	10
3	VRI-3	97.5	-	-	-	-	-	-	-	10
4	TMV-9	97.5	-	-	-	-	-	-	-	10
5	CO-2	92.5	-	-	-	-	-	-	-	10
6	TG-14	100	-	-	-	-	-	-	-	10
7	TG-3	97.5	-	-	-	-	-	-	-	10
8	JL-24	90	-	-	-	-	-	-	-	10
9	ICG-7512	87.5	-	-	-	-	-	-	-	10
10	TG-6	97.5	-	-	-	-	-	-	-	10
11	POL-2	97.5	-	-	-	-	-	-	-	10
12	ICG-459	90	-	-	-	-	-	-	-	10
13	ICG-1231	92.5	-	-	-	-	-	-	-	10
14	TMV-2	90	-	-	-	-	-	-	-	10
15	ICG-1883	0	45	87.5	-	-	-	-	-	30
16	ICG-7269	0	85	-	-	-	-	-	-	20
17	TG-15	7.5	17.5	100	-	-	-	-	-	30
18	TG-17	7.5	15	92.5	-	-	-	-	-	30
19	TMV-10	12.5	37.5	57.5	77.5	95	-	-	-	50
20	Robut-33-1	0	0	12.5	85	-	-	-	-	40
21	ICG-6301	0	0	27.5	77.5	82.5	-	-	-	50
22	ICG-8281	0	0	20	60	97.5	-	-	-	50
23	ICG-4861	0	0	0	27.5	77.5	82.5	95	-	70
24	ICG-1002	0	0	0	17.5	27.5	65	80	92.5	80
25	ICG-1037	0	0	0	7.5	27.5	60	72.5	87.5	80
26	ICG-6193	7.5	20	62.5	82.5	100	-	-	-	50
27	ICG-1063	0	0	0	10	85	-	-	-	50
28	ICGG-861	0	0	52.5	87.5	-	-	-	-	40

change. The ISTA method of germination in petridishes was taken as standard (Table 33). It was observed that fourteen genotypes completed their dormancy on the tenth day and they were considered as non-dormant and the rest of the fourteen genotypes as dormant. Among dormant genotypes dormancy ranged from 20 days (ICG-7269) to 80 days (ICG-1037 and ICG-1002). Out of the fourteen dormant genotypes, four recorded 30 and less than thirty days dormancy, seven recorded between 30 and 60 and three genotypes recorded more than sixty days dormancy.

4.2.2 Dormancy studies in early generations

Germination tests were conducted at 10 days interval upto 30 days in F_1 seeds, F_2 seeds, F_3 seeds $BC_{1(ND)}$ seeds, $BC_{1(D)}$ seeds, $BC_{1(ND)}$ F_2 seeds and $BC_{1(D)}$ F_2 seeds in ten crosses. The data are presented in Tables 34 to 39. In the case of F_2 seeds, F_3 seeds and BC_1 F_2 seeds observations were recorded on per plant basis. The frequency distribution of F_1 and F_2 plants for different germination classes (0-20%,21-40%, 41 to 60%, 61 to 80% and 81-100%) was worked out and presented in Tables 40 and 41 and Fig. 2 to11..

4.2.2.1 Germination percentage in F_1 seed (F_1 embryonic generation)

The germination percentage of F_1 seeds of ten crosses are presented in Table 34. All the hybrids recorded zero percentage germination on the tenth day just like the dormant parents where as the two non dormant parents

Table 34 Germination in F_1 seeds (F_1 embryonic generation) and parents 10-30 DAS

Designation	Germination percentage			Germination after ethrel treatment
	10D	20D	30D	
i) Crosses				
JL-24 / ICG-7269	0	88.89	100	-
VRI-3 / ICG-7269	0	37.50	100	-
JL-24 / TG-17	0	15.00	100	-
VRI-3 / TG-17	0	17.65	100	-
JL-24 / TMV-10	0	11.76	34.29	52.94
VRI-3 / TMV-10	0	37.50	62.50	36.50
JL-24 / ICG-4861	0	31.58	78.95	21.05
VRI-3 / ICG-4861	0	0	21.43	78.57
JL-24 / ICG-1037	0	56.25	62.50	31.25
VRI-3 / ICG-1037	0	21.05	68.42	31.58
ii) Dormant parents				
ICG-7269	0	90.00	90.00	-
TG-17	0	15.00	100	-
TMV-10	0	5	25.00	70.00
ICG-4861	0	0	5.00	80.00
ICG-1037	0	0	10.00	70.00
iii) Non-dormant parents				
JL-24	100	-	-	-
VRI-3	100	-	-	-

recorded 100 per cent germination, indicating the dominant nature of the character in the heterozygous F_1 embryo. The 20 D germination ranged from zero percentage in VRI-3/ICG-4861 to 88.89 per cent in JL-24/ICG-7269. The cumulative germination upto 30 days varied from 21.43 per cent in VRI-3/ICG-4861 to 100 per cent in four Spanish x Spanish hybrids viz. JL-24/ICG-7269, VRI-3/ICG-7269, JL-24/TG-17 and VRI-3/TG-17.

4.2.2.2 Germination percentage in F_2 seeds (F_2 embryonic generation - F_1 plant generation)

The mean 10D germination of F_2 seeds (Table 37) borne on 20 F_1 plants ranged from 9 per cent in VRI-3/ICG-1037 to 35 per cent in VRI-3/TG-17 and 31 per cent in VRI-3/ICG-1037 to 84 per cent in JL-24/ICG-7269 for 20 D germination (Table 38). For 30-D germination, it was 55 per cent in VRI-3/ICG-1037 to 92 per cent in JL-24/ICG-7269 (Table 39).

The frequency distribution of F_1 plants for 10D, 20D and 30D germinations in F_2 seeds is presented in Table 40. For 10D germination the F_1 plants of *fastigiata x fastigiata* crosses were distributed in the first three classes and the F_1s of inter-subspecific crosses fell in the first two classes, indicating that dormancy is dominant over non dormancy (Fig. 2 to 11). In the 20D germination the *fastigiata x fastigiata* crosses were distributed in the

Table 35 Germination in $BC_{1(ND)}$ seeds ($BC_{1(ND)}$ embryonic generation) and parents 10-30 DAS

Designation	Germination percentage			Germination after ethrel treatment
	10D	20D	30D	
i) Crosses				
JL-24 / ICG-7269	100	-	-	-
VRI-3 / ICG-7269	69.23	100	-	-
JL-24 / TG-17	66.67	100	-	-
VRI-3 / TG-17	57.14	100	-	-
JL-24 / TMV-10	71.42	100	-	-
VRI-3 / TMV-10	0	87.50	100	-
JL-24 / ICG-4861	33.33	100	-	-
VRI-3 / ICG-4861	7.14	21.43	92.86	-
JL-24 / ICG-1037	50.00	64.20	92.77	-
VRI-3 / ICG-1037	42.50	55.5	100	-
ii) Dormant parents				
ICG-7269	0	100	-	-
TG-17	0	62.50	100	-
TMV-10	0	0	25	75
ICG-4861	0	0	37.5	62.50
ICG-1037	0	0	0	100
iii) Non-dormant parents				
JL-24	100	-	-	-
VRI-3	100	-	-	-

Table 36 Germination in $BC_{1(D)}$ seeds ($BC_{1(D)}$ embryonic generation) and parents 10-30 DAS

Designation	Germination percentage			Germination after ethrel treatment
	10D	20D	30D	
i) Crosses				
JL-24 / ICG-7269	9.1	100	-	-
VRI-3 / ICG-7269	28.57	57.14	85.70	-
JL-24 / TG-17	0	22.22	55.55	44.44
VRI-3 / TG-17	0	20.00	100	-
JL-24 / TMV-10	0	0	77.78	22.22
VRI-3 / TMV-10	0	12.50	37.50	50.00
JL-24 / ICG-4861	0	8.33	33.33	58.33
VRI-3 / ICG-4861	0	36.36	90.90	-
JL-24 / ICG-1037	0	42.86	100	-
VRI-3 / ICG-1037	0	18.18	54.54	45.45
ii) Dormant parents				
ICG-7269	0	100	9.00	-
TG-17	0	62.50	100	-
TMV-10	0	0	25	75
ICG-4861	0	0	37.50	62.50
ICG-1037	0	0	0	100
iii) Non-dormant parents				
JL-24	100	-	-	-
VRI-3	100	-	-	-

Table 37 Average 10D germination percentage of parents and early generation populations

Designation	P_1	P_2	F_1	F_2	$BC_{1(ND)}$	$BC_{1(D)}$
JL-24 / ICG-7269	87.5	0	34	52	70	51
VRI-3 / ICG-7269	90.5	0	29	42	81	34.28
JL-24 / TG-17	87.5	0	34	56.5	68.33	35.94
VRI-3 / TG-17	90.5	0	35	47	70	36.67
JL-24 / TMV-10	87.5	0	24	39.50	36.67	14
VRI-3 / TMV-10	90.5	0	26	41.50	47.78	7
JL-24 / ICG-4861	87.5	0	19	40	48.33	8.33
VRI-3 / ICG-4861	90.5	0	12	45	46	28
JL-24 / ICG-1037	87.5	0	11	41	54.29	18
VRI-3 / ICG-1037	90.5	0	9	34	58	14

Table 38 Average 20D germination percentage of parents and early generation populations

Designation	P_1	P_2	F_1	F_2	$BC_{1(ND)}$	$BC_{1(D)}$
JL-24 / ICG-7269	87.50	75	84	80.50	93.33	91.25
VRI-3 / ICG-7269	90.50	75	77	78.50	97	81.43
JL-24 / TG-17	87.50	38	74	81.50	93.33	75
VRI-3 / TG-17	90.50	38	68.89	84.50	91.66	64.44
JL-24 / TMV-10	87.50	25	46	71	56.67	40
VRI-3 / TMV-10	90.50	25	44	72	72.22	39
JL-24 / ICG-4861	87.50	12	38	66.50	65	28.33
VRI-3 / ICG-4861	90.50	12	46	62.50	84	67
JL-24 / ICG-1037	87.50	9	33	66.50	68.33	31
VRI-3 / ICG-1037	90.50	9	31	63.50	83	45

Table 39 Average 30D germination percentage of parents and early generation populations

Designation	P_1	P_2	F_1	F_2	$BC_{1(ND)}$	$BC_{1(D)}$
JL-24 / ICG-7269	87.50	94	92	99.50	93.33	91.25
VRI-3 / ICG-7269	90.50	94	86	93.50	97	89.43
JL-24 / TG-17	87.50	87	81.8	96.50	93.33	86
VRI-3 / TG-17	90.50	87	71.89	98.50	91.66	83.46
JL-24 / TMV-10	87.50	62	66	88	88.67	70
VRI-3 / TMV-10	90.50	62	62	87	87.22	62
JL-24 / ICG-4861	87.50	41	65	87.50	86	58.33
VRI-3 / ICG-4861	90.50	41	82	81.50	84	89
JL-24 / ICG-1037	87.50	30	67	85.50	81.33	40
VRI-3 / ICG-1037	90.50	30	55	83.50	91	53

Table 40 Frequency distribution in F_1 plants for germination in the F_2 seeds borne on them (F_2 embryonic generation) at 10-30 DAS

Designation	Nnumber of F_1 plants	10D germination classes					20D germination classes					30D germination classes				
		0 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%	0 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%	0 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
i) Crosses																
JL-24 / ICG-7269	20	4	10	2	–	–	–	–	–	14	6	–	–	–	–	20
VRI-3 / ICG-7269	20	10	4	4	2	–	–	–	2	12	6	–	–	–	4	16
JL-24 / TG-17	18	8	4	6	–	–	–	–	4	6	8	–	–	–	6	12
VRI-3 / TG-17	18	4	8	6	–	–	–	2	6	6	4	–	–	–	6	12
JL-24 / TMV-10	18	12	8	–	–	–	2	4	10	4	–	–	–	–	10	8
VRI-3 / TMV-10	18	14	4	–	–	–	–	8	6	2	2	–	–	6	10	2
JL-24 / ICG-4861	18	14	4	–	–	–	–	14	2	2	–	–	–	6	10	2
VRI-3 / ICG-4861	18	10	4	4	–	–	4	6	2	2	4	–	–	6	10	2
JL-24 / ICG-1037	20	16	4	–	–	–	8	6	4	2	–	–	4	10	2	4
VRI-3 / ICG-1037	18	18	–	–	–	–	4	10	4	–	–	–	4	8	6	–
ii) Dormant parents																
ICG-7269	20	20	–	–	–	–	–	–	2	16	2	–	–	–	2	18
TG-17	20	20	–	–	–	–	4	10	6	–	–	–	–	–	12	4
TMV-10	20	20	–	–	–	–	12	8	–	–	–	–	2	6	10	2
ICG-4861	20	20	–	–	–	–	8	12	–	–	–	–	4	10	6	–
ICG-1037	20	20	–	–	–	–	16	4	–	–	–	8	10	2	–	–
iii) Non-dormant parents																
JL-24	20	–	–	–	8	12	–	–	–	–	20	–	–	–	–	20
VRI-3	20	–	–	–	8	12	–	–	–	–	20	–	–	–	–	20

Table 41 Frequency distribution in F_2 plants for germination in the F_3 seeds borne on them (F_3 embryonic generation) at 10-30 DAS

Designation	Nnumber of F_2 plants	10D germination classes					20D germination classes					30D germination classes				
		0 - 20%	21- 40%	41- 60%	61- 80%	81 - 100%	0 - 20%	21 - 40%	41 - 60%	61 - 80%	81 - 100%	0 - 20%	21 - 40%	41 - 60%	61 - 80%	81 - 100%
i) Crosses																
JL-24 / ICG-7269	40	10	6	6	12	6	2	2	2	12	22	-	-	-	-	40
VRI-3 / ICG-7269	40	10	12	10	6	2	2	-	6	18	14	-	2	-	6	32
JL-24 / TG-17	40	6	8	8	10	8	-	2	8	8	22	-	-	-	4	36
VRI-3 / TG-17	40	10	6	16	4	4	-	2	-	18	20	-	-	-	2	38
JL-24 / TMV-10	40	18	10	2	8	2	2	2	8	12	16	-	4	4	4	28
VRI-3 / TMV-10	40	10	12	10	6	2	2	4	10	8	16	-	2	2	8	28
JL-24 / ICG-4861	40	10	16	6	4	4	-	4	18	4	14	-	-	6	10	24
VRI-3 / ICG-4861	40	12	8	10	6	4	-	4	14	8	14	-	-	4	10	26
JL-24 / ICG-1037	40	14	6	12	6	2	4	4	8	10	14	2	4	6	4	24
VRI-3 / ICG-1037	40	18	8	8	2	4	-	10	10	10	10	-	-	8	10	22
ii) Dormant parents																
ICG-7269	20	20	-	-	-	-	-	-	2	16	2	-	-	-	2	18
TG-17	20	20	-	-	-	-	4	10	6	-	-	-	-	-	12	4
TMV-10	20	20	-	-	-	-	12	8	-	-	-	-	2	6	10	2
ICG-4861	20	20	-	-	-	-	8	12	-	-	-	-	4	10	6	-
ICG-1037	20	20	-	-	-	-	16	4	-	-	-	8	10	2	-	-
iii) Non-dormant parents																
JL-24	20	-	-	-	8	12	-	-	-	-	20	-	-	-	-	20
VRI-3	20	-	-	-	8	12	-	-	-	-	20	-	-	-	-	20

Fig.2 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross JL-24/ICG-7269

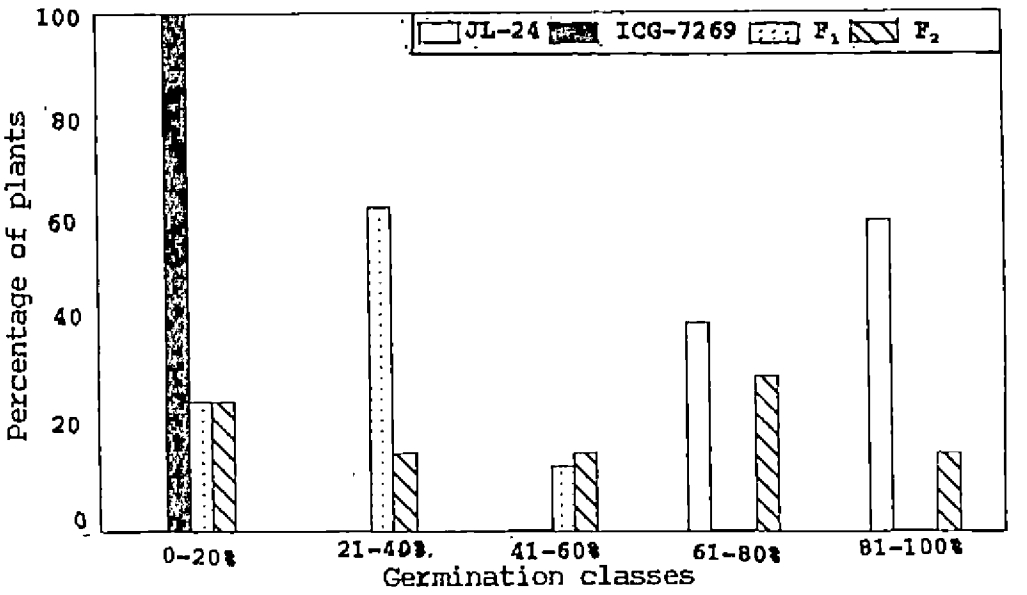


Fig.3 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross VRI-3/ICG-7269

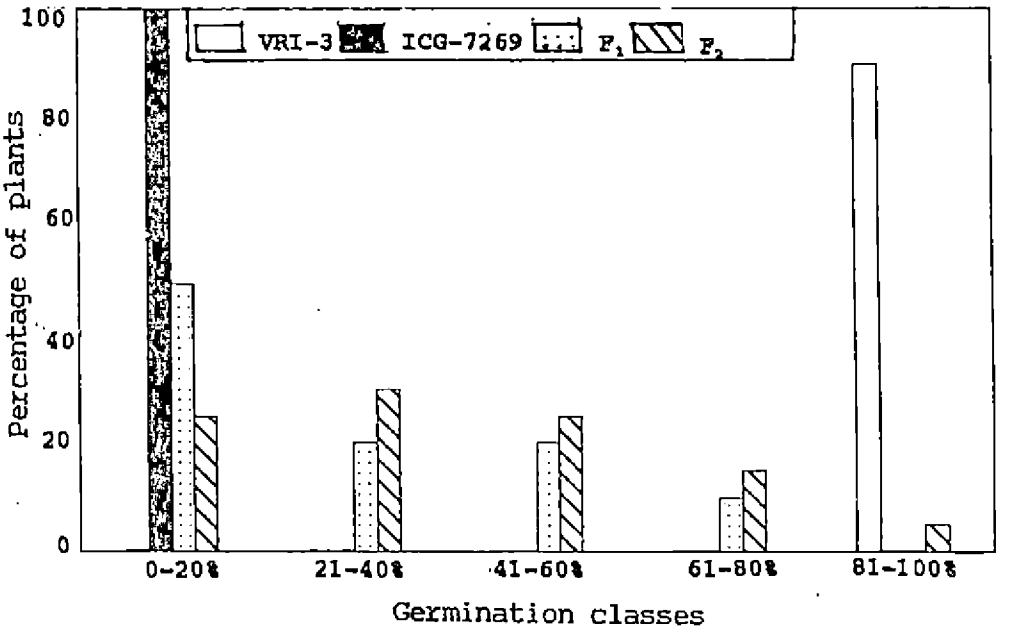


Fig.4 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross JL-24/TG-17

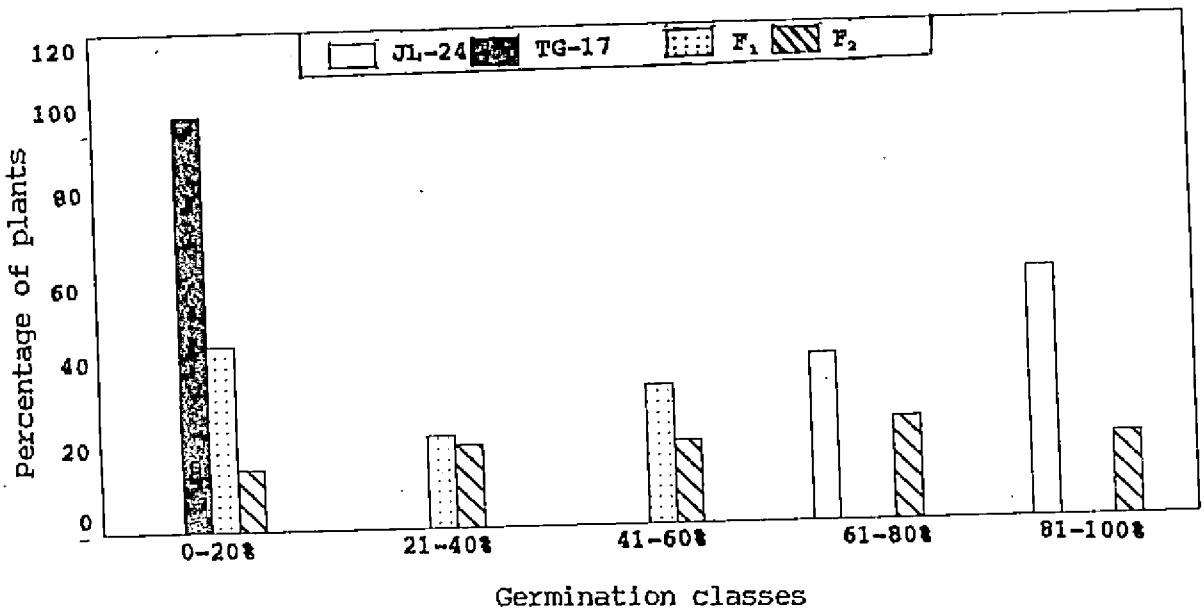


Fig.5 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross VRI-3/TG17

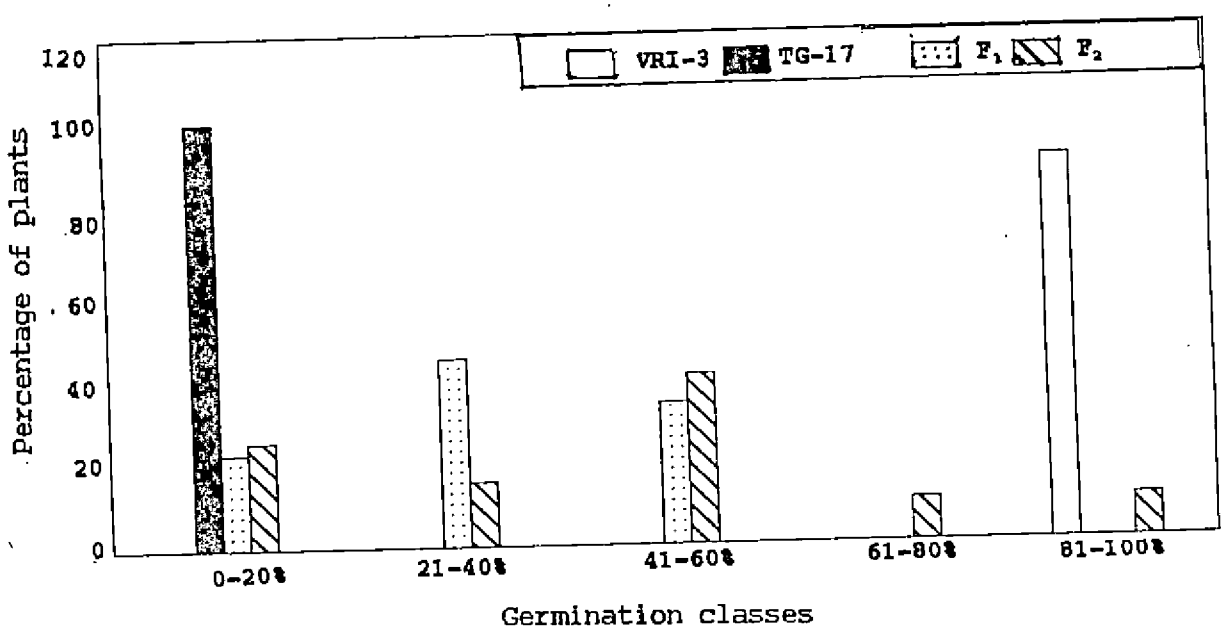


Fig.6 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross JL-24/TMV-10

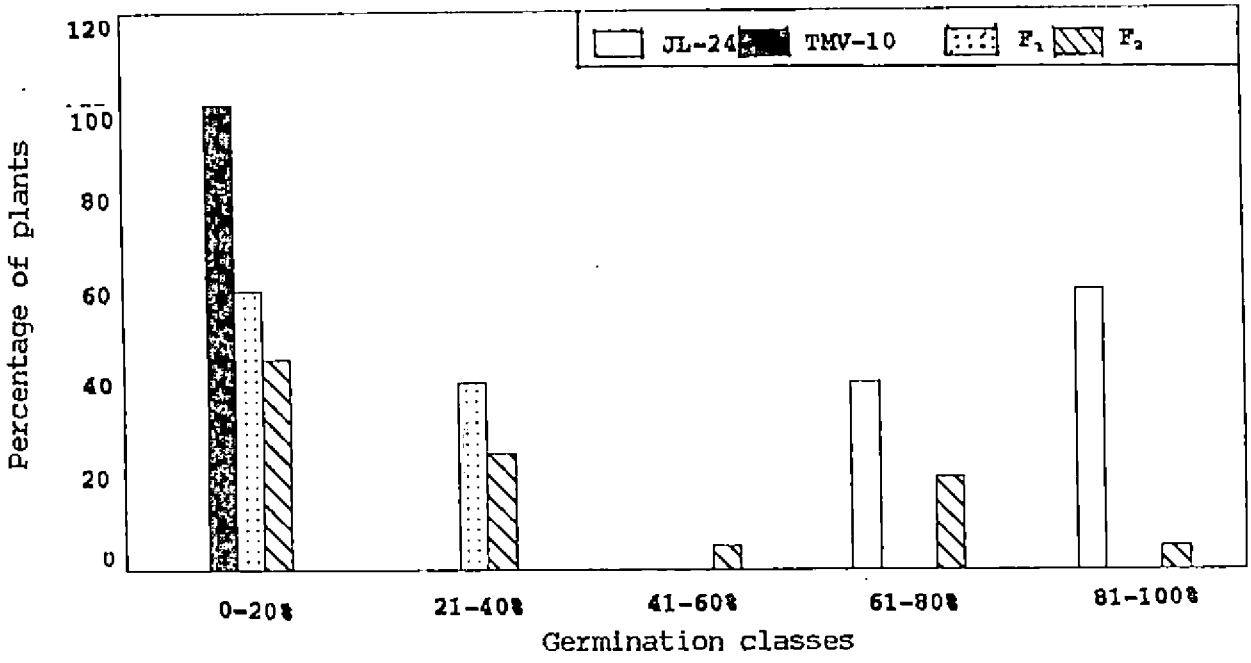


Fig.7 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross VRI-3/TMV-10

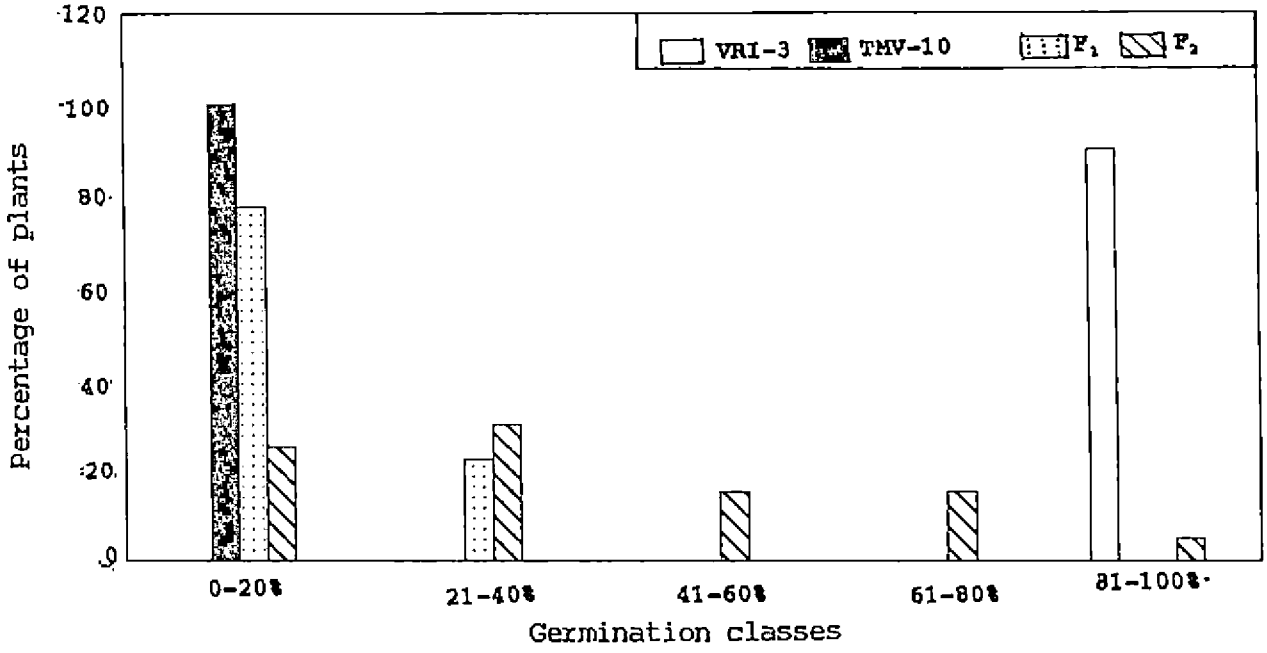


Fig.8 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross JL-24/ICG-4861

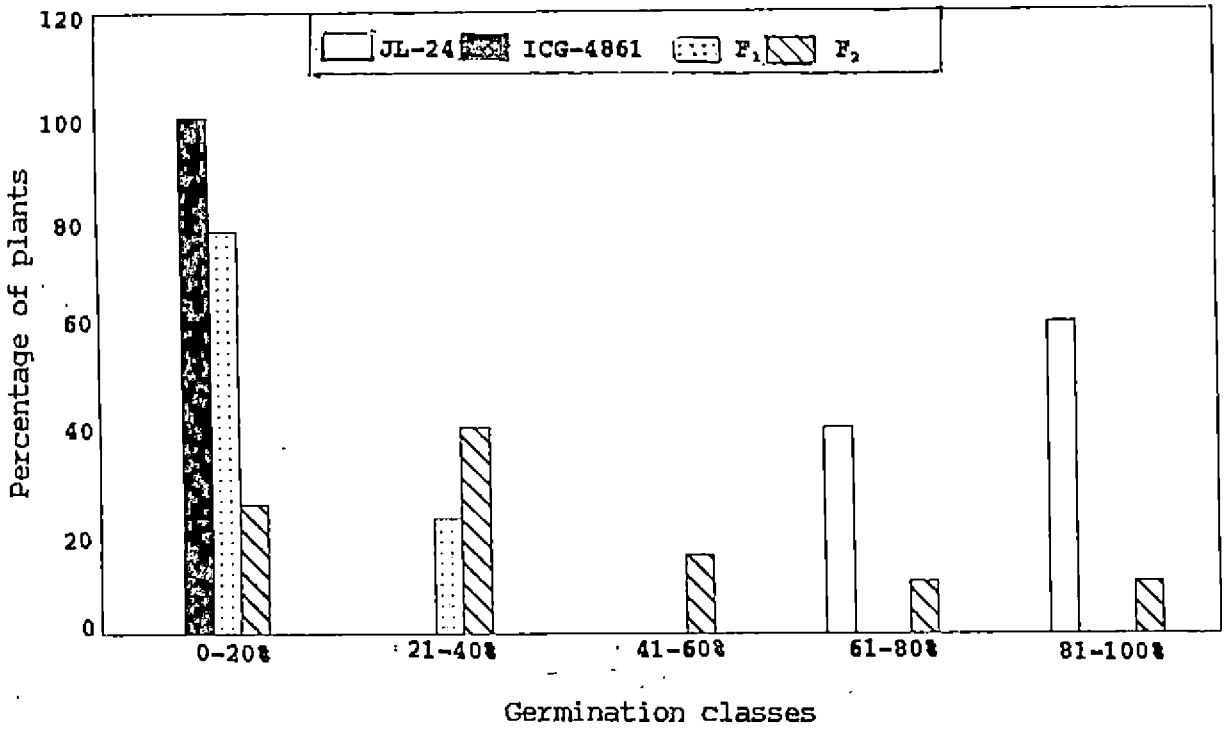


Fig.9 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross VRI-3/ICG-4861

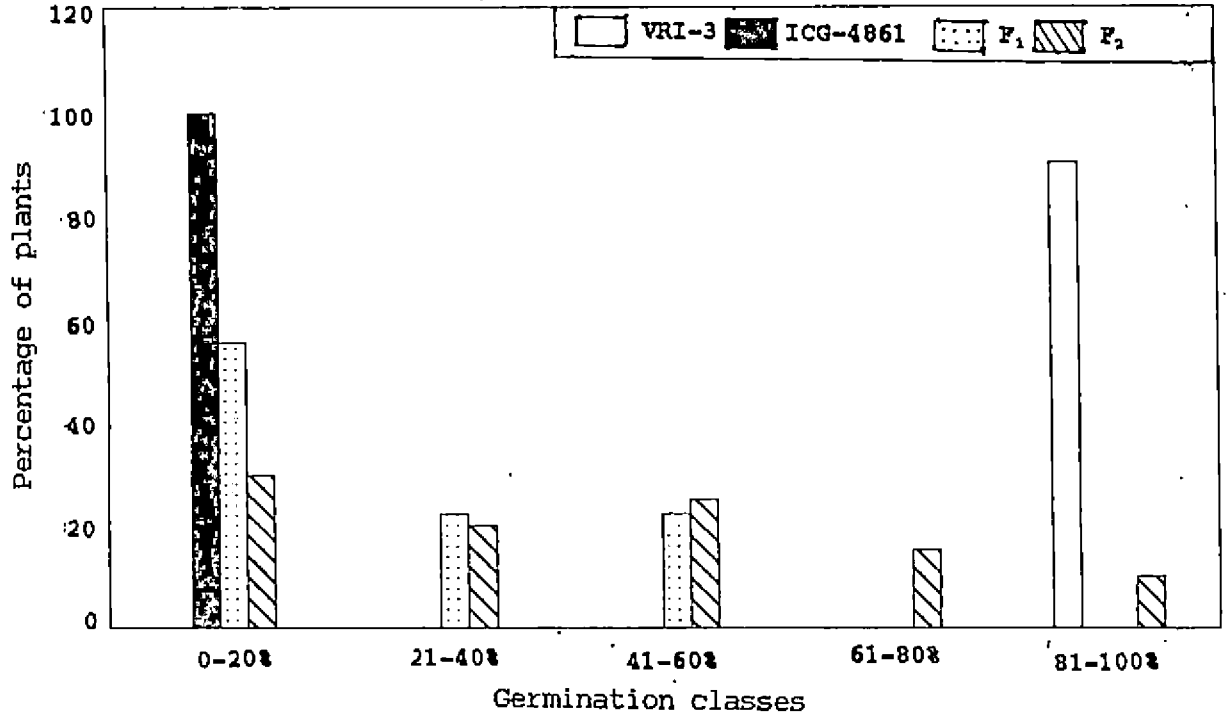


Fig.10 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross JL-24/ICG-1037

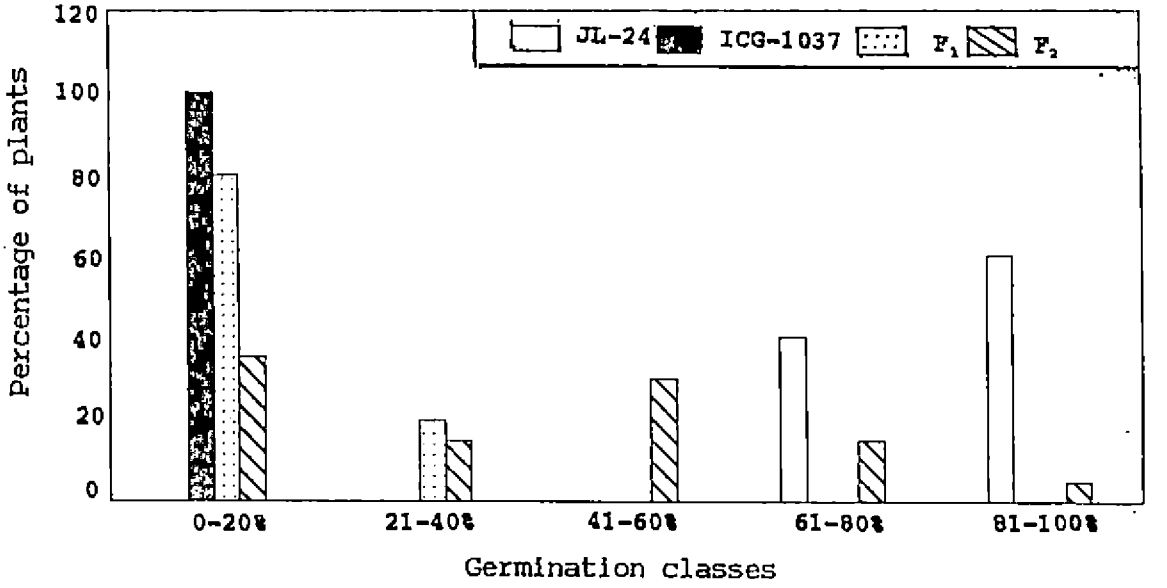
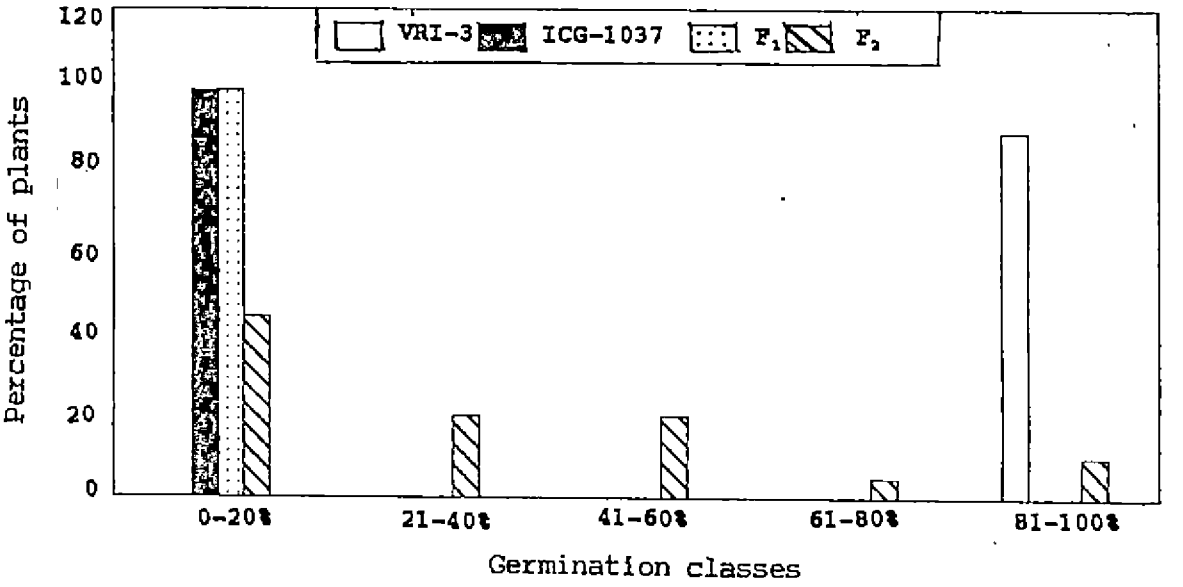


Fig.11 Frequency distribution of parents, F_1 and F_2 populations for 10th day germination in cross VRI-3/ICG-1037



last three classes. Whereas the inter-subspecific crosses, *fastigiata x hypogaea* fell in almost all the classes. For 30D germinations also the F_1 plants were distributed in the last two classes with the exception of a few inter subspecific crosses.

4.2.2.3 Germination percentage in the F_3 seeds (F_3 embryonic generation - F_2 plant generation)

The mean germination percentage of 40 F_2 plants (Table 37) ranged from 34 per cent in VRI-3/ICG-1037 to 56.5 per cent in JL-24/TG-17. In the 20D germination, (Table 38) mean germination ranged from 63.5 per cent in VRI-3/ICG-1037 to 84.5 per cent in VRI-3/TG-17. For 30 D germination the range was between 81.5 per cent in VRI-3/ICG-4861 to 99.5 per cent in JL-24/ICG-7269 (Table 39).

The frequency distribution (Table 41) clearly indicated a multigenic control of the character as the F_2 plants spanned in all the five classes in all the crosses for 10D germination (Fig. 2 to 11) and 20D germination. For 30D germination, the plants were distributed only in last three classes.

4.2.2.4 Germination percentage in $BC_{1(ND)}$ seeds

($BC_{1(ND)}$ embryonic generation)

The 10D germination percentage in $BC_{1(ND)}$ seeds ranged from zero in VRI-3/TMV-10 to 100 per cent JL-24/ICG-7269.

For the 20D germination it ranged from 21.43 per cent in VRI-3/ICG-4861 to 100 per cent in five crosses. By 30 D all the crosses recorded more than 90 per cent germination (Table 35).

4.2.2.5 Germination percentage in $BC_{1(D)}$ seeds

($BC_{1(D)}$ embryonic generation)

The 10D germination percentage in $BC_{1(D)}$ seeds (Table 36) ranged from zero per cent in seven crosses to 28.57 per cent in VRI-3/ICG-7269. The 20D germination ranged from zero in JL-24/TMV-10 to 100 per cent in JL-24/ICG-7269. For 30D germination the range was between 33.33 per cent in JL-24/ICG-4861 to 100 per cent in JL-24/ICG-7269, VRI-3/TG-17 and JL-24/ICG-1037.

4.2.2.6 Germination percentage in $BC_{1(ND)}F_2$ seeds ($BC_{1(ND)}F_2$ embryonic generation - $BC_{1(ND)}$ plant generation)

The mean germination percentage for 10^{th} day germination in $BC_{1(ND)}$ plants (Table 37) ranged from 36.67 in JL-24/TMV-10 to 81 per cent in VRI-3/ICG-7269. The mean values for 20D germination (Table 38) ranged from 56.67 per cent in JL-24/TMV-10 to 97 per cent in VRI-3/ICG-7269 and for 30D germination (Table 39), it ranged from 81.33 per cent in JL-24/ICG-1037 to 97 per cent in VRI-3/ICG-7269.

4.2.2.7 Germination percentage in $BC_{1(D)}$ F_2 seeds ($BC_{1(D)}F_2$ embryonic generation - $BC_{1(D)}$ plant generation)

The mean germination percentage for 10D germination for $BC_{1(D)}$ generation (Table 37) ranged from 7 per cent in VRI-3/TMV-10 to 51 per cent in JL-24/ICG-7269 and from 28.33 per cent in JL-24/ICG-4861 to 91.25 per cent in JL-24/ICG-7269 for 20D germination (Table 38) and from 40 per cent in JL-24/ICG-1037 to 91.25 per cent in JL-24/ICG-7269 for 30D germination (Table 39).

4.2.2.8 Comparison of mean 10D germination of F_1, F_2 and back cross generations with nondormant parent P_1

Comparison of mean 10D germination of early generations with nondormant parent is given in Table 42. In all the generations `t' values were significant except in $BC_{1(ND)}$ generations of two crosses viz., JL-24/ICG 7269 and VRI 3/ICG 7269. This indicated that the different generations were significantly different from the non dormant parent.

4.2.3 Generation mean analysis

The analysis was conducted for seed dormancy over the means of six generation P_1, P_2, F_1, F_2, $BC_{1(ND)}$ and $BC_{1(D)}$ in 10 crosses involving two non-dormant and five dormant genotypes. The dormancy was assessed by germination percentage at 10 days interval. The data from 10D

Table 42 Comparison of average 10D germination percentage of F_1, F_2, $BC_{1(ND)}$, $BC_{1(D)}$ generations with non-dormant parent P_1 in 10 crosses of groundnut

Sl. No.	Cross	Average 10D germination percentage♧						't' value			
		P_1	P_2	F_1	F_2	$BC_{1(ND)}$	$BC_{1(D)}$	P_1 Vs. F_1	P_1 Vs. F_2	P_1 Vs. $BC_{1(ND)}$	P_1 Vs. $BC_{1(D)}$
1	JL-24 / ICG-7269	5.35	0.0	3.31	3.79	4.75	4.06	11.05*	4.05*	1.84^{NS}	5.78*
2	VRI-3 / ICG-7269	5.45	0.0	2.99	2.26	5.40	3.25	6.63*	5.81*	1.58^{NS}	6.25*
3	JL-24 / TG-17	5.35	0.0	2.75	4.16	4.72	2.78	4.86*	4.25*	2.96*	5.07*
4	VRI-3 / TG-17	5.45	0.0	3.01	3.64	4.77	3.04	4.68*	5.09*	3.42*	3.99*
5	JL-24 / TMV-10	5.35	0.0	2.04	3.52	2.83	1.31	5.45*	5.22*	2.78*	6.31*
6	VRI-3 / TMV-10	5.45	0.0	2.68	3.38	3.64	0.77	7.62*	5.80*	3.19*	11.3*
7	JL-24 / ICG-4861	5.35	0.0	2.43	3.32	3.75	1.16	10.78*	5.57*	2.62*	7.77*
8	VRI-3 / ICG-4861	5.45	0.0	2.53	3.64	3.81	2.76	6.57*	6.04*	5.51*	5.87*
9	JL-24 / ICG-1037	5.35	0.0	1.40	3.30	4.18	1.86	8.89*	5.30*	3.16*	6.32*
10	VRI-3 / ICG-1037	5.45	0.0	1.69	2.87	4.01	1.72	12.04*	6.74*	2.84*	8.87*

♧ Arc sine square root transformation applied to decimal fraction of germination percentage
* Significant at 5% level NS - Not significant

germination and 20D germination were utilized for the analysis. Scales A, B and C were estimated and tested with their respective standard errors to examine whether simple additive dominance model (three parameter model) was adequate. The adequacy of the model was further tested by joint scaling test. The genetic parameters (m), (d), (h), (i), (j) and (l) were tested for their significance with their respective standard error.

4.2.3.1 Scaling test

The estimates of scaling test for 10D germination for 10 crosses are presented in Table 43. Seven out of ten cross combinations recorded significance for one or more of the A, B, C scales revealing that simple additive dominance model was inadequate in these crosses.

Scaling tests using 20D germination data (Table 44) revealed that the three parameter model was inadequate for all the crosses except one (VRI-3/ICG-4861).

4.2.3.2 Joint scaling test

The inadequacy of three parameter model was further confirmed by joint scaling test. The estimates are presented in Table 43 and 44. Six out of ten crosses reached the level of significance for the 10D germination (Table 43) showing that non-allelic interactions are present and three parameter model was inadequate.

Table 43 Scaling and joint scaling tests and estimates of gene effects for 10D germination in 10 crosses of groundnut

Sl. No.	Cross	Scales			Joint scaling test	
		A	B	C	χ^2 df = 3	Probability
1	JL-24 / ICG-7269	0.84	3.93*	2.30	49.18*	0.0000
2	VRI-3 / ICG-7269	1.86*	2.64*	1.37	19.46*	0.0002
3	JL-24 / TG-17	1.34*	2.44*	5.44*	14.76*	0.0020
4	VRI-3 / TG-17	1.11	2.70*	2.73	5.84	0.1197
5	JL-24 / TMV-10	-1.73	0.21	4.26*	8.03*	0.0434
6	VRI-3 / TMV-10	-0.84	-1.50	2.35	6.45	0.0916
7	JL-24 / ICG-4861	-0.27	-0.66	2.55	3.67	0.2992
8	VRI-3 / ICG-4861	-0.35	2.44*	3.54*	12.89*	0.0049
9	JL-24 / ICG-1037	1.61	1.76	4.48*	9.00*	0.0294
10	VRI-3 / ICG-1037	0.92	1.21	2.18	3.47	0.3250

*Significant at 5% level

Table 44 Scaling and joint scaling tests and estimates of gene effects for 20D germination in 10 crosses of groundnut

Sl. No.	Cross	Scales			Joint scaling test	
		A	B	C	χ^2 df = 3	Probability
1	JL-24 / ICG-7269	0.49*	0.71*	-0.52	14.08*	0.0028
2	VRI-3 / ICG-7269	0.78*	0.26	-0.48	22.56*	0.0000
3	JL-24 / TG-17	0.68*	1.29*	1.65*	8.55*	0.0358
4	VRI-3 / TG-17	1.05*	1.85*	2.92*	16.80*	0.0008
5	JL-24 / TMV-10	-1.12	-0.14	3.16*	7.06	0.0717
6	VRI-3 / TMV-10	0.23	0.26	3.31*	9.62*	0.0221
7	JL-24 / ICG-4861	0.03	0.83	3.19*	7.24	0.0646
8	VRI-3 / ICG-4861	-0.35	1.47	2.56	5.61	0.1320
9	JL-24 / ICG-1037	2.00*	1.28	5.37*	31.94*	0.0000
10	VRI-3 / ICG-1037	1.76*	3.12*	5.08*	33.38*	0.0000

* Significant at 5% level

For the 20D germination (Table 44) seven out of ten crosses reached the level of significance indicating inadequacy of three parameter model.

4.2.3.3 Estimates of genetic parameters

4.2.3.3.1 10D germination

The estimates of genetic parameters for 10D germination are given in Table 45.

For 10D germination the effect of (m) was highly significant in all cross combinations.

For additive effect(d) except for crosses JL-24/ICG-7269 and JL-24/TMV-10 all the crosses reached the level of significance. Crosses VRI-3/ICG-7269, JL-24/TG-17, VRI-3/ICG-4861 and JL-24/ICG-1037 recorded significant positive dominance effect, while VRI-3/TG-17,VRI-3/TMV-10, JL-24/ICG-4861 and VRI-3/ICG-1037 registered significant negative effect.

The dominance effect (h) was significant in the negative direction in the cross JL-24/TMV-10, JL-24/ICG-4861 and VRI-3/ICG-1037 and in positive direction in VRI-3/TG-17.

The additive x additive interaction effect (i) was significant in the negative direction in JL-24/TMV-10 and in the positive direction in VRI-3/ICG-7269.

Table 45 Estimates of gene effects based on 10D germination data in 10 crosses of groundnut

Sl. No.	Cross	Estimates of gene effects					
		(m)	(d)	(h)	(i)	(j)	(l)
1	JL-24 / ICG-7269	3.79*	0.69	2.66	2.47	-1.55*	-7.23*
2	VRI-3 / ICG-7269	3.42*	1.89*	2.96	3.13*	-0.39	-7.64*
3	JL-24 / TG-17	4.16*	1.94*	-1.77	-1.67	-0.55	-2.11
4	VRI-3 / TG-17	2.96*	-2.49*	0.95*	-	-	-
5	JL-24 / TMV-10	3.52*	1.52	-6.6*	-5.78*	-0.97	7.30
6	VRI-3 / TMV-10	2.89*	-2.55*	-0.22	-	-	-
7	JL-24 / ICG-4861	2.98*	-2.38*	-0.49*	-	-	-
8	VRI-3 / ICG-4861	3.64*	1.05*	-1.92	-1.45	-1.4*	-0.64
9	JL-24 / ICG-1037	3.30*	2.32*	-2.65	-1.11	-0.08	-2.26
10	VRI-3 / ICG-1037	3.07*	-2.38*	-1.11*	-	-	-

* Significant at 5% level

The additive x dominance interaction effect (j) was positive and significant in the negative direction in the cross combination JL-24/ICG-7269 and VRI-3/ICG-4861.

4.2.3.3.2 20D germination

The estimates of genetic parameters for 20D germination are given in Table 46.

All cross combinations registered significant and positive (m) effects.

The additive effect (d) was significant in seven cross combination. The effect was in negative direction in VRI-3/ICG-4861 and in positive direction in JL-24/TG-17, VRI-3/TG-17, VRI-3/TMV-10, JL-24/ICG-4861, JL-24/ICG-1037, VRI-3/ICG-1037.

The dominance effect (h) was highly significant in the negative direction in JL-24/TMV-10, VRI-3 /TMV-10, VRI-3/ICG-4861 and positively significant in JL-24/ICG-7269

The additive x additive effect (i) was negatively significant in VRI-3/TMV-10 and positively significant in JL-24/ICG-7269 and VRI-3/ICG-7269.

Table 46 Estimates of gene effects based on 20D germination data in 10 crosses of groundnut

Sl. No.	Cross	Estimates of gene effects					
		(m)	(d)	(h)	(i)	(j)	(l)
1	JL-24 / ICG-7269	5.08*	0.07	1.81*	1.72*	-0.11	-2.92*
2	VRI-3 / ICG-7269	5.03*	0.48	1.39	1.52*	0.26	-2.56*
3	JL-24 / TG-17	5.15*	0.63*	0.97	0.32	-0.31	-2.29
4	VRI-3 / TG-17	5.21*	0.57*	0.02	-0.03	-0.41	-2.86*
5	JL-24 / TMV-10	4.68*	0.79	-4.76*	-4.42	-0.49*	5.68*
6	VRI-3 / TMV-10	4.77*	1.31*	-3.15*	-2.82*	-0.01	2.33
7	JL-24 / ICG-4861	4.30*	1.52*	-2.20	-2.33	-0.40	1.47
8	VRI-3 / ICG-4861	3.69*	-1.74*	-0.90*	-	-	-
9	JL-24 / ICG-1037	4.55*	2.51*	-2.09	-2.09	0.37	-1.20
10	VRI-3 / ICG-1037	4.50*	1.5*	-0.25	0.2	0.68	-4.67*

*Significant at 5% level

The additive x dominance effect (j) was significant but in negative direction in only one cross JL-24/TMV-10. None of the crosses showed significance in positive direction.

The dominance x dominance effect (l) was significant in four crosses in negative direction. They are JL-24/ICG-7269,VRI-3/ICG-7269, VRI-3/TG-17,VRI-3/ICG-1037 None of the crosses showed significance in positive direction.

Discussion

DISCUSSION

Developing high yielding early maturing groundnut cultivars with seed dormancy has recently been realised as a major objective in groundnut breeding programmes of countries or regions, where the rainy seasons are short and unexpected rains are likely to fall at maturity, causing *in situ* germination and spoilage of the produce. The two subspecies of cultivated groundnut, *hypogaea* and *fastigiata* differ in their season length and in their seed dormancy after maturity. The *fastigiata* genotypes are characterised by short life cycle and have non-dormant seeds, while the *hypogaea* genotypes generally mature later and have dormancy for a considerable period after maturity.

Earlier peanut breeders believed that earliness and dormancy were too closely linked to combine the two traits within one cultivar. The inadequacy of information on gene action of yield contributing traits, earliness and seed dormancy, has been a reason for not achieving a major break through in this line. The distribution of desirable genes in different subspecies necessitates a combination breeding programme, where there is possibility for shuffling genes between the subspecies and botanical forms and widen the pattern of segregation and to realise recombinants with all the required traits.

In the present investigations, it was envisaged to select appropriate parents and to inquire into the relative importance of different types of gene effects of the biometrical characters and seed dormancy, by involving different subspecies and botanical forms, with a view to suggesting appropriate breeding procedures for evolving high yielding early maturing dormant genotypes.

To achieve the above objective a preliminary investigation to select divergent parents belonging to different subspecies and botanical forms was found necessary. Fourteen dormant and fourteen non-dormant genotypes belonging to the four botanical groups were evaluated for two seasons for their *per se* performance and subjected them for genetic divergence analysis.

After selecting three non-dormant, short duration, high yielding female parents and five divergent, dormant male parents, they were crossed in a line x tester fashion. Combining ability analysis and study of heterosis helped in identifying parents with good general combining ability and cross combinations with good specific combining ability and the study also brought to light whether additive or non-additive gene action governed the metric traits. The germination percentages in six generations in ten crosses were subjected to generation mean analysis with a view to

understanding the genetic effects of seed dormancy so that appropriate breeding procedures for yield improvement could be suggested.

5.1 Variability analysis

5.1.1 *Per se* performance of the genotypes

Out of the twenty eight genotypes maximum per hectare yield was recorded by VRI-3 (2040 kg ha^{-1}). Seven genotypes, all belonging to subsp. *fastigiata,* were statistically on par with VRI-3. The pooled general mean for 18 *fastigiata* genotypes was 1776 kg ha^{-1} whereas it was only 1452 kg ha^{-1} for the *hypogaea* genotypes, showing that the performance of *hypogaea* genotypes were significantly inferior to *fastigiata* in pod yield under Vellanikkara conditions. In the *rabi* season the highest pod yield per hectare was recorded by JL-24. Ten genotypes were on par with JL-24, of which only one (ICG-4861) belonged to subspecies *hypogaea*. The general mean for subspecies *fastigiata* genotypes was 1888 kg ha^{-1} and that of *hypogaea* genotypes was 1564 kg ha^{-1}. In *kharif* season, the performance of the *hypogaea* genotypes was comparatively better. The highest yielder was VRI-3 (2265 kg ha^{-1}). Thirteen cultivars were on par with top ranking genotype VRI-3. Among them two genotypes Robut 33-1 and ICG-1037 were *hypogaea* types. Thus, in general, the *fastigiata* genotypes were performing better than, *hypogaea* genotypes, which must be due to long flowering phase in the latter.

Though the number of fruiting nodes were high in *hypogaea* the number of sound mature pods realised at harvest was only on par with *fastigiata* genotypes. This may be due to the adverse soil conditions prevailing at the end of *kharif* season and during *rabi* season. The amount of soil moisture in the surface soils is fairly restricted near to harvest in both seasons, thereby leading to pod development and harvest problems (Virmani and Singh, 1986). Pushkaran and Nair (1985) have also reported the suitability of bunch varieties for the three seasons of Kerala.

Virginia genotypes possess many of the economic traits especially large number of fruiting nodes and branches which can be incorporated into the Spanish and Valencia (bunch types) varieties without any appreciable change in the early maturing nature of bunch genotypes. Early maturing varieties are now increasingly preferred by farmers, over long duration spreading types. Gibbons (1976) and Reddy (1980) have also suggested the prospects of inter-subspecific crosses for evolving high yielding genotypes.

The genotypes which can be used as donors of specific traits based on their *per se* performance are listed below:

Character	Genotypes
Per hectare pod yield	VRI-3, JL-24, CO-2, TG-14, TG-17, TG-15, TG-6, ICG-7269
Number of mature pods per plant	Robut-33-1, ICG-861, TMV-10
Shelling percentage	ICG-459, TG-3, JL-24, ICG-7269
Oil content	TMV-10, TG-6, TG-15
Hundred seed weight	ICG-8281, TG-15, TG-17, TMV-10
Early maturity	ICG-128, ICG-7269, ICG-5461, ICG-1231, ICG-1883, VRI-3, TG-3, TMV-2
Dormancy, short duration and high per hectare yield	TG-17, TG-15, ICG-7269

5.1.2 Genetic parameters of variation

Broad sense heritability estimates were high for almost all the biometric traits studied, indicating little influence of environment on these traits. Selection based on phenotypic expression should be effective for these traits. Johnson *et al.* (1955) reported that heritability values along with genetic advance should be considered together to arrive at a more reliable conclusion. In the present study, total number of branches and hundred seed weight recorded high heritability coupled with high genetic

advance expressed as percentage over mean, consistently in both the seasons indicating that improvement of these traits would be possible by selection.

5.2 D^2 analysis

The D^2 statistic based on multivariate analysis measures the genetic divergence among genotypes. Estimation of divergence among genotypes would help the breeder in the choice of parents for hybridisation. The success in obtaining highly heterotic hybrids and creating a wide spectrum of variability for selecting desirable segregants in advanced generations depends to a large extent on the degree of divergence between parents chosen (Murthy and Arunachalam, 1966; Bhatt, 1970; Arunachalam, 1993).

In the present study nine biometric traits were considered together, both for *kharif* and *rabi* season. Wilk's criterion was used for simultaneous test of significance of the differences in the mean values of the characters. The pooled value was found significant for both the seasons indicating wide genetic diversity among the genotypes selected.

The twentyeight genotypes which formed the experimental material included all the four botanical groups viz., Spanish and Valencia groups, belonging to

subspecies *fastigiata* and virginia bunches and runners belonging to subspecies *hypogaea*. The D^2 statistics applied to these twenty eight genotypes resulted in identifying four clusters both for *kharif* and *rabi* seasons. The clustering pattern for *kharif* season showed a clear separation of the two subspecies *hypogaea* and *fastigiata*. Cluster I and IV contained only *fastigiata* varieties, Spanish and Valencia. The clusters II and III, contained the *hypogaea* varieties, virginia bunch and runners. There was overlapping of varieties within the subspecies in different clusters ie: in cluster I both Spanish and Valencia genotypes were grouped together. In cluster II a virginia bunch was grouped together with five virginia runner genotypes. The genotypes belonging to a particular subspecies were grouped together in one or two clusters because of their similarity in morphological and biometric traits and genotypes belonging to different subspecies separated to different clusters because of their divergence. This pattern of clustering was also observed by Sigamani (1984) and Durgaprasad *et al.* (1985).

During *rabi* season, the virginia bunch genotypes were found to be grouped along with Spanish types and virginia

runners. This might be probably due to modification of biometric traits by the stress condition prevailing at the end of *rabi* season. The virginia bunches which are transitional forms of the two subspecies, thus got grouped with immediate related groups, Spanish and virginia runners. The clustering thus points out the evolutionary significance of subspecies and botanical groups, subspecies *hypogaea* being formed early and *fastigiata* originated later.

The inter cluster distance during the *kharif* season also brought out the evolutionary significance. Maximum inter-cluster distance was between cluster I and II. Cluster I represented the Spanish and Valencia group and cluster II contained the virginia runners which are the extreme forms in the evolutionary sequence. Crosses between these divergent genotypes are likely to give desirable, transgressive segregants.

The intra-cluster distance in cluster I which included the short duration high yielding Spanish and Valencia types, was the least for both *kharif* and *rabi* seasons. This obviously indicates the lack of phenotypic diversity

among these genotypes. But crosses between Spanish and Valencia are very potent in the context of breeding for early maturity and yield. Durgaprasad *et al.* (1985) have observed high intra cluster distances within Spanish and Valencia genotypes. This may be accounted for large number of genotypes included in that study (160 accessions).

The study of cluster means of nine character revealed that the highest mean values for different characters were recorded by different clusters. Cluster I and IV contained the subpecies *fastigiata* genotypes. Cluster I recorded highest mean value for per hectare yield, oil content and minimum number of days to 50 per cent flowering. Cluster IV gave the highest mean for shelling percentage and number of mature pods per plant. The cluster II and III consisted of subspecies *hypogaea* genotypes. Cluster II gave the highest mean value for hundred seed weight and total number of branches. The study of cluster means indicated that subspecies *hypogaea* could contribute for plant height, total number of branches and hundred seed weight where as subspecies *fastigiata* could contribute for oil content, short duration, per hectare yield and shelling percentage. This points to the high potential of inter-subspecific

crosses, for evolving improved varieties with ideal plant type, combined with high yield of kernel and oil.

The study of D^2 analysis was repeated in *rabi* season, so as to further confirm the divergence of genotypes. But for minor discrepancies the clustering pattern was found to be fairly stable. The virginia bunch genotypes forming cluster IV of *kharif* season, were found overlapping along with Spanish cluster (cluster III) and virginia runner cluster (cluster II) of *rabi* season. This can be accounted for the modification of biometric traits due to the effect of stress conditions prevailing during *rabi* season. The seasonal variation in vegetative and reproductive traits in different botanical groups have been pointed out by several workers (Joshi and Gajpara, 1971; Scandaliaris *et al.*, 1978; and Reddy *et al.*, 1984).

5.3 Line x Tester analysis

Line x Tester analysis proposed by Kempthorne (1957) is a simple and efficient tool for selection of parents and has been extensively used by breeders in recent years in almost all major field crops. It measures the general and

specific combining ability variances and effects and the genetic components of variances, A (additive) and D (non-additive) and thus aids in the selection of parents and also in choosing appropriate breeding procedures.

5.3.1 Mean performance of parents and hybrids

A critical evaluation of the performance of parents and inter and intra-subspecific hybrids revealed the following facts. Though the subspecies *hypogaea* recorded high values for vegetative characters, for pod yield and number of mature pods they did not record significant superiority over the parental mean. Among the four hybrids which recorded significantly superior yield over hybrid mean two were intra-subspecific crosses (JL-24/ICG-7269) and (CO-2/ICG-7269) and only two were inter-subspecific (JL-24/ICG-4861, JL-24/ICG-1037). Several previous workers, have highlighted the importance of subspecies *hypogaea* in contributing the economic traits and involving this subspecies in hybridisation for improvement of yield (Parker *et al.*, 1970; Singh and Labana, 1980; Labana *et al.*, 1981; Dwivedi *et al.*, 1989). Such a superiority of sub-species *hypogaea* and its hybrids for yield was not evident in this study.

Subsp. *hypogaea* parents and inter-subspecific crosses, Spanish x virginia bunch and Spanish x virginia runner were showing marked increase in total number of branches. Total

number of branches is reported to be highly correlated with pod yield by several workers (Bhargava *et al.*, 1970; Dholaria and Joshi, 1972; Khangura and Sadhu, 1972; Dholaria *et al.*, 1973). In the present study, the adverse soil conditions prevailing during the summer season might have affected the pod set and pod yield of the long duration interspecific hybrids. A repetition of the trial during *kharif* season will bring out the full yield potential of the hybrids.

Out of seven yield characters studied, higher hybrid mean than parental mean was observed for total number of branches, number of mature pods, pod yield per plant and lesser values for plant height, shelling percentage and hundred seed weight.

5.3.2 Heritability in narrow sense

Narrow sense heritability is a useful tool for predicting the transmission of characters from the parents to offspring. It also gives the extent of additive genetic variation compared to other components of variation for a character.

In the present study, heritability in narrow sense was very high for all the characters except for pod yield per plant and for number of mature pods which was in agreement with the study of Basu *et al.* (1986a). Ali and Wynne (1994) also reported high heritability for seed weight and early

maturity. High heritability in these characters has indicated that they are controlled by additive gene action and phenotypic selection can be exercised to improve them.

Pod yield registered the lowest heritability estimate of 47.84 per cent. This may be due to the fact that yield is a complex character determined by direct and indirect effects of several attributes which in turn are highly influenced by environment.

5.3.3 Combining ability

Combining ability measures the potentiality of parents in hybrid combinations. When a character is controlled by intra-allelic interaction, additive effects have a major role and parents can be selected based on *per se* performance. But when non allelic interaction governs a character, the selection of parents based on combining ability gains importance.

5.3.4. GCA and SCA variances

In this study characters like days to 50 per cent flowering, plant height, total number of branches and shelling percentage recorded a higher magnitude of GCA variance over SCA variance indicating predominance of additive gene effects in the inheritance of these characters. On the other hand the variance components of SCA were higher than that of GCA for pod yield, number of

mature pods and hundred seed weight. The results obtained in this study are similar to those of Sadhu and Khehra (1976), Singh and Labana (1980). Labana *et al.* (1981), Labana and Singh (1983) for pod yield, pod number and 100 kernel weight where as Layrisse *et al.* (1980), Wynne and Isleib (1980) reported that additive effects were more important than non-additive effects for pod yield and 100 kernel weight. The preponderance of additive effects for vegetative characters like plant height, number of branches etc. had also been reported by Wynne *et al.* (1970), Singh and Labana (1980) and for plant height alone by Manoharan *et al.* (1985).

To harness both additive and non-additive type of gene actions for different characters, pedigree method of breeding with selections in advanced generations will be effective. Natarajan *et al.* (1990) has suggested intermating of F_2 (biparental approach) in the superior crosses of green gram, which will generate higher variability for selecting transgressive segregants for high yield. Katiyar *et al.* (1987) have suggested biparental mating followed by recurrent selection to fix the genetic variability of non fixable nature in peas as this methodology is likely to hasten the rate of genetic improvement.

5.3.5 General combining ability effects

The gca effects of parents for different characters showed that ICG-7269 and JL-24 were good combiners for pod yield. JL-24 also recorded significant and positive gca effects for all characters except for days to 50 per cent flowering, total number of branches and plant height.

High gca effects are mostly due to additive gene effects (Griffing, 1956). Hence JL-24 and ICG-7269 could be considered as best general combiners in breeding programmes for development of improved varieties by pedigree selection or its modified approaches. ICG-7269 has the added advantage of short seed dormancy and this line can serve as a donor for seed dormancy as well as a good combiner for yield attributes.

Virginia bunch genotype TMV-10 and Virginia runner ICG-4861 were parents with good general combining ability for total number of branches while ICG-1037, ICG-7269 and CO-2 were good combiners for plant height. JL-24 was the best combiner for hundred seed weight. ICG-7269 and TMV-10 were good combiners for number of mature pods per plant.

5.3.6 Specific combining ability effects

Significant and positive sca effect for pod yield was recorded in four crosses of which two were intra subspecific crosses (VRI-3/TG-17 and CO-2/ICG-7269) and two were inter subspecific crosses (JL-24/ICG-4861, JL-24/ICG-1037).

None of the crosses showed significant positive sca effects for days to 50 per cent flowering, plant height or total number of branches. Cross JL-24/ICG-1037 gave positive sca effect for number of mature pods, pod yield and hundred seed weight and cross VRI-3/TG-17 for pod yield, shelling percentage and hundred seed weight.

Specific combining ability effects represent dominance and epistatic components of variation which are not fixable. For the improvement of self pollinated crops high SCA effect for yield and related attributes will be useful only if commercial exploitation in the form of hybrid varieties is feasible. In groundnut flower structure is not amenable for this. Natarajan *et al.* (1990) suggested that if crosses showing high sca effects involved, both parents which were good general combiners, they could be exploited for varietal improvement programme. But in the present studies such a cross with high sca effect and both the parents being good general combiners, could not be pointed out.

5.3.7 Heterosis

Among the three measures of heterosis, heterosis over better parent can be considered as the most efficient estimate, since it records only minimum percentage increase. For heterobeltiosis in pod yield maximum expression of 77.42 per cent was observed in CO-2/ICG-7269

followed by JL-24/ICG-4861 (56.35 per cent), JL-24/ICG-7269 (49.39 per cent), VRI-3/TG-17 (49.10 per cent) and JL-24/ICG-1037 (44.56 per cent). Thus out of fifteen hybrids only five hybrids have recorded significant heterobeltiosis. Among this three are intra subspecific Spanish x Spanish cross and only two are inter subspecific crosses. Several workers (Syakudo and Kawabata, 1963; Parker *et al.*, 1970; Durgaprasad, 1981; Isleib and Wynne, 1983) have reported significant heterosis in yield in intersubspecific crosses, but very few reports are there regarding the heterotic response of intra-subspecific Spanish x Spanish crosses. Reddy (1982) has reported Spanish x Spanish crosses were equally heterotic and comparable to other crosses. Basu *et al.* (1986b) studied heterosis in inter and intra-subspecific crosses and have recorded high desirable negative heterosis for days to 50 per cent flowering and high positive heterosis for number of mature pods and pod yield in Spanish x Spanish crosses. Present study has also highlighted the heterotic potential of Spanish x Spanish crosses.

It is notable that all the crosses with tester ICG-7269 (an exotic line from Zimbabwe) are giving significant heterobeltiosis in all the three crosses. This can be attributed to the geographical diversity. Gibbons *et al.*, (1972) considered Africa as a secondary centre of diversity. Layrisse *et al.* (1980) and Isleib and Wynne, (1980) have also reported heterosis in crosses having parents from different centres of diversity.

In groundnut, whatever be the magnitude of heterosis, at present it cannot be exploited for commercial production of hybrid varieties because of the restrictions in the flower structure, like, the cleistogamous nature, inadequate pollen supply, difficulties in transfer of pollen from one genotype to the other etc. Arunachalam *et al.* (1980) and Manoharan *et al.* (1990) have suggested that heterotic crosses may produce desirable transgressive segregants in advanced generations.

5.3.8 Comparison of *per se* performance, heterosis and sca effect of groundnut hybrids

The mean performance, significant and positive heterobeltiosis and significant and positive sca effect of the best few hybrids for pod yield, number of mature pods hundred seed weight and days to 50 per cent flowering are presented in Table 47 and Plates 10-13.

JL-24/ICG-4861, JL-24/ICG-1037, CO-2/ICG-7269 are the three cross combinations that have recorded high *per se* performance for pod yield, besides significant heterobeltiosis and sca effect. Among them JL-24/ICG-1037 has also recorded high sca effect for number of mature pods and hundred seed weight. JL-24/ICG-4861 recorded high mean and high SCA effect for hundred seed weight. CO-2/ICG-7269 recorded both high mean and heterosis for number of mature pods and heterosis for total number of branches.

Table 47 Superior hybrids for *per se* performance, heterobeltiosis and sca effect

Per se performance	Heterobeltiosis	sca effect
Pod yield		
JL-24/ICG-4861	CO-2/ICG-7269	JL-24/ICG-4861
	JL-24/ICG-7269	VRI-3/TG-17
JL-24/ICG-7269	JL-24/ICG-4861	JL-24/ICG-1037
JL-24/ICG-1037	VRI-3/ICG-7269	CO-2/ICG-7269
CO-2/ICG-7269	JL-24/ICG-1037	
Number of mature pods		
VRI-3/ICG-7269	CO-2/ICG-7269	VRI-3/ICG-7269
CO-2/ICG-7269	VRI-3/ICG-7269	JL-24/ICG-1037
JL-24/TMV-10		
Hundred seed weight		
JL-24/ICG-1037	VRI-3/ICG-1037	JL-24/ICG-4861
JL-24/ICG-4861		VRI-3/TMV-10
JL-24/ICG-7269		VRI-3/TG-17
VRI-3/TG-17		JL-24/ICG-1037
		CO-2/TG-17
Days to 50 per cent flowering (in the negative direction)		
JL-24/ICG-7269	JL-24/ICG-1037	-
VRI-3/ICG-7269	CO-2/ICG-4861	
CO-2/ICG-7269	VRI-3/ICG-4861	

Plate 10a F_1 plant of cross JL-24/ICG-4861

Plate 10b F_1 plant of cross JL-24/ICG-7269


JL 24
X
ICG - 4861


JL 24
X
ICG - 7269

Plate 11a F_1 plant of cross JL-24/ICG-1037

Plate 11b F_1 plant of cross CO-2/ICG-7269


JL 24
X
ICG - 1037


CO - 2
X
ICG - 7269

Plate 12a F_1 plant of cross VRI-3/ICG-7269

Plate 12b F_1 plant of cross CO-2/TG-17


VRI - 3
X
ICG - 7269


CO - 2
X
TG - 17

Plate 13a F_1 plant of cross VRI-3/TG-17

Plate 13b F_1 plant of cross JL-24/TMV-10


VRI 3
x
TG 17


JL 24 x TMV 10

5.4 Analysis of seed dormancy

5.4.1 Duration of dormancy in 28 groundnut genotypes

The germination studies revealed that genotypes lacked definite periodicity in the expression of dormancy. But it was observed that the four dormant *fastigiata* genotypes recorded only less than 30 days rest period while the *hypogaea* genotypes recorded more than 30 days dormancy. Most of the workers, who have evaluated *fastigiata* genotypes for their dormancy have also reported the range of dormancy between two weeks to four weeks (Varisai Muhammed and Dorairaj, 1968; Huang, 1982; AICORPO, 1984; Ashok Kumar *et al.*, 1991; Vindhiyavarman and Arjunan, 1990). The range of dormancy in *hypogaea* genotypes observed was between 40 and 80 days. Zade *et al.* (1986) observed it between 40 and more than 70 days and Presanna Kumari (1992) recorded the same upto 110 days.

The effect of season and the germination media on germination was not fully brought to light by the present studies. A daily count of germination would be necessary for a clear understanding of the effect.

Three genotypes, ICG -7269, TG-17 and TG-15 were found to combine high yield short duration and seed dormancy in the present study. The wide range in the duration of dormancy and presence of dormancy even in *fastigiata* genotypes showed the breeding prospects for incorporation

of desirable levels of dormancy, in the popular, short duration, bunch cultivars.

5.4.2 Dormancy studies in early generations

Inheritance of dormancy in crop plants has received relatively little attention in the past. A possible reason may be the fact that genetic analysis of seed dormancy in early generations is complicated. In the early generations, a non-endospermous seed consists of two genetically different tissues (a) embryo which results from the fertilization of the microspore and the megaspore; (b) the testa with the maternal genetic constitution. In the case of F_1 seed, embryo is heterozygous while the testa has maternal genetic constitution. Since dormancy can be inherent in the embryo or can be imposed by the extra-embryonic tissues, its genetics may be complex and the chance for a true mendelian inheritance is remote.

Physiological factors which operate in the mother plant is likely to affect the phenotype of the embryo. Physiologically, seed dormancy in groundnut is reported to be the result of hormonal balance between a germination inhibitor abscisic acid produced in the aerial part of the plant, (which then accumulates in the cotyledons and the seed coat) and a germination activator, ethylene produced by the embryo through the action of cytokinin during seed imbibition (Ketring and Morgan, 1972).

In a hybrid seed the genotype of the embryo and that of the mother plant are different. In the subsequent generations the genotype of the embryo is always one generation advanced than the generation of the mother plant on which they are borne. The original hybrid seeds possess F_1 embryos, seeds of F_1 plants possess F_2 embryos and seeds of F_2 plants posses F_3 embryos. Johnson (1935) while studying on inheritance of seed dormancy in *Avena fatua* x *A. sativa* hybrids has stated that in dormancy studies with different generations, one deals primarily with generations of embryos, rather than mature plant generations and one has to look upon the embryo and the plant developed from it as the same individual in different stages of development.

The recent advances in the biochemical aspects of seed dormancy has brought to light the hormonal control of the trait. Presence of inhibitors in the testa (Sondheimer *et al.*, 1974; Hayashi and Himeno, 1973; Hayashi, 1987), which is a maternal tissue, and translocation of inhibitors from mother plant to seed (Ihle and Dure, 1972; Ketring and Morgan, 1972) have been reported in several crops. These evidences indicate that not only the embryo genotype but also the maternal genotype are involved in the expression of this character. Hence in the present case, dormancy studies were conducted in the embryonic generations (F_1 seed, $BC_{1(ND)}$ seed, $BC_{1(D)}$ seeds) and in normal mature plant generations (F_2 seed, F_3 seed, $BC_{1(ND)}$ F_2 seeds, and $BC_{1(D)}$ F_2 seeds).

In groundnut, due to the indeterminate nature of subspecies *hypogaea* or its derivatives, the pods of same plants vary in maturity (Nautiyal *et al.*, 1993). The dormancy of seed also appears to be dependent upon its position in the pod. Toole *et al.* (1964) and Patil (1967) reported that in two seeded groundnut pods the basal seed always had more dormancy. This reveals that in groundnut, seeds within a plant differ individually in their degree of dormancy, which is termed as heteroplasty or polymorphism by Bewley and Black (1982). This phenomenon further complicates the data collection. In the present study, from each plant uniformly matured pods, selected based on the browning on the inside of pericarp, were used, to minimise the difference in the maturity of seeds taken for germination test.

Dormancy of genotypes was assessed by germination tests. Many different approaches to analysing seed germination have been employed for various purpose (Scott *et al.*, 1984). The methods of evaluation for pre-harvest sprouting resistance in wheat breeding programmes suggested by Paterson *et al.* (1989), chosen for the present study are well suited to plant breeding objectives. They suggested that rather than conducting germination tests for several weeks, data collection can be terminated after a sufficient duration, to be confident of including the period of maximum difference between genotypes. In the present

studies observations were taken at 10 day interval upto 30 days, beyond which in some of the crosses the differences between genotypes were negligible (Table 38 and 39). The point in a germination test at which genotypes are compared is the time at which the difference between the corresponding parental lines accounts for a maximal portion of total phenotypic variance (Paterson and Sorrells, 1990). In the present study maximum difference between the dormant and non-dormant parents was observed for 10D germination (Table 37). Hence 10D germination data was utilized for comparison of genotypes.

Bewley and Black (1982) recognised basically two types of dormancy, involving different dormancy mechanism. Embryo dormancy, where control of dormancy resides within the embryo itself, and coat imposed dormancy in which dormancy is maintained by structures enclosing embryo ie. testa. He also stated that in certain species both types of dormancy might exist simultaneously or consecutively.

The mechanism of dormancy in groundnut reported by a few workers, appears to be contradictory. Toole *et al.* (1964) and Sengupta *et al.* (1977) have demonstrated that removal of seed coat helped in the loss of dormancy. Patil (1967) has shown that excised embryos from dormant seeds irrespective of the stage of development had a very high percentage of germination, while intact seeds did not

germinate. From this it can be inferred that the factor for dormancy in groundnut is situated in the seed coat. In contrast to this, Vaithalingam and Rao (1973) observed presence of germination inhibitors in cotyledons and primary axis showing that dormancy resided in the embryo. Presannakumari (1992) demonstrated that removal of testa enhanced germinability in dormant seeds upto 58 per cent where as control seeds recorded zero germination. The excised embryonic axis without cotyledons recorded 86.05 to 95.12 per cent germination. This indicated that both embryo dormancy as well as coat imposed dormancy are present in the seeds of groundnut.

In the present study, presence of dormancy in the F_1 seed borne on the non dormant female parent (Table 34) indicated that embryo dormancy was also present in groundnut in addition to testa imposed dormancy. Here, in the F_1 seed, the inhibitory maternal effect could be completely ruled out since the maternal genotype was non-dormant by nature. The expression of dormancy of the F_1 seed may be entirely due to the heterozygous genotype of the embryo. The manifestation of dormancy may be probably by way of metabolic block in the production of germination activator, which is reported to be ethylene, by Ketring and Morgan (1972). This aspect needs further study. The behaviour of F_1 seed clearly proved that dormant nature is dominant over non-dormancy. In inter-subspecific crosses in

groundnut, dormancy of F_1 seed can be taken as a marker character for selecting true hybrids, if the dormant subspecies *hypogoea* is taken as male parent. A seed marker is advantageous over morphological markers, as elimination of selves, later from the laid out genetic experiments in the field, can be avoided.

The dispersed frequency distribution of F_1 generation (F_2 embryonic generation) and F_2 generation (F_3 embryonic generation indicated that dormancy could be treated as a quantitative trait with multiple gene control of the trait. The comparison of average germination of F_1, F_2 and backcross generations, to the non-dormant parent revealed that dormancy was largely dominant. Except in the case of $BC_{1(ND)}$ generation in two crosses, all the four generations of ten crosses were significantly different from the non-dormant parent (Table 42). A comparison of average 10D germination percentage of F_1 generation and F_2 generation showed that F_1 generation had a stronger dormancy than F_2. Among the two back cross generations $BC_{1(D)}$ generation expressed a stronger dormancy than $BC_{1(ND)}$ generation.

Stokes and Hull (1930), Hull (1937), John *et al.* (1948) and Ramachandran *et al.* (1967) have conducted their studies in seeds borne on F_1 plants and not in F_1 seeds. They have reported the F_1 population (F_2 embryonic generation) being intermediate between parents and dormancy

can be partially or incompletely dominant over non-dormancy. They have reported a wide range of variability within F_2 population with non-dormant, intermediate and completely dormant progenies, indicating multiple gene control of the trait. In the present study also a complete phenotypic dominance of the trait in the F_1 generation was not seen. Nine to 34 per cent of the seeds of F_1 plants in various crosses germinated indicating incomplete dominance. This might be due to the genotypic differences of segregating embryos carried by the F_2 seeds borne on these F_1 plants and its interaction with maternal genotype.

5.4.3 Generation mean analysis

Generation mean analysis was conducted in ten crosses involving two non-dormant and five dormant parents with the objective to understand the types of gene effects for the trait, seed dormancy. The analysis detected the presence or absence of non allelic interactions for the trait. This genetic analysis provides information on the mean effects, as well as additive and dominance effects when a simple additive dominance model is satisfied by scaling tests and in addition, it provides information on additive x additive, additive x dominance and dominance x dominance interaction effects when the digenic model is satisfied.

Gene effects on seed dormancy in groundnut was previously studied by Khalfaoui (1991) in a single Spanish x Spanish cross. The limitation of such a study with just two genotypes will restrict the universality of its application. In the present case crosses were effected with parents having different levels of dormancy belonging to different subspecies, which would ultimately give a more generalised picture of the gene action for the trait.

As discussed earlier, both maternal genotype and embryonic genotype are involved in the expression of dormancy. Since the number of hybrid seed and back cross seed, produced per female plant/F_1 plant was very few (three to four seeds per plant) the germination studies could not be taken up on a per plant basis and hence generation mean analysis could not be conducted using embryonic generations. In this study for generation mean analysis, per plant values of mature plant generations were used with the assumption that maternal genotype determined the character. A similar situation has been discussed by Paterson and Sorrells (1990) while studying the inheritance of seed dormancy in white kernelled wheat.

In this study the arc sine transformation of decimal fraction of germination percentage on 10th day and 20th day were utilized for generation mean analysis. From the 30th day onwards, in some of the crosses, there was no

appreciable difference in the germination percentage of parents. For the sake of discussion the estimates from 10D germination was used, since at this point, the parents were showing maximum difference. Similar procedure was adopted by Paterson *et al.* (1989).

The results of the scaling test and joint scaling test showed that in seven out of ten crosses for 10D germination analysis and nine out of ten crosses in 20D germination analysis, the simple additive dominance model was inadequate showing that predominantly non-allelic or epistatic gene action was present for dormancy. Khalfaoui (1991) has also reported the presence of non-allelic interactions for dormancy in a Spanish x Spanish cross studied by him.

In the crosses VRI-3/TMV-10, JL-24/ICG-4861 and VRI-3/ICG-1037 simple additive dominance model was found to be adequate. In VRI-3/TMV-10 dormancy was governed by additive gene effects where as in the latter two, both additive as well as dominance effects were evident.

In the crosses which indicated presence of epistasis, additive x additive type of epistasis was present in cross JL-24/TMV-10, additive x dominance type was present in cross VRI-3/ICG-4861, both additive x additive and dominance x dominance in VRI-3/ICG-7269 and both additive x dominance and dominance x dominance in JL-24/ICG-7269.

In three out of six crosses in 10D germination analysis and seven out of nine crosses in 20D germination analysis, dominance effect (h) and dominance x dominance effect (l) estimates have opposite signs indicating that non- allelic interactions were essentially duplicate in nature in these crosses. In rest of the crosses where (h) and (l) effects were in the same direction indicating that complementary epistasis governed the trait. Considering the allotetraploid nature of groundnut and control of several quantitative traits by duplicate genes (Hammons, 1973; Wynne *et al.*, 1975), the presence of duplicate epistasis can be expected to govern seed dormancy also. Cahaner *et al.* (1979) and Wynne *et al.* (1970, 1975) have also recorded epistatic interaction governing many of the yield traits.

The preponderance of epistatic effects observed for seed dormancy indicated that the trait was non-fixable and selection in early segregating generations adopting simple selection procedures might not yield good results. But selection postponed to advanced generations would be fruitful in fixing the trait.

High yield, short duration with short seed dormancy will be an ideal criteria for selection for Kerala conditions. To fit into the short cropping seasons of Kerala a short duration genotype of 95 to 105 days will be ideal (Pushkaran and Nair, 1985). For achieving this, the

selection for bunch growth habit of subspecies *fastigiata* have to be pursued in the segregating generation of inter-subspecific crosses.

A short dormancy period of 20 to 25 days only is necessary for bunch varieties so that the dormancy in the seeds of one crop will not hinder germination in the next crop. The dormancy of seed should be just sufficient to prevent *in situ* germination, in case of untimely rains near harvest.

The selection of dormant bunch genotypes from segregating generations of inter subspecific crosses is extremely difficult (Nautiyal *et al.*, 1993). Dormancy is found to vary with degree of maturity, position of seed in a pod (apical or basal) or in the plant, even in a fixed genotype and in a segregating generations it will be all the more varying. It is observed that in some bunch genotypes the seed will germinate only gradually when attached to mother plant which is green healthy and well watered near the harvest period, indicating a false type of dormancy reported as fresh seed dormancy in ICRISAT (1981). But this is broken by seed drying after harvest. In the field if there was a stress period like disease or drought followed by rain, germination was found to occur in the field itself. Such type of dormancy is not agronomically

useful. This was called as `fresh seed dormancy by Wadia *et al.* (1987). They have suggested a laboratory technique to identify sources of seed dormancy in *fastigiata* genotypes derived from the crosses between the genotypes belonging to two subspecies.

Inter sub-specific hybridisation to obtain dormant *fastigiata* types has been successfully attempted by Ramachandran *et al.* (1967); Varisai Muhammad *et al.* 1969; Reddy *et al.* (1985) and ICRISAT (1981). The observation of dormant seeds beyond thirty days dormancy in the F_1 and F_2 and heterosis of Spanish x Spanish crosses gave hope for obtaining high yielding dormant *fastigiata* segregants without much change in the crop duration.

Summary

SUMMARY

Genetic analysis of seed dormancy and productivity in groundnut was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 1992-95, with a view to understanding the gene action of yield contributing traits and seed dormancy, so as to suggest appropriate breeding methodology and parental combinations, to evolve dormant, high yielding and early maturing varieties.

Fourteen dormant and fourteen non-dormant genotypes were evaluated for two seasons for nine biometric traits and seed dormancy. Three non-dormant, short duration genotypes were selected as lines and five dormant, divergent genotypes as testers. Crosses were effected in a 3x5 line x tester fashion to yield fifteen hybrids. In ten crosses, back crosses to both the parents yielded $BC_{1(D)}$ and $BC_{1(ND)}$ generations. The six generations in ten crosses, P_1, P_2, F_1, F_2, $BC_{1(ND)}$, $BC_{1(D)}$ were evaluated for seed dormancy by germination tests. The data were subjected to statistical analysis.

The following conclusions were drawn from the study:

Wide range of variability existed among the genotypes for the nine biometric traits studied. The *fastigiata* genotypes performed significantly better than *hypogaea*

genotypes with regard to pod yield under Vellanikkara conditions. The best yielders among the twenty eight genotypes were VRI-3, JL-24 and CO-2. The genotypes which could be utilized as donors for specific traits were identified as ICG-459, TG-3 and JL-24 for shelling percentage, TMV-10, TG-6 and TG-15 for oil content, ICG-8281, TG-15 and TG-17 for hundred seed weight and ICG-128, ICG-7269 and ICG-5461 for early maturity.

Broad sense heritability estimates were high for almost all the biometric traits studied. For total number of branches and hundred seed weight, both heritability and genetic advance estimates were consistently high for both the seasons confirming that improvement of these two very important yield components was possible by simple phenotypic selection.

Wide genetic diversity existed among the 28 genotypes studied. The genotypes were grouped into four clusters in both the seasons. The clustering pattern was in general based on subspecific status. The genotypes belonging to cluster I and II of *kharif* seasons and III and IV in *rabi* seasons were having maximum genetic divergence.

Line x tester analysis revealed that variances due to parents, hybrids and parents vs. hybrids were highly significant for all characters except shelling percentage. The variance due to lines was significant for all the

characters except total number of branches, shelling percentage and pod yield. Variance due to testers was significant for all characters except shelling percentage. The variance due to lines vs. testers was significant for all characters except pod yield per plant.

Four hybrids recorded significantly superior pod yield over hybrid mean viz. JL-24/ICG-7269, CO-2/ICG-7269, JL-24/ICG-4861 and JL-24/ICG-1037. Out of seven characters studied, higher hybrid mean than parental mean was observed for total number of branches, number of mature pods, pod yield per plant and lesser values for plant height, shelling percentage and hundred seed weight.

Characters like days to 50 per cent flowering, plant height, total number of branches and shelling percentage recorded a higher magnitude of GCA variance over SCA variance indicating predominance of additive gene effects governing these characters. On the other hand the variance components of SCA were higher than that of GCA for pod yield, number of mature pods and hundred seed weight. Narrow sense heritability estimates were also high for all characters except pod yield per plant and number of mature pods indicating that non-additive gene action governed these characters. To harness both additive and non-additive type of gene action for different characters pedigree method of breeding with selections in advanced generations would give better results. Biparental mating followed by recurrent selection would be an ideal method of

breeding to fix high yield which is found to be governed by non-additive gene action.

The analysis of gca effects of parents revealed that JL-24 and ICG-7269 were good combiners for pod yield. JL-24 also recorded significant and positive gca effects for all characters except total number of branches and plant height. ICG-7269 possessed the added advantage of short seed dormancy and could serve as a donor for seed dormancy as well as a good combiner for yield. Significant positive sca effects were recorded for number of mature pods per plant, pod yield per plant, shelling percentage and hundred seed weight. JL-24/ICG-4861, VRI-3/TG-17 and JL-24/ICG-1037 were the crosses which recorded maximum sca effect for pod yield.

Relative heterosis, heterobeltiosis and standard heterosis were observed for all characters in most of the crosses. Significant heterobeltiosis for yield was observed in five out of fifteen crosses. CO-2/ICG-7269, JL-24/ICG-7269, JL-24/ICG-4861 were the crosses which gave maximum heterobeltiosis for yield.

The range of dormancy in 14 dormant genotypes varied from 20 to 80 days. The *fastigiata* genotypes recorded only less than 30 days of dormancy while the dormancy in *hypogaea* genotypes ranged from 40 to 80 days ICG-7269, TG-17 and TG-15 were the promising genotypes combining high yield potential, seed dormancy and short duration. After multilocational testing these genotypes can be recommended

for general cultivation in areas where untimely rains are likely to occur at crop maturity.

Investigations on dormancy studies in different generations showed that dormancy is an inherited character. The hundred percent dormancy of the F_1 seeds indicated that dormancy was dominant over non-dormancy in groundnut. The dormancy of F_1 embryo in a non-dormant maternal genetic background indicated that embryo dormancy was also present in groundnut in addition to coat imposed dormancy so far reported. The dispersed frequency distribution of F_1 generation (F_2 embryonic generation) and F_2 generation (F_3 embryonic generation) indicated that dormancy was a quantitative trait and multiple genes might be controlling the trait. The significant difference of F_1, F_2, $BC_{1(ND)}$, $BC_{1(D)}$ generations from non-dormant parents revealed that dormancy was largely dominant.

The generation mean analysis over six generations has indicated that, predominantly, non-allelic gene action governed seed dormancy. All the three types of epistatic effects, viz., additive x additive, additive x dominance and dominance x dominance were prevailing in different crosses. The interactions were essentially duplicate in nature in majority of the crosses. The pre-ponderance of epistatic effects observed for seed dormancy indicated that the trait was non-fixable and hence pedigree method, with selection postponed to advanced generations would be fruitful for the improvement of the trait.

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GENETIC ANALYSIS OF SEED DORMANCY AND PRODUCTIVITY IN GROUNDNUT (*Arachis hypogaea* L.)

By

TESSY JOSEPH

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

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ABSTRACT

Investigations on Genetic analysis of seed dormancy and productivity in groundnut (*Arachis hypogaea* L.) were carried out in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara from 1992-95. The objective of the study was to find out the gene effects of biometric traits and seed dormancy in groundnut, so as to suggest appropriate breeding methodology and parental combinations to evolve dormant, high yielding and early maturing varieties. The findings of the study are briefed below.

Evaluation of 28 genotypes (14 dormant and 14 non dormant) for two seasons revealed that wide range of variability existed among them. Donors for specific traits were identified. The genotypes were also genetically diverse and could be grouped into four clusters.

The line x tester analysis with three lines and five testers revealed that additive gene effects governed most of the characters except pod yield and number of mature pods, for which, non additive gene effects were important. To harness both the types of gene effects pedigree method followed by selection in advanced generations will be fruitful.

Analysis of gca effects of parents revealed that JL-24 and ICG-7269 were good combiners for yield. Good combiners for specific traits were also identified. Significant positive sca effects were recorded for the pod characters.

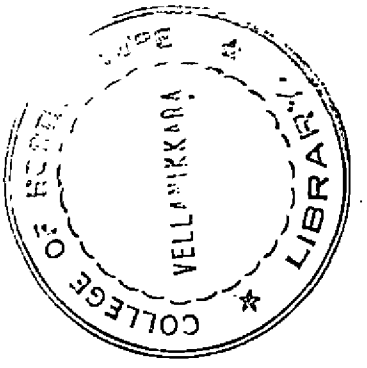
Relative heterosis, heterobeltiosis or standard heterosis were observed for all characters in most of the crosses. Significant heterobeltiosis for yield was observed in five crosses.

The dormancy studies in different generations revealed that dormancy is dominant over non dormancy. The dispersed frequency distribution in F_1 and F_2 indicated that dormancy is a quantitative trait and multiple genes might be controlling the trait.

The generation mean analysis over six generations indicated that predominantly non-allelic gene interactions were present for seed dormancy. Hence pedigree method of breeding with selection from advanced generations will be ideal for fixing the character.

EFFECT OF DIFFERENT MULCHES ON SOIL TEMPERATURE AND SOIL WATER RETENTION IN RELATION TO SEEDLING EMERGENCE AND CROP GROWTH

By
JAYASREE, P.



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VELLAYANI
TRIVANDRUM

1987

DECLARATION

I hereby declare that this thesis entitled "Effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth" is a bonafied record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma associateship, fellowship or other similar title, of any other University or Society.

P. JAYASREE

Vellayani,

June, 1987.

CERTIFICATE

Certified that this thesis entitled "Effect of different mulches on soil temperature and soil water retention in relation to seedling emergence and crop growth" is a record of research work done independently by Smt.P.Jayasree under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

Uncertain water availability, unstable crop prices, environmental constraints and increase in the cost of energy and labour has overwhelmed the present day farmers to a great extent. Water has become such an important commodity and its management is the responsibility of the farmers, to provide the proper amount of water and air for his crops.

One important dimension of land quality is its capacity to hold the inputs that are applied and to ensure their use by the plant. In the case of water, this quality is called water holding capacity. To maintain favourable conditions for crop growth, management of physical conditions of soil is highly necessary. The factors to be considered are moisture, aeration, temperature and the resistance to root penetration to the depth, normally reached by the given crop.

Moisture stress in plants, is a resultant of combined effects of soil moisture stress in the root zone, resistance to water movement in the plant, stomatal control, and

atmospheric evaporation demand (Sivakumar and Virmani, 1979). Soil water in the upper layers, more than any other factor, primarily determines seed germination and establishment of seedlings. Water absorption by seeds, is the first event in the process of seed germination. It is influenced by soil temperature through its effects on the viscosity of the water and permeability of seed coat (Chaudhary et al., 1971).

The moisture situation of the soil can be modified in a variety of ways. The methods used may be direct application or removal of water or through changes in structure and temperature of the soil. The quality of moisture available depends both on the amount and distribution of soil water and on the temperature.

The amount of water in the soil has an indirect effect on soil temperature which can be managed to some extent by using mulches. The soil temperature has great influence, right from seed germination to yielding stage of plants. Soil nutrients and plant uptake are also influenced by soil temperature. Soil temperature has a profound effect on the water supplying power of the soil. The free energy of water increases with temperature.

Under rainfed conditions, especially after the rainy season, excessive rate of water loss by evaporation should be minimised to increase the water availability and water use efficiency of crops. Mulches have an important role in influencing the above factors and also the physical and chemical properties of soil.

Evaporational losses of water from soil is considerably higher in semiarid regions than humid regions and constitute single largest loss of water from field. In higher moisture regimes, more water is used for evaporation rather than crop production, reducing water use efficiency (Selvaraj, 1976). Losses by evapotranspiration are irrecoverable and are usually considered the net water requirement.

Ways and means of cutting this waste had been the object of many investigations in the past. Many have tried in creating a soil mulch and spreading foreign materials over the soil surface with varying degrees of success. The economic aspect of the problems i.e., the possibility of growing crops in more areas with the same irrigation water is of vital importance. For most of the agricultural soils, the reduction in evaporation and temperature management

can be brought about by some cultivation practices like mulching and tillage. A generous amount of residues placed in and above the soil can improve the soil conditions. Mulches have an important role in temperature management and water retention. Numerous types of mulches, from rocks and stones to slowly decomposing materials like wood shavings, sawdust and chips are tried (Lamb and Chapman, 1943).

Mulching protects the soil from rainfall impact, decreases evaporation and reduces the soil temperature fluctuations. Indirectly, mulching increases the moisture content of the soil, raises its heat capacity and helps in slower warming up of the soil in spring season.

It has been reported that the soil covering conserves soil moisture, keeps soil temperature higher than bare soil and decreases frost penetration.

The effect of a given mulch depends on its colour, and its perviousness to water. Crop residue mulches even in small quantities decrease evaporation in the initial stage but large amounts are required to obtain water saving

over extented period (Prihar and Arora, 1960). Appreciable conservation of moisture could be achieved by concentrating on crop residue on a portion of soil surface as well as by larger application of water.

The comparative efficacy of these mulches may vary under different conditions depending on different aspects. Some mulches act as nutrient suppliers also. Paddy straw can provide about 0.05 to one per cent phosphorus. Certain mulches like rice hull act as reflectant preventing the heating up of soil by radiation.

Present study has been undertaken with the following objectives:

1. To study the effect of different mulches on the physico chemical properties of the soil.
2. To study the effect of mulches on soil temperature and seedling emergence.
3. To investigate the effect of mulches on soil moisture characteristic.
4. To study the interaction effects of soil temperature and soil water on plant growth and yield, using Bhindi (Abelmoschus esculentus) as test crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Several processes like water transportation, movement of nutrients and Nitrification are affected by soil temperature. Soil temperature has profound influence on seed germination, root growth, shoot growth, nutrient uptake and crop yield. Research informations from different studies, relating soil temperature and plant growth, mulch treatment effect on soil water and temperature, nutrient uptake and other parameters relating to plant growth and yield, are reviewed here; under different topics.

2.1. Effect of different mulches on soil physical properties, with emphasis on soil temperature and soil water.

2.2. Soil temperature - its influence on seedling emergence, plant growth; yield and nutrient uptake.

2.3. Soil moisture impacts on soil temperature and consequent effect on plant growth and yield.

2.4. Influence of soil moisture and soil temperature on root growth of plants.

2.1. Effect of different mulches on soil physical properties, with emphasis on soil temperature and soil water.

Mulches were applied to crops from the dawn of Agriculture; mainly with a view to conserve the soil moisture. Scientific investigations on the use of mulches was directed mainly to the soil conservation aspects, as well as the changes in soil structure and effect on soil temperature, increase in organic content of the soil, microbial activities and availability of nutrients.

2.1.1 Comparative effect of different mulching materials.

Numerous type of mulches have been tried from rocks and stones to slowly decomposing materials like saw dust, chips and wood shavings, alfalfa and bean straw, hay and manures (Lamb and Chapman, 1943).

Using dry leaves as mulch, the cost of irrigation and weeding can be reduced and soil structure can be improved (Rangacharylu and Nagabhushanam, 1960).

The economy in weed control using mulches had been proved by Green (1961) Knake and Slife (1962) and Sanjeevi (1963).

The greatest amount of research with mulches were with cheap and readily available crop residues and other plant waste products like straw, stover leaves, wood chops etc. and found to increase the rate of infiltration of water into the soil and retain soil moisture for longer periods (Horning and Overson, 1962, Prihar et al 1968, Wiegard et al 1968).

Trials conducted by Mohanty (1977) on ginger shows that dry leaf mulches are superior to grass or soil mulch which gave best result in rhizome yield; sprouting percentage suppression of weed and prevention of soil erosion.

Bhatacharjee et al (1979) showed that by using straw mulch number of irrigations can be decreased by one to two.

Ross et al (1985) proved that lighter coloured more reflective mulches are less efficient than darker ones. Detailed study conducted by him showed that medium and heavy mulches reduced the water loss over 6 days by 1.4 and 2.7 mm respectively.

Anon (1986) has observed that the rice hull act as the superior reflectant but appear to the the most difficult mulch to keep in position during heavy rains. In his opinion straw mulch is the most suitable mulch in South East Asia. It possesses no draw backs; except that the layer should be thin enough to permit the emerging plant to get through.

Mulches will hasten emergence and improve yield. This was proved by Vander Zaag et al (1986). They tried with different mulches in different seasons on potatoes. All mulches hastened the emergence rate and enhanced the yield.

2.1.2 Influence of mulches on soil temperature management.

The loss of heat energy from the soil is mainly by radiation, convection and evaporation of soil moisture. The mulches covering the soil protects the soil from nocturnal cooling and also prevents the evaporational loss during day time and keeps the soil cooler. Wadleigh and Gauch (1948) proved that as the soil temperature increases, the water stress also increases.

Records of soil temperature for five years kept by Kohnke (1963) at 1 to 4 and 10 inches depth in a silt loam, left bare or mulched with 1.5 t/acre straw showed that mulched soil was 1 to 2°F warmer in winter and 1 to 2°F or 3 to 4°F cooler in spring and summer than bare soil. Daily temperature fluctuations at 1 inch depth were twice as large.

An adverse effect of mulch is reported by Dorokhov (1969) that the mulching reduces the day time temperature and increases the night temperature of soil and also increased the possibility of plant injury by night frost.

The straw mulch considerably lowered the maximum soil temperature, especially when the prevailing temperature was high. The minimum temperature was only slightly affected by straw mulch (Banasel et al 1971 and Lal, 1972) mulching significantly reduced the maximum soil temperature measured at 5, 10 and 20 cm depths, where as maximum temperature was recorded by unmulched plot. Tripathi and Katiyar (1984) got the same trend in soil temperature under straw mulch which ranged from 19 - 28.7°C. Similar results were obtained by Moody et al (1985).

Observations made on soil temperature at one hour intervals by Lal (1972) indicated that there were phase differences of daily temperature fluctuations due to mulching. The maximum for unmulched plots at 5 cm depth occured at about 3 PM followed by a sharp decline; while the maximum for the mulched plots was around 4 PM with a gradual decline in the temperature.

Mehta and Prihar (1973) observed progressive decrease in maximum soil temperature with increasing rate of wheat straw mulch from 2 tonnes to 6 tonnes/ha and also the mulching reduced temperature by 7°C at a depth of 5 cm.

Venkatachalam (1976) in his experiment in soil temperature reveals that the rate of heat flow from the soil during night time is reduced considerably and heat is conserved in the soil. This is observed for higher temperatures during the morning hours in the mulched plots. Similar results have been reported by Gajendra Giri and Singh (1983).

Venkatachalam (1976) in his studies have also proved that the mulched plots recorded lower temperature during

afternoon hours than bare soil. This can be attributed to the shading affect produced by the mulches, thus shutting out the soil from direct sun light and a slower rate of heating of soil due to higher moisture content of the soil under mulches.

Studies conducted by Ghuman and Lal (1982) showed that the plastic mulches on a flat surface lowered the maximum temperature at the 1 cm depth by 5°C and rice straw mulch lowered by 16°C compared with the bare flat. These differences decreased with depth.

Redko (1982) opined that the mulches decreases day time soil temperature. Mandal and Ghosh (1983) working on mulching states that Paddy straw is more efficient in reducing soil temperature than paddy husk.

Detailed experiments conducted by Ross et al (1985) reveals that the mulches can reduce soil surface temperature upto 20°C by intercepting incoming radiation. It dessipiates this intercepted energy, quite efficiently by free convection without concomitant increase with temperature of the underlying soil surface. Mulch application

prolongs the process of slow evaporation from the soil surface. The resulting soil water content also decreases soil surface temperature through its effects on soil thermal properties.

The mulches will reduce the soil temperature in hot conditions and in winter it will keep the soil temperature higher than surroundings (Vander Zaag et al 1986)

2.1.3 Soil physical properties as influenced by mulches.

The practice of soil mulching has considerable influence on soil properties such as bulk density, water holding capacity, soil aggregation, porosity, hydraulic conductivity, infiltration etc.

Tuvelle and Mc Calla (1961) reported lower bulk density and higher waterstable aggregation in soil as a result of stubble mulch tillage than clean tillage.

Experiments conducted by Bumescu and Petracha (1969) in a soil which had a pH of 7.4 to 7.6, a humus content of 3.75 to 3.9 % and field capacity of 24.8 % and an increase

in temperature from 10 to 40°C increased the amount of resin extractable phosphorous by 50.6 %. Corresponding figures for an increase in bulk density from 1.0 to 1.4 g cm^{-3} and an increase in moisture from 11 to 31 % were 9.6 and 240.4 %.

Lal (1978) reported a higher bulk density in the unmulched plot. Again during 1980 he reported that the Bulk density of newly cleared tropical alfisols was decreased with increase in the mulch.

Kamalam and Kunju (1982) conducted experiment on the effect of mulching on bulk density. The effect on Bulk density of the soil was found to be highly significant. Mulching in general decreased the bulk density. Minimum bulk density was obtained for treatments which received mulching.

Mathen et al (1984) observed insignificant influence of mulches on the bulk density of black soil.

The effect of soil aggregate size on sugar beet seedling emergence was examined by Hammeron (1961). He found that finer aggregates (1mm) have better moisture supplying capacity.

Aggregation increased porosity and oxygen availability which are important in seedling establishment (Anderson and Kemper, 1964). Unger (1969) noted higher water stabble aggregates under mulched conditions.

Kamalam and Kunju (1982) have also reported that the mulching the soil with leaves might have improved the organic matter status of the soil which in turn might have increased the content of water stabble aggregates.

Soil temperature accelerates the infiltration rate Infiltration studies conducted by Moore (1940) reveals that maximum water content in the wetted layer decreased while the infiltration rate increased with increasing soil temperature.

Lal et al (1980) reported that the hydraulic conductivity of the newly cleared tropical alfisols was improved by mulching. Mathan et al (1984) have also reported that the hydraulic conductivity was influenced by mulches. It was 6.0 cm/hr in control plot and it varied from 6.9 to 7.0 cm/hr in mulched plot. Among the mulches there was no significant differences.

Lal et al (1980) reported that the porosity of the newly cleared tropical affisole was higher than the unmulched control. Mathan et al (1984) reported that the total porosity was significantly influenced by mulches during the first crop, the increase was 16.6 %. The difference were not significant for next two crops. The decomposed organic matter below the mulches would have contributed for the above effect.

In the case of particle size distribution the percentage of coarse and medium sand fraction were not altered, though that of very coarse sand is increased with increasing mulch rate. Scott et al (1986) have reported that the practice of soil mulching has considerable influence on soil properties and conditions.

2.1.4 Effect of Different mulches on soil water retention and release.

Mulches were applied for various crops even from very ancient days. The main intention behind mulching is to conserve moisture. Majority of writers conclude that mulches are useful in moisture conservation and tend to increase yields(Mielke et al 1978).

Desilva Asp (1957) has studied the various phases of mulching and concluded with benefits like conservation of moisture; prevention of erosion, increased thickness of cerable layer, elemination of weed competition and economy in its use were attributed to trash mulching.

Hanks and Woodruff (1958) found the primary effect of mulches as increasing the length of vapour path, and the energy absorbed by the mulch had little influence on the water loss.

Baver (1960) was of the opinion that artificial mulches greately retard evaporation and protect the soil from direct rays of the sun and wind current, consequently the soil was kept cool and the vapour pressure of the air in the mulch was more nearly the same as that within the soil air.

In contrast to the findings of the workers mentioned above, many do not corroborate the beneficial effect of mulching. Cahoon et al (1961) showed that the downward movement of water was not in any way different in the mulched plots than that in the unmulched.

Donald, L. Myhre and Joe, O. Sanford (1970) in their studies proved that mulched rough soil surface help in minimizing soil water dificits and therefore reduce the risk when growing a crop without irrigation and he found that the straw mulch was effective in increasing yield.

Mulches are used for various reasons. However, water conservation and erosion control are the most important for agriculture in dry season (Unger 1971, Black and Siddoway 1979 and Subbiah et al 1979).

Lal (1972) in his experiment with mulches in tropical soil states that the water conservation characters of soil was improved by mulches and also the mulches reduced the weed growth. Observations made by them indicated that the mulched plot had a higher soil moisture content throughout the growing season than the unmulched plots for both 0-10 and 10-20 cm depth and he also noticed that the mulching indirectly influenced the water holding capacity and moisture release characters of soil.

Mulches had beneficial and favourable influence on soil temperature and reduced soil water loss through evaporation which resulted in more available soil moisture for

a longer period which helped in improving the yield attributing characters and ultimately grain yield (Mandal and Ghosh 1983). The above result corroborated the findings of several workers (Bond and Willis 1969, Murty and Rao 1969, Lal 1974 and Mandal and Vamadevan 1975 Balyan and Malik 1980 and Gajendra Giri and Singh 1983). Mandal and Ghosh opined that the consumptive water use efficiency was lowest with straw mulch and highest with no mulch. The consumptive use efficiency was also influenced by irrigation levels and mulches.

Surface mulching is more beneficial in reducing evaporational loss of water than sub-surface mulching Abdullah Saadmodaihsh et al (1985).

2.1.5 Effect of different mulches on yield.

Significant increase in yield of potato and considerable decrease in weed growth had been reported by Saptarishi and Azariah (1954) when straw mulch was applied similar results were obtained to Fieldhouse et al (1968) in Asparagus.

Kemper (1961) worked on corn has found that the yield was approximately doubled by a 10°C rise in temperature above 20°C. In vegetable crops yield increase with use of mulches was reported by Patel (1965) and Sassogand Bianco (1967) so also Baxter (1970) and Maehara (1976) proved that the Autumn straw mulching increased the yield. They also proved that the peach trees grow better and produce more fruits on mulched soil.

Lal (1974) also proved that the higher grain yield can be achieved by mulching.

Studies on sandy loam soils at Ludhiana by Khera et al (1976) showed 13-26% increase in dry forage yield of summer maize with straw mulching. Donald L. Myhre and Joe O Sanford (1970) also got similar results.

Allen and Quisumbing (1977) showed that the mulching increases the plant growth parameters and rhizome yield and starch content in ginger. Coconut leaves were the best mulch followed by rice straw.

Mahey et al (1980) have carried out an experiment on turmeric with 3 levels of irrigation and 3 mulches. The result revealed that mulching affected growth and yield factors and economised the use of irrigation water.

Kumar et al (1983) showed an increased yield in straw berry by using cut grass as mulch.

A field experiment conducted at IARI by Krishna murari and Pandey (1983) revealed that the straw mulch improved harvest index (36.4%) than with out mulch (33.2%)

In tomatoes, the mulched plants grew taller and had more branches and a greater number and weight of fruits (Olasantan 1984).

Any type of mulch will increase yield (Vander Zaag 1986). Similar results obtained by Murty and Rao (1969) Black (1970).

2.2. Soil temperature - its influence on seedling emergence, plant growth, yield and nutrient uptake.

Soil temperature profoundly influences various stages of plant growth and soil conditions, from seed germination to yield. It influences uptake of plant nutrients and soil nutrient content.

2.2.1 Influence of soil temperatures on the seed germination.

Studies conducted by Woods (1960) showed that the germination was delayed at soil temperatures below 50°C and inhibited above 30°C, where as Segeta et al (1964) reported that different genotypes show genetic variations in minimum germination temperatures.

Relationship between temperature and seedling emergence in cotton seed was studied by Wanjura et al (1967). They affirmed that the emergence rate can be predicted by knowing the soil temperature; since the rate of emergence of crop is constant with various ranges of soil temperatures.

Black low (1972) and Miedema et al (1982) informed that the soil temperature restricted the germination by its effect on imbibition.

Increasing soil temperature reduced the period of time between sowing and emergence from 10 to 11 days (Launders 1971).

Kailasanathan et al (1976) observed that in sorghum and cowpea, germination at 25°C was poor and at 40°C appeared lethel. High percentage of vigorous seedling growth was observed at 30 and 35°C.

Miedema et al (1982) studied the effect of constant temperature on imbibed seeds sown at a depth of 4 cm and showed that the time from sowing to emergence was 23 days at 10°C, 8 days at 15°C, 4 days at 21°C and 2 days at 32°C. In the case of elongation rate of primary roots show a linear relationship between 10 and 25°C. The minimum temperature was around 9°C, the optimum around 30°C Elongation rate ranged from 0.5 mm/hr at 10°C to 3 mm/hr at 30°C.

The optimum range of soil temperature for emergence of wheat was found to be 20-26°C (Pushkala and Nageraja Rao 1983).

2.2.2 Soil temperature and plant growth.

Influence of soil temperature on plant growth are manifold with increased soil temperature emergence was hastened and earliness promoted in maize (Willis et al 1957). They also found a linear growth rate over a temperature range of 60 - 80°F.

Brouwer (1959) obtained better growth of peas at higher temperature in laboratory as well as field studies. Dry matter production also followed at same trend.

Burrows and Larson (1962) reported that growth rate of maize progressively retarded with decreasing soil temperature.

Research conducted by Chaudhury and Ghildyal (1970) on the shoot growth and yield response of rice variety I.R-1 to different soil temperature revealed that maximum yield obtained at 32/20°C resulted from higher shoot and root dry weight greaternumber of effective tillers and spikelets per panicle and lower spikelet sterility (Lindeman and Ham (1979) and Hunever and Wollum II (1981) have

reported a maximum plant height and dry weight at 25°C. Pushkala and Nagaraja Rao (1982) observed that the leaf area and plant height of soy bean was found to be maximum at a temperature range of 26-32°C.

2.2.3 Effect of soil temperature on nutrient uptake.

Soil temperature influence plant growth by affecting soil moisture, microbial activity, enzymatic activity etc., thereby affecting the nutrient uptake and low temperatures slow down the intake of water by roots and extreme heat makes plant life difficult. By mere raising or lowering the temperature, has pronounced effect on the decomposition of organic and mineral components of the soil resulting release of plant nutrient.

Vander Honest and Hooymans (1955) determined the nitrate uptake at a temperature of 5-40°C. The uptake at 10°C was about 30% of that at 20°C. Shtrausberg (1958) reported that the uptake of P^{32} at 7°C was 32% of that at 21°C. So also the potassium content of roots at 10°C was about 40% of that at 20°C. This experiments show

that the ion uptake is retarded by lowering the temperature. But appreciable amounts of nitrate, phosphate and probably potassium are absorbed at around the minimum temperature for growth. The concentration of nitrogen, phosphorus, calcium, magnesium and minor elements was little affected by the root temperatures.

Simpson (1960), Dormaar and Ketcheson (1960) and Neilson et al (1960), all of them have reported that increased growth rate were noticed with higher temperatures which were attributed with the increased uptake of nutrients by the crop plants.

Low root temperatures decreased the P_2O_5 and water content of the leaves and stems of tomato and snap beans, and the P_2O_5, K_2O, N_2O, CaO and MgO content of cucumber Plants (Hori et al, 1968).

Significant increase in the nutrient uptake with increase in temperature in case of nitrogen, potassium, Mangenese and copper by wheat have been reported by whitefield and Smika (1971). Similar results were reported by Simpson 1960 in Soy bean for phosphorus, Ketcheson (1970) in corn for phosphorus and potassium.

The carbon mineralisation increased with raising temperature, but not linearly, (Bever, 1960). At higher temperatures (35-40°C) shoot and root concentration of nitrogen, phosphorous, potassium and zinc decreased while that of Boron increased.

According to Cornillon (1980) the absorption of plant nutrients by tomato roots were not greately influenced by temperature, the effect seems to be primerily on subsequent translocation.

2.3. Soil moisture impacts on soil temperature and consequent effect on plant growth and yield.

Soil moisture has an important role in deciding the physical and chemical properties of soil, fertility of soil and plant growth greately depends on the moisture status of the soil. As the temperature increases the water stress also increases Wadleigh and Gouch (1948).

2.3.1 Soil water plant relationships.

The leaf area index will be minimum when the available soil moisture is less due to the fact that adequate

water was not available for the full expression of crop growth. Similar result have obtained by Gerard and Cowley (1963), Lashin et al (1970).

Research carried out by Geiger (1950) shows that the specific heat of water being high, the rate of heating and cooling will be slowed down resulting in lower temperature in the afternoons and higher temperature during night.

For seed germination humid (over 98% R.H) environment is required, which is normally present in soils even when the soil moisture content approaches the permanent wilting percentage (Richards and Ogata, 1958).

Hanks (1960) proved that as the temperature increases the evaporational rate also increases resulting the soil drying which leads to the increased crust strength and decreased ability to crop growth.

In cold countries the mulches are used to increase the soil temperature. Works carried out by Clarkson (1960)

and Elmern J Van (1961) showed that soil covering, conserved moisture and kept soil temperature higher than that of bare soil and decreased frost penetration.

Parker and Taylor (1965) have reported that in grain sorghum seeds with the increase in soil moisture tension to 1 bar or more there was a decrease in the rate and amount of emergence and single grain weight was most affected by the moisture stress. So also the plant height was most reduced when moisture stress occured before ear emergence.

The experiment carried out on different water depletion studies (100, 80, 60 40 and 20% of available soil moisture) shows that more the quantity of water supplied, more would be the reduction in water use efficiency. In higher moisture regimes, more water is used for evaporation rather than production, thereby reducing the water use efficiency (Selva raj, 1976). This is in agreement with the findings of Grimes et al (1969).

2.3.2 Soil water and soil temperature in relation to plant growth.

Soil water is influenced by the soil temperature. The research conducted by Moore (1940) revealed that even though the maximum water content in the soil decreased by temperature, the infiltration rate increased with increasing soil temperature.

Moisture content is the most important factor which influences the emergence of seedlings. As the soil temperature increases, at first, the emergence rate increases. But after a level it decreases (Hughes et al 1966). Similar research conducted by spring field (1968) on seed germination at 6 levels of moisture stress in the range of 0-15 bar and at 5 temperatures revealed that germination decreased significantly as the moisture stress increased.

When the soil moisture is maintained at field capacity, the emergence and survival is adversely affected by soil temperature (Sosebee and Herbel, 1969) and when the soil moisture was only slightly above wilting point; the radicle was observed to extend into new soil, fastly to meet the moisture needs (Trouse, 1971).

As moisture tension and soil temperature increased, the rate of emergence and total emergence of all species declined (Weight et al 1978). Sarma (1979) showed that after germination the radicle must remain in a humid atmosphere to assure development of the seedlings for emergence, which decreases with increasing temperature.

2.4. Influence of soil moisture and temperature on root growth of plants.

According to Russel (1961) the soil plant system primarily related through the root system and the rate of root growth. This in turn depends on the temperature, water and air supply in the soil, the amount of carbohydrates translocated to the root system and on the competetion they face from other roots. With the exception of the aquatic plants and a few epiphytes, plants absorb practically all their water through roots and the effectiveness of roots as absorbing surface, depends on this extent of the root system and on the efficiency of individual roots. The importance of root system; for proper maintainance of water balance in the plant and characteristics of "drought hard" varieties, was observed by Khanna and Raheja (1947) and Misra (1956).

2.4.1 Soil temperature and root growth.

High and low temperatures may limit root growth Arndt (1945) and Wilson (1981) found the optimum soil temperature for root elongation, between 33 and 36°C.

Nielson and Humphres (1966) investigated that each species of plant has a minimum soil temperature below which no elongation occures. Above the minimum temperature root elongation rate increased almost linearly with temperature ~~root elongation rate increased almost linearly with temperature~~ to a maximum temperature, above which the elongation decreases rapidly (Chaudhury and Childyal 1970).

Natr and Pura (1970) and Wilson (1981) in their experiment with plants under different root temperatures proved that the dry mater ratio of root and shoot increases with increase in soil temperature.

Research carried out by Pearson et al (1970) showed that the rate of root elongation gradually increased with increasing soil temperature up to 32°C and then sharply

decreased with further temperature increase. The effect of temperature was most pronounced at high pH and at low levels of soil strength.

Allmaras and Neilson (1973) observed that the initiation of adventitious roots of corn in the 0 - 10 cm soil depth was dominently influenced by soil temperature.

The crops are highly sensitive to high soil temperature at the seedling stage Lal (1972) was of the opinion that during early stages, the root activity is confined to the upper few centimeters of soil and the growing point of crop remains below the soil surface during the first week. He also observed some chlorotic symptoms in maize and seedlings grown in unmulched plot. This may be due to the poor root development which restricted the nutrient up take.

Anon (1959) reported that at higher temperatures the root growth was restricted because of the higher ethylene concentration (> 1 ppm) in soil.

The response of maize roots to soil temperature was showed by Prihar et al (1968). The alteration in

soil temperature caused by straw mulch significantly increased rooting density in the upper 10 cm of the soil but decreased below 15 cm depth.

Korovin and Namaev (1975) and Lahav et al (1982) conducted experiments on temperature and dry matter production of Avocado plants and found the dry matter production of roots as maximum at 30°C and minimum at 10°C. Above 35°C it suddenly decreased.

Moorby and Nye (1983) and were of the opinion that the root growth increases with increase in root temperature.

For a soil temperature range of 24 to 37°C, the root length and root distribution was found to decrease at higher and lower ranges of temperatures in soy bean (Pushkala and Nagaraja Rao, 1983). Macduff et al (1985) showed that root temperatures affect root extension, mean radius, root surface area, number and length of roothairs. Both lower and higher temperatures are harmful for root growth and development.

2.4.2 Soil moisture and root growth.

Soil moisture is the deciding factor of root growth and development. Extensive root system was shown to absorb water from greater volume of soil (Talanov, 1926).

Bennet and Doss (1960) observed that the lower levels of moisture increased the root depth in plants where as found as the lower level of moisture increased the root weights. Increase in the number of roots per plant and more root hair under such conditions were observed by Knock et al (1957).

Duncan (1941) found that the root growth in tree seedlings inversely proportional to the available soil moisture content. Cannon (1911) Weaver (1920) and Weaver and Crest (1922) found that the depth of penetration of root system depended on the depth to which the soil was wetted. But Shantz (1927) Breazale and Crider (1934) were of the opinion that roots of at least certain species would penetrate in to soil below permanent wilting point.

However Hendrickson and Veihmoyer (1937). Reed (1939) Kauffman (1945) and Muller (1946) considered such a possibility, most likely under field conditions.

Hunder and Kelley (1946) and Trouse (1971) stated that roots have a tendency to move from a moist area to dry soil and utilize moisture from that area. But at the same time they are unable to utilize the plant nutrients in the dry soil.

Gard (1959) conducted experiments on maize and found that as the soil moisture stress increased, maize roots extracted more water from lower depths. Another study carried out by Dargan et al (1965) showed that by with holding irrigations for 6 to 7 weeks in the early stages, the root system developed better.

Root elongation was appreciably reduced by an increase in soil water suction and vice verse (Taylor et al, 1967). Soil temperature has both direct and indirect effect on water absorption by influencing the root growth and by influencing the synthetic activity of roots.

Selvaraj (1976) showed that root weight is directly proportional to the root length. Root weight decreased with the increase in the available moisture percentage of the soil. Mandal and Ghosh (1983) have opined that the increased water use efficiency with mulching and irrigation was probably due to increased root development, efficient moisture extraction and decreased consumptive use.

Root growth between germination and emergence for the corn hybrids was studied by Cutforth et al (1986) and confirmed that the sensitivity to water content decreased with decreasing soil temperature and both this decreased the root growth rate.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment was carried out as pot culture with Bhindi as test crop in the net house at the College of Agriculture, Vellayani using the red loam garden soil, during May-August 1986.

3.1. Climatic conditions.

Vellayani is situated at a latitude of 8.5°N, longitude of 76.9°E and at an altitude of 29 meters M.S.L. During the period of investigation, there was an average rainfall of 154.6 mm. The average relative humidity maintained during the period was 75.5%. An average maximum day temperature of 30.05°C and minimum of 22.55°C was recorded during the period of investigation.

3.2. Priliminary studies on soil.

The initial analysis for the physico chemical properties of the soil were carried out and are given in table 1 to 5.

3.3. Pot culture Experiment.

11.6 kg air dry soil was filled in each pot. Pots were insulated from solar heating with thick coating of white paint on all exposed phases. Three seeds of Bhindi (Abelmoscus esculentus) variety selection-1 were sown in each pot. Fertilizers were added as recommended in the package of practices of Kerala Agricultural University (N:P:K at the rate of 125:50:50). Plant protection measures were taken whenever needed.

Table 1. Moisture Retention Characteristics.

Pressure applied in atmosphere	0.3	0.5	1.0	3.0	5.0	10.0	15.0
% of moisture	8.89	7.67	6.99	6.02	5.55	5.14	4.29

Table 2. Aggregate analysis (%).

Size of particles in mm	5.0	2.0	1.0	0.5	0.2	0.1	0.1
% of particles	20.20	8.77	15.00	10.80	19.47	15.45	7.24

Table 3. Textural analysis (%).

Coarse sand	Fine sand	Silt	Clay
55.28	11.45	30.20	3.07

Table 4. Physical constants.

Water holding capacity %	Bulk density gcm $^{-3}$	Particle density gcm $^{-3}$	Porosity %	Volume of expansion %
24.90	1.42	2.3	38.6%	5.08

Table 5. Chemical analysis.

Available				Exchangeable		%
N kgh^{-}	P kgh^{-}	K kgh^{-}	SO_4 kgh^{-}	Ca kgh^{-}	Mg kgh^{-}	O.C*
64.96	94.08	306.88	450.2	1276.8	87.36	0.4385

*(O.C = Organic Carbon).

3.4.1 Design and treatments.

The experiment was conducted in a factorial completely randomized design with treatments of 4 mulches and two water levels. The treatment combinations were as follows.

1. Dry leaf mulch with 20% depletion of water from Field capacity
2. Dry leaf mulch with 40% depletion of water from Field capacity
3. Saw dust mulch with 20% depletion of water from Field capacity
4. Saw dust mulch with 40% depletion of water from Field capacity
5. Paddy husk mulch with 20% depletion of water from Field capacity
6. Paddy husk mulch with 40% depletion of water from Field capacity
7. Paddy straw mulch with 20% depletion of water from Field capacity
8. Paddy straw mulch with 40% depletion of water from Field capacity
9. No mulch

All the treatments were replicated five times. Altogether 45 pots were there. Pots were plugged using cement to prevent water loss. On the basis of water retention studies, water treatments were given, as and when the moisture reached 20% depletion of field capacity and 40% depletion of field capacity for the two water levels. These levels were fixed by calibration the tensiometer readings, using corresponding gravimetric moisture content.

3.4.2 Installation of Tensiometer and Thermometers.

Manometric type tensiometers were fabricated in the laboratory and installed in the pots, with the cups buried at a depth of 15 cm from soil surface. Soil thermometers were also installed at a depth of 15 cm in each pot to note the soil temperature. The servicing of the tensiometers were done daily using air free distilled water. Plate-1 shows the installation of tensiometers and thermometers for the treatments.

3.4.3 Mulching and water levels.

Mulching was done on the third day after sowing. Uniformly measured quantity of mulches were applied in