COMPONENTS OF NITROGEN FIXATION AND THEIR RELATIONS TO PRODUCTIVITY IN GROUNDNUT (*Arachis hypogaea* L.)

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COMPONENTS OF NITROGEN FIXATION AND THEIR RELATIONS TO PRODUCTIVITY IN GROUNDNUT (*Arachis hypogæa* L.)

S. G. HEGDE

Thesis submitted to the
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CERTIFICATE

This is to certify that the thesis entitled "**COMPONENTS OF NITROGEN FIXATION AND THEIR RELATIONS TO PRODUCTIVITY IN GROUNDNUT** (Arachis hypogæa L.)" submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN PLANT BREEDING AND GENETICS** to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by Mr. **S.G. HEGDE**, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

Cereal breeders have achieved considerable success in yield improvement. Such yield improvement has not yet been achieved in legumes. The reasons outlined to substantiate such poor improvement in legume yield mainly centers around the secondary importance given to these crops. Provided equal opportunity of growing conditions for both, legumes yield less than half the yield of a cereal crop (**Summerfield** et al., **1978**).

The yield improvement in cereal is mainly, among many other important factors, attributed to its capacity to utilise soil nitrogen. Contribution of organic soil nitrogen to this effect is not properly documented. Generally, high nitrogen demand of intensive agriculture is met through chemical fertilizers. From 1950-74 it has been estimated that roughly half the yield increase in cereals is due to usage of nitrogen fertilizers (**Hardy and Havelka, 1975**) indicating that nitrogen supply is an essential component of high yielding programmes.

Contrary to this situation, response and subsequent utilization of nitrogen by legumes are very poor. Hence high amount of fertilizer nitrogen is generally not recommended. Legumes are expected to satisfy their nitrogen need through biological nitrogen fixation process. This process in one way reduces dependency on costly nitrogen fertilizers, enriching the soil, roughly to an extent of 175×10^6 tons annually (**Burns** and **Hardy, 1975**). That, this value has not changed substantially over the last 25 years indicates that biological nitrogen fixation has not contributed to the increase in the crop productivity

(**Hardy** and **Havelka, 1975**). There is an inherent limitation of reduced N supply during critical period of pod development. The available data indicated that on an average only 25 - 60 per cent of total nitrogen required is supplied through symbiotic route, rest coming from soil nitrogen (**Harper, 1974**).

This nitrogen shortage cannot be alleviated merely by enhancing symbiotic contribution which consumes 15-30 per cent of the plant assimilate for the fixation process (**Schubert, 1982**) indicating that higher amount of N from symbiotic process may be detrimental for realization of higher economic yield.

Application of higher amounts of fertilizer nitrogen to augment such shortage is not a solution either. Higher dose of external nitrogen hinders nodule development and function affecting vital symbiotic process (**Reddy** and **Tanner, 1980**). But in most of the present day crop husbandry practices like mixed and multiple cropping systems, legumes are forced to grow on a nitrogen rich soils, being grown as a companion crop which are well fertilized. In other words, the combination of both N_2 fixation and moderate amount of fertilizer nitrogen may be the answer to the problem of yield improvement in the legumes.

Hence any breeding programme aiming at increasing legume yield should consider in addition to efficient symbiotic nitrogen fixers, evolving genotypes which can resist toxic effect of higher soil nitrogen or which can respond to high fertilizer nitrogen. Such an undertaking requires a clear understanding of interaction triangle among host plant, Rhizobium and mineral nitrogen.

Majority of the legumes as well as rhizobia, exhibit considerable genetic variability and their interaction under high and low soil nitrogen conditions (**Reddy** and **Tanner, 1980**). Now, utilization of such useful variation for yield improvement requires information regarding specific physiological and biochemical limitations, and quantitative assessment of significance of such limitations. This can be more readily realized through an integrated study encompassing genetics, microbiology and physiological assessment of host and Rhizobium under low/ high soil nitrogen conditions.

Present study was, hence, undertaken to know the effect of combined nitrogen on symbiotic effectiveness in legumes. The present investigation is not intended to emphasise much on the use of improved strains of selected rhizobia, since in majority of the cases such attempts have been failed owing to competitive indigenous soil rhizobia. It has been inferred that until our understanding of microbial ecology in the soil increases greatly it will be difficult to derive agronomic benefits from genetically improved rhizobia.

Here, the choice of the crop groundnut (**Arachis hypogea L.**), one of the important oilseed pulse crops of India is purely incidental. The study aims at following objectives listed phase-wise.

1. Screening the groundnut germplasm for the ability to utilize simultaneously soil nitrogen and symbiotic nitrogen.
2. Estimation of genetic parameters of variability for N_2 utilization in groundnut.
3. To study the physiological and biochemical components like translocation and enzyme activities of such genetic variation.

4. Construction of an ideotype with high yileding ability under applied and/or symbiotic nitrogen fixation, which will form the base material for the breeding programme.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Nitrogen fertilizer is generally not recommended in legume cultivation. Under circumstances they are known to grow very well on nitrogen derived from biological fixation process. However, before the onset of nodule initiation, during critical period of pod development, the external nitrogen is recommended for the proper establishment and yield enhancement of the crop. Equally important are many farming conditions, where there is no way out from use of fertilizer nitrogen. Farmers who are currently using modern technology, who are growing legumes on productive soils, who are financially sound and possessing an adequate infrastructure, generally use N fertilizer for their cultivation. Yet another important situation where the inorganic nitrogen used is in mixed and multiple cropping systems, involving legumes as a companion crop. These situations demand a genotype of legume either tolerant or responsive to external soil nitrogen conditions (**Hardarson** et al., **1984**).

However, high dose of external nitrogen hinders the normal development of nodules which in turn affects its functions (**Streeter, 1982**). In addition, prohibitive cost of N fertilizers discourages its usage in all types of farming conditions.

But according to **Postgate** (**1978**) N fertilizers were essential for higher productivity and there is no way without it. If N fertilizers could be produced more cheaply, its use would be valuable.

Following reviews are made to cover the areas in nitrogen fertilization in legumes, the mechanism of inhibition on symbiotic nitrogen fixation (SNF) by fertilizer/external soil nitrogen, utilization of genetic variability of host plants to improve SNF with

and without fertilizer nitrogen and physiological basis of such variations.

1. Need for nitrogen fertilizer

Generally NO_3 in soil does not occur in greater amounts enough to inhibit nodulation. But in order to secure the maximum growth as well as maximum gain of nitrogen in legumes, a small amount of soluble nitrogen is beneficial, while larger amounts are detrimental (**Fred** and **Graul, 1916**).

One of the important features of present day high yielding cereals is its ability to respond to fertilizer nitrogen application. Similar observation was also made by **Allos** and **Bartholomen** (**1955**), in few legumes with reference to symbiotic nitrogen fixation. There was a linear relationship between plant growth and nitrogen fixation. Higher available nitrogen decreased the fixed nitrogen contribution to plant development. But smaller dose of N was found beneficial for higher fixation. In no instance, however, fixation was completely inhibited or all the available N absorbed by the legume plant.

But the complexity of utilization of both fixed and applied nitrogen by legumes complicated the estimation of its nutritional status. Lower estimates of SNF contribution to total plant nitrogen (1-24%) have been reported when soil nitrogen was increased through N fertilization (112 kg N/ha) (**Weber, 1966**). According to **Harper** (**1974**), estimates of symbiotic nitrogen fixation capabilities of soybeans under normal field conditions ranged higher to 160 Kg N per ha with average estimate indicating 100 Kg N per ha. Based on the various yield levels, these estimates indicated from about 25 to 60 per cent of the total plant 'N' is derived from symbiotic fixation, the rest is

derived from soil. But there were situations where soybeans which were effectively inoculated or raised in a soil which had been previously inoculated by soybean rhizobia, did not require any additional nitrogen (**Pal** and **Saxena, 1975**).

Hence, quantification of nitrogen fertilizer need for a legume is a difficult task. To evaluate the same, Bhangoo and Albritton (1976) studied nodulating and non-nodulating isolines of soybean CV. Lee during 3 years in field trials with N at 0, 56, 112, 234 or 448 Kg ha^{-1} a year. Significant responses to N was found each year in seed and fresh matter yield, N content and total N uptake. Seed yields from nodulating line at low N rates equalled those from the non-nodulating line at 112 and 224 Kg applied N ha^{-1}. At the higher N rates, yields from the lines were similar. Symbiotic nitrogen fixation practically ceased with 448 Kg N ha^{-1}. For greatest utilization and efficiency of fixed N they concluded that applied N should be in the range of 56-112 Kg ha^{-1}, with allowance for residual soil nitrogen.

In another comparative study **Summerfield** et al., **(1977)** observed that effectively nodulated cowpea plants, grown in pots without applied N, were vegetatively equal to non-nodulated plants supplied with 60 ppm N throughout growth (88 days) and produced significantly greater seed yield. Supplying non-nodulated plants with 120 or 240 ppm N, improved seed yield but not significantly compared with plants completely dependent on SNF. Thus additional nitrogen fertilization at a single time or multiple times did not appear to be an effective approach, as there was no significant positive yield responses (**Hardy** et al., **1977**). They attributed this ineffectiveness to the compensatory decrease in nitrogen input from N_2 fixation that approximates to the increased nitrogen input from fertilizer nitrogen.

Fertilizer nitrogen application at planting time did not increase yields in areas where soybeans had been grown several times previously, indicating that N_2 fixation could support maximum yields (**Semu** and **Hume, 1979**). For peanut, **More** et al., **(1981)** recommended 15 Kg N ha^{-1} without inoculation.

The pulses and oilseeds vary considerably in their nutritional demand. **Aulakh** et al., **(1985)** studied the nutrient uptake of 6 pulses and 7 oilseed crops and divided them into following 3 groups; heavy feeders (soybeans, Brassica juncea, phaseolus aureus and groundnut), moderate feeders (lentil, Brassica campestris, Cicer aerietinum, Eruca sativa, Seasame and Linum usitatissimum) and light feeders (Vigna mungo, Cajanus cajana and sunflower).

2. Time of nitrogen application

Hera (1976) observed that when nitrogen fertilizer was applied within the growth period instead of at planting, the rate of utilisation was less whilst the amount of nitrogen derived from soil and symbiotic activity was at least equal to that obtained without fertilizer, indicating the suitability of N application during growth period to soybean than at planting.

In the continuation of this study when fertilizer was applied during growth period as well as at planting (30 or 60 kg N ha^{-1}), a decrease in the absorption of the nitrogen from soil and symbiotic activity as well as an icnrease in the rate of fertilizer utilization was noted. This was accounted for by the detrimental effects of nitrogen fertilizer applied at planting time as a starter dose.

Mahon and **Child (1979)** identified two phases of early vegetative growth in pea plants for their differential response to combined

nitrogen. During the first phase, low levels of NH_4NO_3 greatly increased the relative growth rate, the growth per unit leaf area, and the percentage of nitrogen in the tissues. This, they considered to be an indication of a nitrogen stress which lasted only until the third week. Over the next two weeks, combined nitrogen increased the relative growth rates to a lesser extent primarily through an increased partitioning of assimilates to the shoot development. This distribution effect was rapidly reversible on changing nutrient conditions. The stimulation of leaf area development by addition of combined nitrogen during these two growth phases resulted in greater capacity for symbiotic fixation after NH_4NO_3 was removed.

Minchin et al., **(1981)** conducted similar experiments in cowpea. The nodulation and seed yield of plants grown without inorganic N were compared with other plants given 20 ppm NO3 -N in soil either daily throughout the growth period or between or after the onset of flowering only. Providing inorganic N during the vegetative period stimulated nodulation and nitrogenase activity; plants were more leafy and produced a larger potential reproductive sites (nodes) and larger seed yields than those dependent on nodules before flowering. Applying inorganic N during the reproductive period impaired the nitrogenase activity and restricted the symbiotic longevity, but stimulated vegetative dry matter production and improved seed yields significantly compared with plants dependent on nodules throughout growth. For groundnut an application of 30kg N ha^{-1} of urea at pre-flowering or after flowering had a better effect on yield than similar amount applied at planting. Increase in rate of application of urea beyond 30 Kg ha^{-1} did not increase yield (Canessa and Ramirez, 1984).

3. Effect of nitrogen on symbiotic nitrogen fixation

Pawar and **Khuspa** (**1976**) observed effect of external nitrogen during active growth stage (40-55 days) of groundnut. The effect on nodule number per plant was not evident at the initial as well as in the later stages of nodulation.

Streeter (**1982**) opined that moderate nitrate concentration of 30 mg N per litre had little effect on nodule weight per plant while high nitrate concentration of 100 mg N/litre depressed nodule weight per plant by 70 to 80 per cent with harvests 30 to 60 days after planting and initiation of nitrate treatments. The effect of nitrate supply on ammonium, amino and ureide nitrogen concentration in nodules was small and inconsistent. In contrast, nitrate and nitrite concentration in nodules were directly proportional to nitrate supply and inversly proportional to nodule weight per plant.

Groundnut cultivars, Florunners, early Bunch and Tiftrun and 3 non-nodulating experimental lines were sprayed 0, 1, 2 or 4 times with foliar urea beginning 28 days after emergence to supply 13.5 kg N ha^{1}. Seed yields of all the non-nodulating lines and of Tiftrun and Florunner increased significantly with increased N application. Yields were lower in non-nodulated than nodulated cultivars, even at the highest N rate (1.73-1.96 and 3.76 to 4.6 t ha^{-1} respectively). Addition of N to non-nodulating lines increased the number of unfilled pods, seed size and seed weight. Seed N content was also increased in non-nodulating lines but remained higher in nodulating lines (**Walker** et al., **1984**).

Following are the some of the hypotheses formulated to explain the effect of external nitrogen on symbiotic nitrogen fixation.

4. Direct effect of external nitrogen

Wilson (1917) concluded from his divided root experiments that the effect of nitrate was localised. Very high concentration of nitrate in root tissues of plants grown in nitrate solution hindered the growth of the bacteria in turn affecting nodule formation (**Strowd 1920**). According to **Virtanen** (1950) nitrate forms NO - compound with leg -haemoglobin, thus destroying its function as an O_2 supplier to the bacteroids.

Harper and **Cooper** (1971) observed that the uniform application of ammonium nitrate dispersed throughout a 30.5 cm soil column impaired nodule development. Nodule response therefore, they concluded, strictly depended upon internal nitrate content of the roots, indicating that application site may provide a means of partially alleviating the detrimental effect of combined nitrogen on nodulation.

Nitrate was potential inhibitor of nitrogenase activity in the bacteroids extracted from nodules (**Rigaud** et al., **1973**), the nitrogenase enzyme in vitro (**Kennedy** et al., **1975**) and in N2 fixing cultures of Rhizobium (**Pagan** et al., **1977**). According to **Gibson** and **Pagan** (**1977**), NO_2 the reduced form of NO_3 acts on IAA to destroy it catalytically. To circumvent such effect, further **Gibson** and **Pagan** (**1977**) used a mutant Rhizobium strain deficient for nitrate reductase along with external nitrogen. Neither assimilatory nor dessimilatory nitrate reductase could be detected in these nodules, indicating that there was no translocation of nitrite to nodules from the roots. Furthermore, N_2 fixation in culture by the nitrate reductase deficient mutants was not affected by levels of nitrate which when supplied in the plant culture medium, depressed nitrogenase activity by these strains in nodules (**Pagan** et al., **1975**).

5. Carbohydrate-nitrogen balance hypothesis

Many workers tried to understand the extent of relationship between nodule function and carbohydrate supply. **Lawn** and **Brun (1974)** studied the effect of altered source-sink relationship on SNF in soybean. The treatments designed to enhance the photosynthetic source-sink ratio (Supplemental light and depodding) maintained nodule activity well above the control. Conversely treatments designed to reduce the source-sink ratio (shading and defoliation) decreased the nodule activity below the level of the control.

A similar conclusion came from the studies of **Hardy** and **Havelka (1976)** and **Harper (1974)** which showed increased N_2 fixation and photosynthesis by CO_2 enrichment of soybean canopies. They inferred that, given the condition of restrictive photosynthate availability to roots and nodules plus a readily available combined nitrogen supply, photosynthate could be exhausted through metabolism of the combined N in the roots and leave little photosynthates for nodule use. This situation was exemplified by the study of **Latimore** et al., **(1977)**, who had shown that in plants with added nitrogen compound, less carbohydrate (CHO) was transported to the nodules than in the plants without this addition. This photosynthate depreciation was founded upon generally accepted idea that carbohydrate supply was the natural regulator of nitrogenase activity in symbiotic system (**Hardy** and **Havelka, 1976; Pate, 1977**).

Contrary to previous findings **Streeter (1981)** showed a little effect of nitrate on (CHO) composition of soybean nodules. In his experiment plants were grown in full sunlight with NO_3 concentration in the nutrient solution high enough to reduce nodule mass per plant

by about 70 per cent. Retardations in nitrogenase activity caused by supplying plants with nitrate were accompanied by only small change in CHO composition of noudles. Thus, his results did not support the idea of carbohydrate depreciation to nodules under NO_3 grown condition. According to his speculation it remained possible that while nodules might be able to obtain sufficient CHO in the presence of nitrate, their ability to use that CHO might be restricted by some influence of nitrate on CHO transport or metabolism within the nodules.

Vrsino et al., **(1982)** conducted an experiment to confirm the photosynthate depreciation hypotheses. Soybean plants were subjected to four patterns of nutrient fertilization. After seven days of planting, one group received nutriet solution containing 5 mM nitrate, a second group received nitrate free nutrient solution, and other groups received nitrate contain-ing solution either from days 7 to 13 or from days 14 to 20. The results were consistent with the hypothesis that nitrate assimilation in the leaves of $NO3^-$ fertilized plants restricted nodulation and N_2 fixing activity through a reduction in export of recent photosynthate to the nodules.

In recent study **Singleton** and **Vankessel (1987)**, indicated that N_2 fixation creates a strong localized sink for photosynthate that affects both root and nodule development. The control of carbon flow to roots and nodules was affected by the output of N_2 fixation products from nodules. Selective carbon partitioning mainly affects the size of the below ground sink and only partially affected roots and nodule function. The effects of nitrogen assimilation on carbon partitioning to roots were similar whether the source of N is inorganic or from N_2 fixation.

6. Miscellaneous hypotheses

According to **Thornton (1936)**, root hair curling to be a prelude to infection by the bacteria. He observed that if the growth medium contained nitrate, lucerne plants had fewer root hairs, and fewer of the hairs curled in response to inoculation with nodule bacteria. **Munns (1968)** ruled out the possibility of such phenomenon. When nitrate was maintained in continuous supply in solution cultures of concentrations 0.02 mM to 2 mM, it reduced the number of curled root hairs and of nodules. But the addition of Indole-3-acetic acid with the inoculum overcame the nitrate inhibition of curling without affecting nodulation and there was no quantitative connection between numbers of curled hairs and nodules when nitrate treatments of limited duration were applied at different times in relation to inoculation. Nitrate reduced nodule number to some extent even if present before the inoculation or only on the first, second or third day after inoculation, so that the reduction in nodule number was difficult to attribute chiefly to interference with any one phase of nodulation process. However, nitrate inhibited formation of infection threads and augmented the proportion of arrested infection threads, to such an extent that this could be important in the appearance of infection threads.

Reduction in N_2 fixation by NO_3 was brought about by inactivation of leghaemoglobin (**Rigaud** and **Puppo, 1977**). This idea was supported by **Bissling** et al., **(1978)**, who showed that externally applied $(NH_4)_2SO_4$ did not affect nitrogenase directly. Instead there was quantitative correlation between the leghaemoglobin content and the nitrogen fixing capacity of the nodules. The reduction of nitrogenase activity did not result from reduced account of bacteroid proteins gm^{-1} nodule.

7. Genetic variability in the symbionts and its utilization

Ultimate objective of the plant breeder is to improve the economic value of the plant phenotype. Inferences about genotype are made from phenotype and one of the central dilemma of breeding is the strength and stability of the relationship between phenotype and genotype. Most of the time it would be difficult to identify the many genes whose variations contribute to the different economic value of individual plants, often it is very difficult to predict their exact expression in a new genetic or environmental background. This is especially true of the genetics of quantitative variation in nitrogen fixation. Little attention has been given to an operational breeding approach to improve nitrogen fixation and as a result, even the most basic information necessary to success is largely absent.

Nitrogen fixation by Rhizobium-Legume symbiosis is influenced by the genotype of both the bacteria and the plant. Many workers have considered the question whether host or bacteria has the greatest variation for traits influencing N_2 fixation (**Burton** and **Wilson, 1939; Erdman** and **Means, 1952; Gibson 1962; Tan, 1981; Mytton** et al., **1984**). These investigations revealed that both plant cultivars and bacterial strains had significant effects on N_2 fixation. Studies of **Burton** and **Wilson (1939), Erdman** and **Means (1952)** suggested that genetic improvement of Rhizobium should have priority over plant breeding efforts, while the opposite conclusion was supported by the **Gan** et al., **(1981)**. All three studies, however, showed that Rhizobium-strain x host-cultivar interactions were responsible for a large part of the variation. **Mytton (1978)** described a method for breeding to enhance such interactions, where procedures demand essentially twice as much work as improving only the plant or the bacterium.

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Phillips and **Tuber** (**1985**) concluded that it was more reasonable to improve N_2 fixation by genetically altering either Rhizobium or the plant than by selecting for favourable interactions.

Research on Rhizobium improvement had met with a lot of discouragement. The genus Rhizobium consists of diverse groups of bacteria that infect and produce nitrogen fixing nodules on members of Leguminocease. Here exception has become a rule in every aspect of Rhizobium host symbiosis. (1) Rhizobium was found able to nodulate plant parasponia (family Ulmaceae), outside legume family (**Trinick, 1973**), which negates original definition of Rhizobium symbiosis. Perhaps there are other non-legume-Rhizobium symbiosis undiscovered (**Trinick, 1982**), (2) The infection of legume by Rhizobium is an intimate association which depends on their total specific mutual recognition for effective nitrogen fixation. Most of the time Rhizobium effective on one host does not necessarily result in an effective association in closely related host species or even between plant variety, (3) Usually a nodule is occupied by a single strain of Rhizobium but there are reports of diverse rhizobial types in the same nodule (**Franco** and **Vincent, 1976**), (4) Cross-inoculation groups were developed on the premise that each species of Rhizobium would only nodulate plants within the particular cross-inoculation group and that within such groups rhizobia from one plant would nodulate all other Plants, and vice-versa (**Fred** et al., **1932**). However, it soon became evident that these groups were not discrete and many reports of boundary jumping between groups are found in literature (**Trinick, 1980**), (5) There are extreme class of rhizobia - either very specific or promiscuous. There is a high degree of specialization that fre-

quently occurs between the host and its symbionts even within a plant group (**Vincent, 1974**). On the other hand cowpea rhizobia are highly promiscuous (**Trinick, 1982**).

Numerous attempts have been made to increase N_2 fixation by selecting or developing superior Rhizobium strains. In fact, the problem most likely to prevent the successful introduction and use of improved Rhizobium strain is the presence of competitive indigenous rhizobia in legume production area. But until our understanding of microbial ecology in the soil increased greatly, it will be difficult to derive agronomic benefits from genetically improved rhizobia (**Phillips** and **Tuber, 1985**). Hence, it is important to understand how N_2 fixation can be increased by changing host, which can be of more justification for claiming practical advantages. The genetic manipulation of host legume may offer the greatest potential to improve upon current levels of N_2 fixation (**Phillips** and **Tuber, 1985**).

The first report of the nodulation variability of a host to strains of Rhizobium was by **Voorhees (1915)**. He observed that soybean cultivar "Haberlandt" did not nodulate when planted in plots containing Rhizobium japonicum. Five other soybean CV. planted in the same plot were well nodulated. He concluded that different cultivars of the same legume had different powers of resistance to association with the symbiotic bacteria. This was also supported by **Wilson** et al., **(1937)** and **Gibson (1962)**. According to them a given strain of bacterium was not good or poor in an absolute sense, but only relative to other factors which affect the relationship. Results stressed the importance of the host plant in determining whether a given strain of bacteria was effective or ineffective in the association. Importance of host plant in symbiotic process was also highlighted by **Dilworth**

(1969). Two dissimilar legumes, yellow lupin (Lupinus luteus L.) and Serradella (Ornithopus sativus Bort) were effectively nodulated by the same strain of Rhizobium lupini, but produced entirely different types of leghaemoglobin. Conversely, when both these legumes were nodulated by two different strains of R. lupini, leghaemoglobin pattern produced in each legume was apparently same, showing that the genetic specification of leghaemoglobin in legume root nodule was a property of the plant.

Jain's (1975) investigation to understand the legume productivity gave useful hints for a selection programme. According to him lower yield of legumes compared to cereals was not due to its lower genetic potential. In order to give high yields, crop plants have to develop certain agronomic characters which may be of relatively little value under competitive and stress conditions of a wild habitat (Harlan and Martini, 1938). Twenty tons dry matter production per hectare by pigeonpea was much higher than the best wheat variety available, but poor yield of pigeonpea was atrributed to its poor harvest index. Hence, he emphasised that selection for improved plant type, combining a high harvest index and high dry matter production.

In a study of eight yield components in 25 varieties of peanut, significant varietal differences were recorded for all characters except yield and number of nodes. The GCV, h^2, and GA were high for height of main stem and number of pods (Sivasubramanian et al., 1977). Duhigg et al., (1978), recorded considerable variation for nodulation score, nodule colour score, root score, dry weight of the top growth, per cent N in the top growth, total N in top growth among 278

plants of the cultivar Mesilla (alfalfa). **Zary** et al., **(1978)** in cowpea and **Ganeshaiah** and **Shivashankar (1980)** in horsegram observed significant differences in nitrogen fixation efficiency. In a study of nodulation pattern of 48 groundnut genotypes, it was revealed that Virginia types were more heavily nodulated than Spanish or Valencia types (**Wyne** et al., **1980**). In addition Virginia types also showed higher nitrogen fixation, vegatative and fruit yields than spanish cultivars (**Ball** et al., **1980**).

Bhagat et al., **(1986)**, critically examined Virginia resources for root nodulation status and made following classification (1) Virginia bunch out of 803 accessions 94.7 per cent contained 1-100 nodules and 5.3 per cent with 101-200 nodules, (ii) Virginia runners out of1005 accessions, 91.6 per cent with 1-100 nodules and 8.4 per cent with 101-230 nodules. According to **Kulkarni (1986)** nodulation was significantly higher in Virginia runner types, followed by Virginia bunch, Valencia and Spanish types.

Arunachalam et al., **(1980)** observed considerable genetic divergence within Spanish and Valencia groundnut varieties apart from separation of Spanish and Valencia varieties from Virginia varieties. Variance analysis of **Singh et al., (1982)** in 50 lines of groundnut revealed significant differences for pod : peg ratio, number of undeveloped pods, biological yield/plant, number of pods per plant, harvest index and 100-seed weight. Broad sense heritability estimates were high for 100-seed weight (99.4%), shelling out turn (88.7%) and number of undeveloped pods (82.85%). Qadri and Khunti (1982) observed higher genotypic variation for harvest index, pod yield, dry fodder

weight, pods/plants, pegs/plant, peg bearing nodes/plants and 100-seed weight in groundnut. Broadsense heritability was high for all the characters studied. Higher nodule mass played an important role in higher groundnut production (**Lodha** et al., **1983**). The higher N_2 fixing capacities of mutants TG-1 and TG-16, as compared with that of parent was attributed mainly to the higher nodule mass in the mutants.

Mytton et al., (**1984**), reported 4.8 per cent and 21 per cent phenotypic variance to host genotype and Rhizobium genotype, in lucerne. The results also indicated low heritability of general symbiotic effectiveness. In the host substantial genetic variaibility for characters associated with nitrogen fixation was observed for groundnut cultivars by **Arunachalam** et al., (**1984b**). These N_2 fixing characters were also found to explain more than 86 per cent of variation in kernel yield.

Harper and **Gibson (1984)** compared twelve soybean cultivars for tolerance to NO_3^- when inoculated with single strain. There was delay in nodulation relative to controls, and there was corresponding degree of inhibition (30-99%). Further, they deduced that the host plant might play a greater role in nodulation tolerance to NO_3^{-3} than did the Rhizobium strain, since more variability in nodule tolerance to NO_3^{-3} appeared among soybean cultivars than among strains. Similar such reports had also been published by **Hardarson** et al., (**1984**) who observed higher variability in soybean varieties to fix N_2 at different inorganic level (20kg-100 kg N ha^{-1}). **Gibson** and **Harper (1985)** observed good nodulation tolerance of soybean cultivars to NO_3^{-3} when infected by Rhizobium USDA 110 strain and indicated that with selection and breeding enhanced NO_3^- tolerance of nodulation should be possible. There may be lot more such mutants in the natural population

of legumes which were constantly subjected to higher soil nitrogen conditions. Even artificially induced mutant NH 382 in soybean showed significantly higher levels of nodulation than Bragg in the presence and absence of several combined nitrogen sources (KNO_3, urea, NH_4Cl and NH_4NO_3) (**Caroll** et al., **1985**).

8. Inheritance studies

Langham (**1961**) had developed a high-low method of crop improvement. According to him some genes (H) with a strong potential to exceed the high limit and others (L) with strong potential to exceed the low limit were resident in the germplasm of a natural population but could not be showed their maximum expression because they were buffered. However by crossing high x low and selecting the F_2 generation for the H and L, genes segregate free of their buffers giving transgressive segregation. Such results were obtained in groundnut by **Arunachalam** et al., (**1980**). In their analysis of two diallels of 15 and 10 parents of distinct groups, highest frequency of heterosis was observed between crosses of high and low GCA varieties. **Deshmukh** et al., (**1985**) also opined in this direction stressing that parental genetic diversity was more important for expression of heterobeltosis. There were many studies conducted to understand the genetic parameter in groundnut. High heritability was reported for yield/plant (**Patra, 1975**), pod number and seed number (**Soomaro, 1977**), fruit length (**Mohammad** et al., **1978**), number of fruiting node, primary branch and 100-seed weight (**Labana** et al., **1980**), and a number of pegs and length of first primary branch (**Rao, 1980**).

But some of the findings were quite contradictory to these results (**Prasad** and **Arunachalam, 1983** and **Arunachalam** et al., **1984a**). In a study of 64 single crosses involving eight male and eight female parents showing genetic divergence, **Prasad** and **Arunachalam (1983)** observed that crosses between parent with intermediate divergence showed high F_1 heterosis.

Significant positive heterosis were reported for pods and seeds per plant and 100-pod and seed weight (**Garet, 1976**), pod size and length (**Isleib** and **Nynne 1983**), partial biomass, total pod number, total seed weight and total seed number (**Swe** and **Branch, 1986**). In addition to this, negative heterosis were reported for number of aerial pegs and number of immature pods (**Basu** et al., **1986**).

There were only few reports on genetic advance estimates. Genetic gain for yield/plant (**Patra, 1975**) pod and seed number (**Soomaro, 1977**), Leaflet breadth and fruiting nodes per secondary branches (**Labana** et al., **1980**) and leaf length and breadth (**Rao, 1980**) were reported.

A total of 27 exotic cultivars representing each of the five centres of diversity in South America, as well as Africa and China, were test crossed to a high yielding adopted Virginia line. The parents had been sorted into five morphological groups. Twenty selected F_2 families per cross were bulked in the F_4 and tested. Variation among bulks for pod and seed yield and other traits was predmoinantly due to differences among morphological groups (**Isleid** and **Wynne, 1983**).

A diallel cross was performed with 3 Spanish varieties (Var. Vulgaris) and 2 Valencia varieties (var. fastigiata) (**Basu** et al., **1986**). Negative heterosis over the better parent was observed for days

to 50 per cent flowering in Spanish x Spanish crosses and for days to maturity in Spanish x Valencia crosses. Most crosses showed (desired) negative heterosis for number of aerial pegs and number of immature pods. Spanish x Spanish showed heterosis for better parent for number of mature pods. Heterosis was low for 100-seed weight and shelling percentage.

9. Association analysis

A reliable and accurate method of measuring phenotypic variation in nitrogen fixation is essential. The total nitrogen accumulated by the plant as a result of its association with Rhizobium is the most direct method of measuring overall symbiotic effectiveness. However, the work involved in its determination is considerable: it involved destructive harvesting which is not always desirable, a less indirect method has to be considered as alternatives (**Mytton, et al., 1984**). Correlations, regression and path coefficient analyses are some such indirect method useful in selection programme.

Plant appearance, number, size, weight and interior colour of nodules have been used to assess symbiotic effectiveness (**Fred, et al., 1932; Chen** and **Thornton, 1940; Brockwell, 1956; 1958; Jones, 1962; Dobereiner, 1966; Jones and Burrows, 1968**).

In trials with 21 cultivars each of spreading and bunch type groundnuts were given 50kg N or 25 kg N ha^{-1}. Number of branches per plant in the spreading type and number of pods per plant in the bunch type made greatest contributions to pod yields (**Dholaria et al., 1973**). In a multiple correlation study in groundnut **Sangha** and **Sandhu (1974)** reported the pod number, 100-seed weight, number of secondary branches, length of primary branch and number of primary branches as

important contributors to the total variability in that order.

In bunchy type of groundnut, **Rao (1979, 1980)** identified strong correlations between yield and 100-seed weight, height and days to flowering. Further he also reported positive correlation of yield with number of pegs, length of first primary branch, leaf breadth, number of pods, number of flowers and height of the plant. Several characters were studied in F_2 of a spreading x buncy habit groundnut cultivars (**Labana** et al., **1980**). Pod yield was correlated with the number of pods, 100-seed weight and the number of secondary branches. Significant correlation between root volume and dry weight (**Ketring, 1984**) and, between total dry matter and yield (**Choudari, 1985**) were also reported among groundnut cultivars. The association and path analysis studies in peas revealed that selection for high harvest index of nitrogen can bring about correlated response for nitrogen fixation ability and grain yield (**Singh** et al., **1984**).

10. Enzyme : Nitrogenase

Nitrogenase catalyzes the reduction of a variety of substrates (**Dalton** and **Morteson, 1972; Zumft** and **Mortenson, 1975; Zumft, 1976; Burns** and **Hardy, 1975; McKenna** and **Huang, 1979**), most being small molecules which, like N_2 contain triple bonds. The reduction of C_2H_2 to C_2H_4, discovered by **Dilworth (1966)** has become a standard technique for determining nitrogen fixation activities. The acetylene reduction test is a useful qualitative indication of nitrogen-fixing ability. However, it is unwise to make quantitative assessments of nitrogen fixing activity in the field on the basis of a 6- and 2-electron requirement for N_2 and C_2H_2 reduction respectively (**Bothe** et al., **1983**). There is a growing body of evidence to suggest that a number of

variables affect the accuracy of the acetylene reduction assay and, as a consequence, the theoretical ratio of 3:1 for C_2H_2 to N_2 has been found to vary in practice from 1.5:1 to 25:1 (**Hardy** et al., **1973**). However, acetylene reduction method is a quick, inexpensive and extremely sensitive method compared to other nitrogenase assays.

Connolly et al., **(1969)** cautioned the use of acetylene reduction assay (ARA) in plant selection programme. They had shown that in white clover (Trifolium repens) variation in acetylene reduction were almost completely accounted for by plant growth differences and that the technique therefore offers little or no advantage as a selection criterion over dry matter production.

Among 100 cowpea (Vigna unguiculate (L.) Walp.) lines **Zary** et al., **(1978)** reported nitrogenase activity (ARA measured as μ mol C_2H_4 ha^{-1} pl^{-1}) ranged from 0.6 to 43.3. In a later study **Zary** and **Miller (1980)** studied seasonal pattern of nitrogen fixation (C_2H_2) using 7 cowpea genotypes. Diurnal activity peaked at 1200 hours at both 34 and 53 days after planting (DAP). Significant differences in total activity between genotypes were observed with maximum activity generally coincident with full flowering. High flowering genotypes were higher in total nitrogenase activity throughout the growing season, than were the low fixing genotypes.

Seasonal patterns of nitrogen fixation by field grown soybeans have been reported by several authors (**Thibodeau** and **Jaworski, 1975; Harper** and **Hageman, 1972; Ham** et al., **1976; Hardy** et al., **1968; Weber** et al., **1971**). In soybeans, activity starts at the initial flowering stage which occurs, on an average, 4 weeks after sowing. Nitrogen fixation increases rapidly during the flowering period, reaching a

maximum during the early and mid-part of pod filling, and then declining sharply with senescence. **Weber** et al., **(1971)** found that about 80 per cent of the nitrogen was fixed between flowering and the subsequent green bean stage. Similar patterns of nitrogenase activity have been observed in soybeans grown hydroponically **(Harper, 1971; Harper** and **Hageman 1972)** and in field grown Phaseolus plants **(Franco** et al., **1979)**.

There are hardly any reports of effect of external nitrogen on nitrogenase activity of groundnut symbiosis. However, there are several reports on seasonal nitrogenase activity in groundnut (ICRISAT Annual Report, 1977-78; **Nambiar** and **Dart, 1983)**. There was marked diurnal and seasonal variation in acetylene reducing activity (ARA) of groundnut. There were large differences between cultivars in nitrogen fixation **(Nambiar** and **Dart, 1983)**.

Elkan et al., **(1980)** observed a high correlation between field and green house grown groundnut genotypes for nitrogenase activity and suggested that green house evaluation of Rhizobia strains for groundnuts was useful as a preliminary screen before evaluation in the field.

Arunachalam et al., **(1984b)** also stressed the use of ARA activity in selection programme. In diverse groundnut collection, nitrogenase activity and root nodule mass measured at 20 or 30 days after first flowering were closely correlated with a measure of relative performance based on 17 characters and involving measurement at 4 growth stages between flowering and harvest.

Many reports highlighted the use of ARA in selecting parents for hybridization programme **(Pierce, 1978; Duhigg** et al., **1978; Hobbs** and **Mahon, 1982)**. In lucerne **Pierce (1978)** observed that acetylene

reduction from crosses where both parents had a high ARA was twice as high as in hybrids where both parents had a low rate. Hybrids from crosses between parents of different rates had an intermediate rate. Similar results were reported in alfalfa by **Duhigg** et al., **(1978)**. In ICRISAT, a cross between a Virginia cv. NCAC 2821 ranked highest in mean nitrogenase activity with Robot 33-1 had resulted in high yielding progenies (ICRISAT Annual Report, 1982). This suggested the possibility of increasing yield potential by incorporating high nitrogen fixing lines in the breeding programme.

11. Enzyme : Nitrate Reductase (NR)

The assimilatory reduction of nitrate by plants is a fundamental biological process in which a highly oxidized form of inorganic nitrogen is reduced to ammonia. This ammonia becomes in turn combined with carbon skeletons to form different biological nitrogeneous compounds. This process has been observed both in higher plants and variety of bacteria and fungi (**Guerreo** and **Vega, 1981**). Legumes are in an advantageous situation as far as their nitrogen nutrition, fixing atmospheric nitrogen. Like other plants, they can also utilize combined nitrogen present in the soils. According to **Rigaud (1976)** it was of interest to compare the respective roles of the nitrogen fixing and nitrate utilization pathways and to determine their relative efficiencies, particularly in relation to the possible improvement of crop productivity at a lower cost.

Experiments have been carried out using nodulating and non-nodulating isolines of soybeans with dilute nitrate solution (**Wych** and **Rains, 1978, 1979**). Absorption was found to proceed linearly in both

nodulated and non-nodulated soybeans after the first hour, but nodulated soybeans exhibited a nitrate absorption capacity 2.5 fold lower than non-nodulated plants. **Wych** and **Rain (1978)** have proposed that nitrogen stress was a characteristic of the nodulated plants, which could be responsible for their low absorption capacity.

The differential uptake of nitrate by legumes have been reported in many crops. **Streeter (1972)** observed substantial levels of nitrate in the sap of field grown soybean during their vegetative growth period and these levels corresponded with the high nitrate concentrations in the soil. Nitrate uptake decreased during pod and seed development, inspite of its continued availability in the soil. In cowpea **Rhoden** et al., **(1987)** reported 31 per cent higher NRA in the 20 mg N/plant treatment than the control throughout the growing period. The highest activity occurred in the seedling stage and declined towards anthesis. Diurnal variations were marked by an increase in NRA from 6 to 18 hours and declined to a minimum at 24 hour. These observations suggested that supplementing nitrate during the final stages of development would be of no effect on nitrogen levels in the pod.

Wallace and **Pate (1965)** extracted active nitrate reductase from field pea roots and levels were fairly constant from 7 to 315 ppm. Shoots on the other hand showed a dramatic increase in levels of extractable nitrate reductase. **Ayala (1977)** studied NRA of groudnut nodule along with plant N and dry matter contents and opined that NRA of root nodules appeared to be the best test for evaluation of strains.

Streeter (1982) had observed little effect of nitrate on nodule ammonium, amino acid and ureide metabolisim, but was positively

correlated with nodule nitrate and nitrite content and negatively correlated with nodule weight/plant . Thus, nodule themselves can contribute to nitrate reduction. An active nitrate reductase, both constitutive and inducible, had been reported in Rhizobium legumino-sarum, R. Japonicum and many other strains of bacteria (**Pagan** et al., **1975; Kurz** and **Larue, 1975;** and **Bergersen, 1961**).

Becana et al., **(1985)** in Rhizobium meliloti observed high specific activities of nitrogenase and nitrate reductase. Nitrite levels in the bacteriods were linearly correlated with specific activities of the enzymes. According to him, this accumulation of NO_2 might be responsible for inhibition of nodule activity.

Leaves were considered to be the major site of nitrate reduction in legume plants (**Harper, 1971**), as in other plants. According to **Harper** and **Hageman (1972)** at the initial flowering and full bloom stages of development of soybean there was marked activity of nitrate reductase which declined from the top to the bottom of the canopy. This activity was decreased during the later stages of soybean development and was low at the immature pod stage. Rapid drop in nitrate reductase activity prior to pod fill stage associated with low nitrate content in the leaves was also reported by **Thibodeau** and **Jaworski (1975).** At ICRISAT Centre (ICRISAT Annual Report, 1985) responses of groundnut and sorghum to fertilizer nitrogen were compared. Leaf NRA and nitrate contents were estimated from top, middle and lower canopy positions at different growth stages. The results showed high NRA at low nitrate content in sorghum leaves and low NRA at high nitrate content in the groundnut leaves at all stages of growth implying that groundnut was a poor user of mineral nitrogen.

It has been suggested that (**Randall** et al., **1978**) the efficiency of nitrate utilization in legumes could be improved by nodule nitrate reductase being prominent during the early stages of vegetative development, when nitrogen fixation was not completely established. It might be of lesser importance during the later stages of development when leaf nitrate reductase declines (**Thibodeau** and **Jaworski, 1975**). However, **Rigaud (1976)** identified two periods within the growing season of legumes, to improve legume nitrogen nutrition, by complementing symbiotic nitrogen fixation during the early stages of development and the reproductive period. Low levels of nitrogen should be applied after nodule initiation (**Pate** and **Dart, 1961**) to avoid depressing effect on nodulation. According to their report low levels of combined nitrogen stimulated nodule number and growth in Vigna and nitrogen starvation was reduced. Dry matter production and C_2H_2 reduction are enhanced in Medicago under these conditions (**Hogland, 1973**).

12. Photosynthesis and translocation studies

The nodule uses photosynthate for its growth and maintenance, to provide energy and reductant for nitrogenase, and for the incorporation and transport of newly fixed nitrogen to the shoot (**Larue** et al., **1984**). **Minchin** et al., (**1981**) estimated that upto 20 mg of carbon was used per mg of N_2 fixed. Carbohydrates were used for energy production by both bacteroids and host plant portions of nodules. The host plant also utilizes carbohydrate for assimilation and transport of fixed N_2. There is ample evidence that symbiotic fixation is demanding of energy. Physiological experiments (**Streeter, 1974; Hardy** and **Havelka, 1975**) with symbiotically grown soybeans suggested that the nitrogen

fixation process is limited by carbon compounds supplied by photosynthesis. Although soybeans undergo a period of nitrogen-limitation during nodule development (**Fred** et al., **1932**), the carbon limitation has received greater consideration since it has been assumed (**Hardy** and **Havelka, 1975**) that this period may have a more direct effect on the overall yield potential in the field.

Jain (1975) pointed out that main factors responsible for lower grain yields of legumes compared to cereals was their poor harvest index, and not their photosynthetic capacity or poor sink capacity. However, earlier conclusions that photosynthetic activity in pulse crops declined as pod formation began has important implications. He advocated selection for an improved plant type associated with a more uniform distribution of photosynthetic activity with higher harvest index during the life of the plant. **Sinclair** and **deWit (1975, 1976)** based on seed biochemical composition concluded that nitrogen requirement of the pulses were very high and sustained seed growth demanded continued nitrogen translocation from vegetative tissues, eventually inducing senscence in these tissues and restricting the duration of seed fill. Similar results were also reported in groundnut (**Lodha** et al., **1985**).

Extensive review is available regarding photosynthesis, and its partitioning in groundnut (**Bhagsari** and **Brown, 1976; Duncan** et al., **1978; Wynne** et al., **1981; Rao** and **Das, 1981; Kulkarni, 1986; Duncan** et al., **(1978)**) attributed higher yield of present day peanut cultivars over their predecessors to three physiological processes; the partioning of the assimilate between vegetative and reproductive parts, the length of the filling period, and the rate of fruit establishment. Of these, the partitioning of assimilate had the

greater effect on fruit yield. Estimates of partitioning to fruit ranged from 41 per cent in most recently released cultivar. Crop growth rates did not differe significantly among peanut cultivars but all were much higher than the crop growth rate of soybeans. **Wynne** et al., **(1981)** accounted 75-90 per cent of variation in growth rate of groundnut to leaf area duration. Even leaf dry matter measurements explained 75 per cent of the variability in both nodulation and nitrogen fixation, highlighting the importance of photosynthesis in groundnut and nitrogen fixation. Growth habit of groundnut botanical groups also have important implications on nodulation and nitrogen accumulation (**Kulkarni, 1986**). Leaf area index, leaf area duration, specific leaf weight and chlorophyll content were significantly higher in Virginia types than Valencia and spanish types. Abscence of flowers on main stem and alternate flowering habit on the branches in the Virginia types, according to him, helped in better distribution of photosynthate to reproductive sinks and nodules.

Significant differences in photosynthate translocation to different parents in groundnut have been reported. **Bhagasari** and **Brown (1976)** noticed differences in ^{14}C translocation among groundnut genotypes in the growth chamber. A significant positive correlation occurred between translocation rates and rates of net photosynthesis. **Shashidhar** and **Sastry (1986)** concluded that fixation of $^{14}CO_2$ per unit dry weight of leaf was more reliable than photosynthetic rate per gram dry weight in distinguishing varieties under stress conditions.

Labelled $^{14}CO_2$ was fed to the leaves of different branches during pod development and, translocation and assimilated ^{14}C was measured from different plant parts of 2 groundnut cv. J-11 and M-13 (**Sengupta**

and **Sharma, 1984**). The low yielding J-11 incorporated higher amount of $^{14}CO_2$ but the assimilate translocation to other plant parts was less than in the high yielding cv. M-13. During the peak pod development stage most of the translocated ^{14}C was recovered from the pods of M-13, while a small amount was recovered from the pods in J-11. It was suggested that the bold seed and high yield in M-13 may be due to better sink efficiency and partitioning of photosynthates compared to J-11.

Gibson (1966) tried to estimate the cost of N_2 fixation in Trifolium subterraneum by comparing differences in relative growth rates and total carbon content of plants grown in NH_4NO_3 and those dependent on biological fixed N. During the period of active N_2 fixation, there was no apparent difference in carbohydrate requirements for N_2 fixing plants over control plants. However, during nodule development, there was an increased utilization of reduced carbon by nodulated plants, to an extent of 0.3 g g^{-1} N_2 fixed. From these results he concluded that carbohydrate requirements were not substantially different from those required for assimilating combined N. Supplying combined nitrogen (**Small** and **Leonard, 1969**), decreased the proportion of photosynthate translocated to the nodule with a corresponding increase in the proportion going to roots. Of the 'C' gained photosynthetically (**Minchin** and **Pate, 1973**) by the shoot from the atmosphere, 26 per cent was incorporated directly into its dry matter; 32 per cent was translocated to the nodules, and 42 per cent to the supporting root. Of the nodules share 5 per cent was consumed in growth, 12 per cent in respiration and 15 per cent returned to the shoot via the xylem as amino acid compounds generated in N fixation. According to him nodule required 4.1 mg 'C' (= 10.3 mg CHO) for each

mg of N fixed.

Silsbury (1979) reexamined the **Gibson**'s (**1966**) findings and concluded that the energy requirement for symbiotic N_2 fixation was substantially greater than that for assimilating combined N. Likewise, **Mahon** and **Child (1979)** found that nitrate treated plants had relative growth rates 15 to 20 per cent greater than those fixing N_2. Similar differences in growth of soybeans have been reported by **Ryle** et al., **(1978)** for plants fixing N_2 or grown on nitrate.

Latimore et al., **(1977)** studied the effect of NH_4 -N and NO_3 -N on translocation of ^{14}C, N fixation and accumulation of dry matter in soybean. During the pod formation little $^{14}CO_2$ and N was exported to nodules following photosynthesis of $^{14}CO_2$ and N fixation was low. NO_3 -N brought greater reduction than NH_4 -N. The transport of $^{14}CO_2$ to the plant parts was not affected. Demand for N at the pod filling stage was high, 23 per cent of the total being required during a period of 20 days from mid to late pod filling stage. At the same time fixation of N by nodules was declining. In groundnut N application significantly increased crop growth rate, leaf area and leaf area index (**Jadhav** and **Natkhede, 1982; Selamat** and **Gardner, 1983**). Several suggestions have been made on how to alleviate a possible photosynthate deprivation. In laboratory experiments, addition of organic substrates like glucose (**Wong, 1977; Houwaard, 1980**) or sucrose (**Houwaard, 1979**) could partially limit nitrate effects on nodulation and C_2H_2 reduction. But in experiments using NH_4Cl, a 30 per cent recovery of C_2H_2 reduction was also observed (**Houwaard, 1979**), making the results difficult to interpret in terms of nitrate reductase competition.

Since photosynthate was considered to be general limiting factor for nitrogen fixation, CO_2 enrichment techniques have been used to increase the rate of photosynthesis (**Hardy** and **Havelka, 1976**). Increasing CO_2 concentrations supplied to Pisum shoots were unable to overcome the depressive effect of 20 mM nitrate on C_2H_2 reduction, although more assimilates were available for the root nodules (**Chen** and **Phillips, 1977**). In other experiments, foliar application of nitrate stimulated leaf nitrate reductase without affecting the nitrogenase activity of nodules, pointing out a sufficiency of photosynthate for the nodules (**Chen** and **Phillips, 1977**).

13. Nitrogen accumulation and translocation studies

Nitrogen accumulation is an important contributor to high grain and grain protein yield (**Cregan** and **Berkum, 1984**). **Desai** and **Bhatia (1978)** observed that of 15 durum wheats the genotype which accumulated the most N (g/m^2) produced the highest grain protein yield and near maximal yield. Also, they reported a correlation of r = 0.81 between plant N accumulation and grain yield. **Pollmer** et al., **(1979)** suggested that high grain protein yield in maize would result from more intensive 'N' uptake and prolonged N accumulation.

Hardy et al., **(1971)** observed sigmoidal curve for N_2 fixed v/s age in peanuts. Less than 10 per cent of the total N_2 fixation occurred prior to flowering while more than 90 per cent occured during fruit formation and maturation. About 250 mg or less than 25 per cent of the nitrogen of each mature plant was supplied by fixation. **Williams (1979)** measured the N content and its accumulation in the leaf, stem, husk and seeds of groundnut crop. The crop accumulated 2.39 kg N ha^{-1} during vegetative growth and 3.7 kg during first half

of reproductive growth after which N accumulation ceased, coinciding with the cessation of vegetative growth. A total of 30 $g(m^2)^{-1}$ was accumulated by the crop.

Crafts-Brander et al., **(1984)** compared pattern of N accumulation in nodulated and non-nodulated soybean cultivars having similar net photosynthetic ability and pod filling duration. The nodulated plants obtained 71-81 per cent of total plant N from uptake of soil N and non-nodulated plants were under moderate N stress, where both were grown without aupplemented N. In addition, rate of reduced accumulation was less in non-nodulated plants.

Green house and field studies were undertaken (**Schonbeck** et al., **1986**) to document the effect of a decreased pod number on N accumulation in soybean. Removal of about 40 per cent of the pods had not affected total N accumulation and dry matter indicating that partial depoding did not cause feed back inhibition of photosynthesis. **Cregan** and **Yaklich (1906),** by their comparative studies of modern and ancestral cultivars of soybean, concluded that modern cultivars had highest N and dry matter accumulation than their wild counterparts.

Jeppson et al., **(1978)** and **Austin** et al., **(1980)** reported near identical harvest index for soybean and wheat respectively. All the same, wheat accumulated 85 per cent and soybean 25 per cent of total season N before anthesis. Therefore, relative to soybean the nitrogen remobilization efficiency (NRE) of wheat was higher. The high nitrogen harvest index (NHI) coupled with low NRE in soybean indicated that a large proportion of the assimilated N was used by the developing soybean seed immediately rather than first being incorporated into leaf or stem proteins as in cereals (**Cregan** and **Berkum, 1984**). They further emphasised that the incorporation of N into leaf and stem

proteins and its subsequent remobilization and translocation to the developing grain may be an inefficient process and therefore consideration should be given to the possible development of genotypes in which a greater proportion of N was used directly by the developing seed.

Vegetative N mobilization in groundnuts during pod filling period was studied using foliar applied ^{15}N labelled ammonium sulphate prior to initial pod set and monitoring ^{15}N throughout the plant growth until harvest. N concentration and ^{15}N enrichment of the vegetative parts of the cultivars declined continuously until the optimum harvest date and this was coincident with a continuous increase in ^{15}N by the developing fruit. It was concluded that N was mobilized from the vegetative tissues into the developing pods throughout pod development. However, during reproductive development pods were not the only parts that served as a sink for N (**Doughlas** and **Weaver, 1986**). In their study, nitrate derived ^{15}N was distributed throughout the plant; 40 per cent in pod, 19 per cent in roots and 26 per cent in leaves.

Cregan and **Berkum (1984)** outlined following points for the enhancement of N metabolism and plant productivity. Their approach combined the traditional methods of estimating harvestable end product together with measurements of the interacting genetically controlled physiological processes which precede plant maturity to understand the physiological events leading to the improvement. According to them then it should be possible to develop an integrated physiological/ biochemical selection programme to define harvestable and products, to identify range of genetic variation available in each trait, and to identify those factors which limit N metabolism and plant producti-

vity. This approach would also permit the identification of parents with exceptional levels of specific parameters to be followed by hybridization and continued selection to combine these traits into unique genotypes with the potential for more efficient N metabolism and higher productivity.

MATERIAL AND METHODS

III MATERIALS AND METHODS

3. General Description

3.1 Location

All the field and pot culture experiments included in this investigation were conducted at the Agriculture Botany garden and Post-graduate research plots of Departments of Agriculture Botany, University of Agricultural Sciences, Hebbal, Bangalore.

3.1.2 Soil

Soil is sandy loam in nature. It is low in available nitrogen and high in available P_2O_5 and medium in available K_2O (**Mahabaleshwar, 1983**).

3.2 Experimental material

The material used for present investigation comprised of 97 groundnut (*Arachis hypogaea* L.) genotypes belonging to Spanish and Valencia botanical types. They were selected from ICRISAT groundnut collections. The material was chosen from diverse origin, representing collections from China, Africa, North and South America besides many Indian collections (The list of the genotypes and their sources are presented in Appendix I). All these genotypes mature in about 110-120 days. Virginia types were not included, since selection was aimed at uniform maturity of the genotypes.

3.2.1 Description of the crop

Arachis hypogaea 2n=40, belonging to tribe *Aeshynomeneae*, subtribe *Stylosanthinae*, is a perennial or annual

herb. Arachis hypogaea species consists of Virginia, Valencia and Spanish botanical types, which differ from one another in the arrangement of vegetative and reproductive branches on n, n+1 and n+2 branches. It is a crop of South American origin now under cultivation in both tropical and warm temperate regions of the world.

3.3 Methodology

The entire investigation was carried out in a phasewise manner where each preceeding experiments helped to continue the subsequent investigations. The methodology followed in each step is briefed below.

3.3.1 Experiment I

Preliminary screening of groundnut genotypes at different nitrogen levels.

This was an initial screening programme of 97 groundnut genotypes for more detailed experiment to follow.

3.3.2 Layout of the experiment

The experiment was laid out in a split-plot design with three nitrogen levels as main plot treatments and 97 groundnut genotypes as sub-plot treatments with two replications, during the summer of 1985.

Main treatments

Nitrogen levels (Kg/ha)	Symbols
N P_2O_5 K_2O	
0-50-25	N_0
25-50-25	N_1

75-50-25 N_2

To maintain a high level of soil nitrogen 75 kg/ha was added once in 15 days until 90 days of crop maturity for all the crops raised under field conditions. Each genotype was sown in 2 rows of 60 x 30 cm spacing in a 3 x 4 sq.m plots. All the recommended package of practice of UAS Bangalore for groundnut were followed.

3.3.3 Recording observations

Following observations were recorded at 60th day and at harvest on following characters on 5 randomly selected plants.

At 60th day

1. Shoot dry weight
2. Leaf dry weight
3. Leaf area

At harvest

1. Final pod yield

Based on the results, 50 genotypes were carried forward. Selections were made for poor and excellent performance with and without fertilizers nitrogen.

3.4 Experiment II : Study of genetic variation for physiological characters in 50 groundnut genotypes.

This was an extension and repetition of previous experiment. Main aim of the experiment was to estimate the extent of genetic

variability present in some of the physiological characters which have got direct or indirect bearings on nitrogen fixation.

3.4.1 Layout of the experiment

Fifty groundnut genotypes were sown in a split-plot design, taking two nitrogen levels (N_0 and N_2) as main plot treatments and genotypes as sub-plot treatments, during 1985 kharif season. Each genotype was sown in 3 rows of 60 x 30 cm spacing in a 4 x 4 m^2 plots with two replications.

Main treatments

Nitrogen levels (Kg/ha) $N.P_2O_5.K_2O$	Symbols
0-50-25	N_0
75-50-25	N_2

3.4.2 Recording observations

The following characters were recorded at 30, 60, and 90 days after sowing. At harvest, only final pod yield was recorded.

1. Shoot dry weight
2. Leaf dry weight
3. Pod dry weight
4. Total dry weight
5. Leaf area
6. Nodule number
7. Final pod yield

Dry Weights: Leaf, stem and pod dry weights were recorded after oven drying at $80^{o}C$ for 24 hours and total dry matter

per plant was computed by summing up the dry weights of leaves, stem and pods and was expressed in g.

3.4.3 Leaf area

Leaf area was determined using leaf punch method. The leaflets were collected at random for each one of the plants used for leaf dry weight observation and punches of known area were taken avoiding the mid-rib as far as possible. The punches then collected and rest of the leaves were dried separately in a hot air oven at $80^{o}C$ for 24 hours. Then dry weights of leaf punches and other leaves were determined and leaf area was calculated using the formula.

$$LA = \frac{a \times c}{b} \ cm^2/plant$$

LA = Total leaf area

a = Leaf area of 10 leaf punches

b = Total dry weight of 10 leaf punches

c = Total dry weight of all the leaves of the plant.

3.4.4. Nodule number

Only effective nodules (based on colour) were scored for nodule number.

3.5 Methodology adopted while selecting genotypes at the end of I and II experiments.

3.5.1 Classification of genotypes based on mean and critical difference (C.D.) Values.

In the present investigation 97 groundnut genotypes during the first season and 50 groundnut genotypes out of 97

in the second season were evaluated to estimate the extent of genetic variability for soil nitrogen utilization.

While evaluating the genotypes for soil nitrogen utilization, different soil nitrogen levels were treated as main-plot treatments and groundnut genotypes as sub-plot treatments in a split-plot design. This design helps only in identifying genotypic difference under all main treatments put together. However to identify individual genotype per-formance in each nitrogen level, a system of classifica-tion was followed as described below.

The classification was based on two statistical parameter viz, Mean and Critical Difference (C.D.) values. C.D. is routinely used in comparing significance of treatment mean differences. Here C.D. values of sub-plot treatments were utilized.

For instance, in case of I experiment, 97 groundnut genotypes are to be assessed for their performance under each nitrogen level for a particular character, say, leaf area. Then the grand mean ($\overline{X_G}$) of treatment means of all the 97 groundnut genotypes for the leaf area was calculated. Taking the grand mean and C.D. value of sub-plot treatment for leaf area, genotypes were assigned to any one of the following categories.

I. If leaf area of a particular genotype exceeded or equalled to $\overline{X}_G$ + C.D. value then for that character genotypic performance was considered superior and indicated by the symbol "H".

II. If, leaf area were to be in between X_G to X_G + C.D., the genotypic performance was considered medium high and indicated by the symbol "M_1".

III. If, leaf area were to be in between, X_G - C.D. to X_G, the genotypic performance was considered medium low and indicated by the symbol "M_2".

IV. If, leaf area was less than X_G - C.D., genotypic performance was considered low and indicated by the symbol "L".

This classification was followed for all the characters observed in a genotype under each nitrogen level.

3.5.2 Scoring of the categories L, M_2, M_1 and H of genotypes

In the above formulated exercise a genotype was designated L, M_2, M_1, or H for each character observed. To find out the worth of a genotype across the characters observed a system of scoring was followed. Here, a score of 1, 2, 3 and 4 had given to the classes L, M_2, M_1 and H respectively. Total score for each genotype was calculated by summing up the scores of all the characters across the growth stages and nitrogen levels. Selection was exercised on these scores to identify desirable genotypes both in I and II experiments.

3.5.3 Selection of genotypes for pot culture experiment (experiment III) from II experiment

Preceding exercises helped in identifying overall genotypic performance across the nitrogen level. To find out the

genotypic performance for each nitrogen level in the II experiment following method was followed.

A. Nitrogen levels	N_0				N_2			
B. Growth stages characters	60 (Days)	80	100	Final Status	60 (Days)	80	100	Final Status
1. Leaf area	L	L	L	L	H	H	H	H
2. Leaf dry weight	L	L	M_2	L	H	H	M_1	H
3. Shoot dry weight	L	M_2	M_2	L	H	M_1	M_1	H
4. Total dry weight	M_2	M_2	M_2	L	M_1	M_1	M_1	H
5. Pod dry weight	M_1	M_2	M_2	L	H	H	M_2	H
6. Nodule number	H	M_2	M_2	L	H	H	M_2	H
7. Final pod yield	H	L	L	L	H	H	L	H

This method assigned a final status to each character under each nitrogen level. While giving a final status all the three growth stages were considered. If a character showed a minimum of two M_2 or L status out of three growth stages, that character was given a final status 'L' indicating overall poor performance. On the other hand, characters showing a minimum of two M_1 or H were given a final status of 'H' indicating better performance. This way, all the characters were given a final status separately at N_0 and N_2 soil nitrogen conditions.

With the help of above said classification following four classes of genotypes were selected for pot culture experiment and hybridization programme.

I Genotypes which exhibit 'H' for all or most of the characters both under N_0 and N_2 nitrogen conditions. They were designated as 'HH'.

II Genotypes which exhibit 'H' for all or most of the characters under N_0 and 'L' for all or most of the characters at N_2. They were designated as 'HL'.

III Genotypes which exhibit 'L' for all or most of the characters at N_0 and H for all or most of the characters at N_2. They were designated as 'LH'.

IV Genotypes which exhibit 'L' for all or most of the characters both at N_0 and N_2 nitrogen levels. They were designated as 'LL'.

3.6 Experiment III : Pot culture experiment to study the physiological and biochemical variations in the selected genotypes.

From each above mentioned category, one genotype was carried further for pot culture experiment. This study was undertaken to understand 'how' and 'why' genotypes differ in their nitrogen responsiveness.

Earthen pots of 1 kg volume were filled with granite powder and perlite in equal volumes which created a partially sterile condition to have different treatment combinations in the experiment.

Treatments	symbols
Control	C
Nitrogen	N
Rhizobium	R
Rhizobium + Nitrogen	R + N

Each pot was shown with 4-5 seeds. After proper establishment of seedling, only two plants were retained in each pot. All the four selected genotypes were tried in these treatments with two replications, during 1986 summer.

Control was not supplied with any nitrogen or rhizobial inoculation throughout the growing season. For rhizobial treatment soil suspension was added which was taken from the site where groundnut was previously cultivated and which contained native rhizoba for groundnut. Hoagland nutrient solution without nitrogen except in case of N treatment was added to control and rhizobial treatment to supply essential nutrients for plant growth.

3.6.1 Recording of observations

The following observations were recorded at 60, 75 and 100th days after sowing, on 4 plants.

1. Shoot dry weight
2. Root dry weight
3. Leaf dry weight
4. Total dry weight
5. Leaf area
6. Nitrate reductase activity
7. Nitrogenase activity
8. Translocation study using ^{14}C counts
9. Per cent nitrogen estimation in different plant parts

3.7 Experiment IV : Study of F1 progenies of selected genotypes

3.7.1 Floral biology of groundnut

Groundnut is essentially a self-pollinated crop, the extent of natural cross-pollination being very small (**Kushman** and **Beatti, 1946**). Flowers occur either solitary or in clusters of about three or more from leaf axils. The flower is sessile, yellow in colour carried on long calyx tube papilionaceous corolla arising from the rim of the calyx tube. The keels are united, stamens non-adelphous of which 8 fertile and 2 sterile. Anthers are dimorphic (4 long and 4 round). Gynoecium consists of a monocarpellary superior ovary with 1-3 ovules.

Anthesis : Dehiscence of anthers takes place between 5 A.M. to 6 A.M. and the flowers open between 6 A.M. to 8 A.M.

3.7.2 Crossing programme

The four genotypes previously selected for experiments were used in the crossing programme.

Category	Genotypes	Cross-combinations
HH	No. 276	Mani Blanco x US-1
LH	US-1	Mani Blanco x RS-113
HL	RS-113	Mani Blanco x No. 276
LL	Mani Blanco	US-1 x RS-113
		US-1 x No. 276
		RS-113 x No. 276

In this crossing programme, the genotypes US-1 and RS-113 were used as both male and female parents. Mani Blanco

was used only as female parent and No. 276 was used only as male parent.

All the female parents were sown in the crossing blocks of Agriculture Botany department green house, and male parents were sown in the field, during kharif 1986, Emasculation was done in the late afternoon or in the evening. Flower buds that will open the next morning were selected for emasculation. The petals were spread apart with forceps in order to remove the stamens, after which the petals are placed back in their original position.

Flowers from male parents were collected early in the morning in plastic cups and pollens were dusted on desired female parents. All the crossed flowers were tagged with colour threads to identify crossed pods from uncrossed ones, if any.

Crossing blocks were irrigated immeditely after crossing, to enhance the humidity percentage around plant microclimate to achieve higher success in outcrossed flowers. Crossing programme was continued till 80-90 days after sowing. Plants were nurtured throughout the crossing programme.

3.8 Experiment V : Evaluation of F1 genotypes

Four parents and F1 seeds of six cross combinations were sown with two nitrogen levels (N_0, N_2) and two replications during 1987 summer season.

Nitrogen levels (Kg/ha) N P_2O_5 K_2O	Symbols
0-50-25	N_0
75-50-25	N_2

Parents	Fls
No. 276	Mani Blanco x US-1
US-1	Mani Blanco x RS-113
RS-113	Mai Blanco x No. 276
Mani Blanco	US-1 x RS-113
	US-1 x No. 276
	RS-113 x No. 276

Both parents and Fls were grown in 3 rows with 60 x 60 cm spacing.

3.8.1 Recording observations

Observations were recorded on following characters listed at 60th and 80th day.

1. Shoot length
2. Rooty length
3. Number of internodes on main branch (n)
4. Number of internodes on side branches (n = 1)
5. Length of main internode (n)
6. Length of the internode in n+1 branch
7. Leaf length
8. Leaf width
9. Nodule number

Following characters were recorded on 60th, 80th day and at the time of harvest.

1. Shoot dry weight
2. Leaf dry weight
3. Total dry weight
4. Leaf area
5. Nitrate reductase activity
6. Final pod yield (only at harvest)

3.9 In vivo nitrate reductase activity (NRA)

NR activity was estimated as per the method described by **Nicholas** et al., **(1976)** and **Hageman** et al., **(1980)**. Enzyme activity was estimated by infilterating and incubating the tissue with nitrate (NO_3) in dark and estimating the amount of nitrite (NO_2) formed in the assay medium at the end of the incubation period. Thus the amount of NO_2 formed will give the rate of reduction of NO_3 through NR activity.

In each genotype a composite sample of leaves was collected around 9.30 - 10 A.M. Avoiding the tip and basal portion of the leaves, leaf discs of about 0.7 cm in diameter were taken. About 25-30 punches weighing 500 mg were sampled for each assay. The leaf punches were put in a 25 ml beaker containing 10 ml assay medium of phosphate buffer, KNO_3 and propanol. Care was taken to see that all the leaf punches were immersed in the assay medium. The samples with assay medium were subjected to vacuum infiltration for 2 + 2 minutes and incubated at 38^{o} C for 1 hour in a shaking water bath under dark condition.

From this assay medium, 0.5 ml of aliquot was taken and volume was made up to 2 ml using distilled water. To this, one ml of P-aminobenzene sulphonamide (1% in 1.5N HCl) and 1 ml N-1-

(naphthyl) ethylene diamine di-HCl (0.02%) were added in that order. The reaction was allowed to proceed for 10 minutes and activity was recorded at 540 nm using double beam spectrophotometer (model VV-2005, Shimadzne) and activity was expressed as μ mol NO_2 formed/h/g fresh weight of leaves.

3.10 Estimation of nitrogenase activity through acetylene reduction assay (ARA)

One day prior to estimation of nitrogenase activity groundnut genotypes were irrigated to facilitate easy removel of plants from pot. Sampling was done between 10 A.M. to 12 noon. Plants in each variety was pulled out carefully, and roots were excised at the collar region. Two roots from a variety were placed in an incubation vessel (250 ml conical flask) fitted with rubber septum of appropriate size to give a leak proof fit.

With a 50 ml plastic syringe 12 per cent (30 ml) of the air was removed from the incubation vessel and immediately replaced with equal amount of acetylene gas. Incubation was carried out for 3 hours under shade. Five ml of gas was removed from these vessels and injected into 15 ml evacuated vacutainers. After every 10 samples a blank was run without plant roots. ARA was measured using GLC Hewieg-Packard and expressed as μ mole of C_2H_4 formed/h/g of fresh root and on organ weight basis (**Somasagaran** and **Hoben, 1985**).

3.11 Feeding of $^{14}CO_2$ to groundnut genotypes under canopy condition

A chamber made out of acrylic sheet measuring 68 x 68 x 40 cm was kept over the pots containing four varieties of groundnut.

This chamber was burried into the soil to depth of 3" to 4" to prevent any air leakage. A conical flask containing 125 μ Ci of $Na_2{}^{14}CO_3$ and 0.3 g of ordinary Na_2CO_3 was kept in the center and was connected to a funnel kept outside the chamber through a rubber tube and a bent tube. Experiment was conducted usually between 11 A.M. to 12 noon when diurnal fixation of N_2 was maximum. The whole chamber was wet inside with soap solution to prevent water drops from sticking to the inside walls. Then chamber was covered with black cloth from all sides, then sufficient quantity of perchloric acid (35%) was added till air bubbles inside the funnel stopped coming. After three minutes black cloth was removed and cold water was poured on top of the chamber to prevent excess heating. Plants were allowed to photosynthesise for period of 10 minutes. Later the chamber was removed. After 24 hours, plants were heat killed in an oven, and plant parts (leaf, shoot, root and peg) were separated, powdered and weighed for estimation of radioactivity.

3.11.1 Estimation of ^{14}C counts on scintillation counter

Ten mg of powdered sample was weighed into 1.5 ml exppendorf tubes. Sample was digested with 0.1 ml concentrated HNO_3 at 90^oC for 1 hour. This digested sample was neutralized with 0.9 ml Tris buffer. From this 0.2 ml was pipetted out into 10 ml scintillation (Bray's solution; Appendix II) fluid and counts were recorded on packard Tricarb 4530, liquid scintillation spectrometer. Scintillation vials showing higher ($>$ 50) counts were discarded and for

others back ground counts were substracted from sample counts.

3.12 Per cent nitrogen estimation in different plant parts

Nitrogen per cent in different plant parts was estimated following the method suggested by Jackson, 1973.

3.13 Statistical analysis

Analysis of variance for split-plot design was done according to the usual procedure e.g., as of **Sundararaj** et al., **(1972)**.

ANOVA table for split-plot analysis

Source	d.f.	M.S.S.	F ratio
Whole plot analysis			
Replications	(r-1)		
Main treatment (A)	(a-1)	Ma	Ma/MEa
Error(a)	(a-1) (r-1)	MFa	
Sub-plot analysis			
Sub-treatment (B)	(b-1)	Mb	Mb/MEb
Sub-treatment x whole treatment (A x B)	(a-1) (b-1)	Ma xb	Ma x b/MEb
Error (b)	a(b-1)(r-1)	MEb	

where:

r = number of replications

a = number of main treatments

b = number of sub-treatments

Ma, Mb, Ma x b = Mean squares of main, sub and interaction treatment effect respectively.

MEa and MEb = Mean squares of errors associated with main and sub-treatments respectively.

The computed 'F' ratio was compared with Table 'F' value. Further standard error of means (S.Em), critical difference (CD) and coefficient of variation expressed in percentage (CV%) were worked out using appropriate formulae for comparing varietal means.

3.13.1 Estimation of genetic parameters

(a) Components of variance

The components of variance namely phenotypic (p^2), genotypic (g^2) and environmental (e^2) variances were used for the estimation of phenotypic and genotypic coefficients of variation as per the method suggested by the **Burton** and **Devane (1953).**

(b) Genotypic coefficient of variability (GCV)

$$GCV = \frac{\text{(Genotypic variance) } 1/2}{\bar{X}} \times 100$$

where, genotypic variance (g2) $= \frac{\text{Varietal M.S.S. - Error M.S.S.}}{\text{Number of replications (r)}}$

and $\bar{X}$ the general mean of the population.

(c) Phenotypic coefficient of variability (PCV)

$$PCV = \frac{\text{(Phenotypic variance) } 1/2}{\bar{X}} \times 100$$

Where, Phenotypic variance (p^2) $= \frac{\text{Genotypic M.S.S. + Error MSS}}{}$

and $\bar{X}$ = the general mean of the popultion.

3.13.2 Heritability (h^2) in broadsense was calculated as a ratio of genetic variance (G.V.) to total variance (P.V.)

$$\% h^2 = \frac{G.V.}{P.V.} \times 100$$

3.13.3 Genetic advance (GA) : GA was calculated using the formula provided by Lush (1949).

$$GA = K \times h^2 x \; / \; \text{Phenotypic variance}$$

K = Selection differential i.e. 2.06 at 5 per cent selection intensity

h^2= Heritability

3.13.4 Correlation coefficient

(a) Simple Correlation: Correlation coefficient was worked out to determine the degree of association among the characters as well as yield. This was done according to the methods suggested by **Aljibouri** et al., **(1958)**.

$$r_{p_{12}} = \frac{p_{12}}{p_{11} \times p_2}$$

$$r_{g_{12}} = \frac{g_{12}}{g_{11} \times g_{22}}$$

Where;

$r_{p_{12}}$ = Phenotypic correlation coefficients between characters X1 and X2

$r_{g_{12}}$ = Genotypic correlation coefficients between the characters X1 and X2

P_{12} = Phenotypic covariance between characters X1 and X2

P_{11} = Phenotypic variance of character X1

P_{22} = Phenotypic variance of character X22

g_{12} = Genotypic covariance between characters X1 and X2

g_{11} = Genotypic variance of character X1

g_{22} = Genotypic variance of character X2

The test of significance was carried out by means of Fisher's 't' test.

3.13.5 Estimation of heterosis (H)

Heterosis was calculated as the percentage increase or decrease of mean F_1 performance

(i) Heterosis over better parent value (H) = $\frac{F_1 - Br.P}{Br.P} \times 100$

(ii) Heterosis over best parent value, i.e. Heterobeltosis (HB) = $\frac{F_1 - B.P.}{B.P.} \times 100$

Better parental value (Br.P.): For each character, the superior value between the parents in each cross was taken.

Best parental value (B.P.): For each character, the best value among 12 parents involved in the crossing programme was taken.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Experimental results are presented in a phase-wise manner. Results of previous experiments were utilized in ensuing steps.

Experiment 1: Initial evaluation of 97 groundnut genotypes under N_0, N_1 and N_2 levels of soil nitrogen.

The aim of this initial evaluation was to find out the extent of genetic variability present among 97 groundnut genotypes for few selected physiological/or physiomorphological characters under different soil nitrogen levels. The whole plot treatment analysis of variance (Table 1) revealed that none of the characters studied exhibited significant variation for nitrogen levels. However, at sub-plot level, genotypes exhibited significant variation for leaf area and final pod yield. Interaction effect of leaf area with nitrogen levels was also significant.

The leaf area and final pod yield were having a mean of 971.12 cm^2 and 26.73 gram and range of 635.81-1419.96 cm^2 and 3.73-36.72 gram respectively. These two characters also showed a moderate amount of genotypic variability (25.94 and 31.58) appreciable amount of herita-bility (47.22 and 44.82) coupled with high genetic advance (353.02 and 11.64) respectively.

Association of leaf area with leaf dry weight and shoot dry weight was highly significant and positive at all levels of soil nitrogen (Table 2). But, with pod yield significance was observed only at N_2 level of soil nitrogen. Correlations of leaf and shoot dry weights with final pod yield were not significant.

Table 1 : Whole and sub-plot analysis of variance for 97 groundnut genotypes at three nitrogen levels for different characters at 60th day and final pod yield at harvest.

	Character	Treat-ment	Mean	Range	Mean square	C.D. 5%	GCV	PCV	h^2	GA 5%
1.	Leaf Area (Cm)	M	971.12	695-84-1135.65	NS	812.46				
		S	971.12	635.81-1419.96	*		25.94	37.55	47.22	353.02
		I			NS					
2.	Leaf Dry weight (g)	M	12.18	11.36-12.92	NS	6.44	10.84	52.49	4.26	56.06
		S	12.18	7.75-18.54	NS	7.07				
		I			NS					
3.	Shoot dry weight (g)	M	24.31	20.85-25.85	NS	7.75				
		S	24.31	11.75-31.83	NS	12.97	22.42	52.21	18.44	4.82
4.	Final pod yield (g)	M	26.73	24.09-30.64	NS	9.75	31.58	47.17	44.82	11.64
		S	26.73	24.09-30.64	*	10.60				
		I			NS					

* Significant at 5% level of significance

M = Main treatments
S = Sub treatments
I = Interaction

Table 2 : Phenotypic correlation among four characters at different nitrogen levels.

Combination	Nitrogen level	r
1.2	N_0	0.32**
	N_1	0.75**
	N_2	0.62**
1.3	N_0	0.71**
	N_1	0.32**
	N_2	0.61**
1.4	N_0	-0.18
	N_1	0.02
	N_2	0.25*
2.3	N_0	0.48**
	N_1	0.39**
	N_2	0.90**
2.4	N_0	-0.11
	N_1	0.06
	N_2	0.05
3.4	N_0	-0.20
	N_1	-0.06
	N_2	0.002

1 = Leaf area

2 = Leaf dray weight

3 = Shoot dry weight

4 = Final pod yield

* = Significant at 5% level of significance

** = Significant at 1% level of significance

Consequent to the variability study a system of classification was formulated to study individual genotype at each level of soil nitrogen condition. For example, if we designate $\bar{x}_g$ as mean of genotype over replications at any given level of soil nitrogen ($N_0/N_1/N_2$) then $\bar{x}_G$ represents mean of 97 groundnut genotypes at any given level of nitrogen. Further using critical difference (C.D.) value and genotypic mean ($\bar{x}_G$) following system of classification was formulated.

A genotypic performance was considered (i) high (H) if its value for that character exceeded or equalled to $\bar{x}_G$ + C.D. value, (ii) medium high (M_1), if its value was in between $\bar{x}_G$ to $\bar{x}_G$ + C.D., (iii) medium low (M_2) if its value was in between $\bar{x}$ to $\bar{x}_G$ - C.D. and (iv) Low (L), if its value was less than or equal to $\bar{x}_G$ - C.D.

This whole exercise was an attempt to identify genotypes with the relative worth for different characters observed. Following this classification, for each character (shoot dry weight, leaf area, leaf dry weight and final pod yield) genotypes were arranged in ascending order under each main treatment (N_0, N_1 and N_2).

In this classification, genotypic distribution for leaf area was near normal at N_0 nitrogen level. Amongst 97 genotypes, majoriy belonged to M_1 or M_2 status (Table 3). Consequently, with nitrogen enrichment (N_1 nitrogen level) number of genotypes under 'L' and 'H' categories was increased (Table 4). However, effect was more evident with further nitrogen enrichment of soil (N_2 level, Table 5).

Genotypic distribution for leaf dry weight showed entirely different pattern. At N_0 level of soil nitrogen, none of the genotypes were under 'L' status and only one with 'H' designation (Table 6). Same pattern continued throughout the nitrogen levels (N_1 and N_2) (Tables 7 and 8). Similar response was also observed for shoot dry

Table 3 : Treatment means of 97 groundnut genotypes for leaf area arranged in ascending order at no level of nitrogen

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
1.	EC-106985	310.80		35.	Small pod	590.50	
2.	Mani Blanco	325.50		36.	Local alarge	596.00	
3.	Non nodulating	345.89		37.	No. 53	597.91	
4.	KG-61-99	361.70		38.	EC-21164	603.25	
5.	S-196	363.00	L	39.	Ah-7986	616.49	
6.	U-2-1-28	402.50		40.	EC-21073	622.13	
7.	Jatuti	405.97		41.	Ah-7116	622.39	
8.	RB-1	408.00		42.	A-15	623.75	
9.	S-206	408.00		43.	EC-21081	627.75	
10.	U-1-2-3	409.25		44.	EC-16675	636.00	
11.	RB-181	425.50		45.	Spanish-5	654.00	
12.	EC-161297	437.94		46.	Ah-39	656.00	
13.	Natal common	447.07		47.	JH-357	657.50	
14.	G-0173	448.00		48.	Khandesh	662.50	M_2
15.	28-8-2	449.44		49.	RS-113	665.50	
16.	A-17-1700	463.09		50.	S-196	670.75	
17.	Manfredi-84	464.38		51.	Short-1	671.75	
18.	K-35	475.50		52.	R-4	672.71	
19.	Khandesh	479.00		53.	Exotic-7-3	692.50	
20.	RS-60	485.54		54.	J-11	694.50	
21.	Manfredi-118	492.00		55.	EC-16674	704.50	
22.	EC-21093	497.00		56.	US-1	709.00	
23.	EC-20957	511.40		57.	EC-21032	723.50	
24.	TMV-7	515.50		58.	No. 243	726.67	M_1
25.	TMV-2	521.63		59.	EC-21107	728.00	
26.	EC-21105	529.75		60.	Russian International-2	741.70	
27.	Dohad No.1	542.00	M_2	61.	Roiet No.3	742.25	
28.	S-277	552.00		62.	Taluka Harur local	758.50	
29.	EC-21128	553.98		63.	U2-12-6	773.07	
30.	RS-12	554.00		64.	EC-24447	784.00	
31.	No.53	569.00		65.	U-2-1-8	785.50	
32.	Ah-811	569.83		66.	U-2-1-13	794.00	
33.	EC-21119	572.50					
34.	S-40-DR	582.38					

Table 3 (Contd.)

Sl. No.	Genotyes	Local Area (Sq. Cm)	Status
67.	Spanhoma	795.25	
68.	Almel No.1	801.00	
69.	TG-3	819.00	
70.	No. 276	825.88	
71.	Ah-24439	826.00	
72.	Local Claire	829.63	
73.	Limidi-4	833.00	
74.	Limidi-5-3	840.13	
75.	US-16B	850.00	
76.	US-1613	852.00	
77.	NG-337	875.75	
78.	Sir 07 Durgapur	878.50	
79.	Tej Amra Local	881.98	
80.	Mani Blanco	891.68	
81.	EC-21080	898.50	
82.	Starr	899.25	
83.	JH-133	919.89	
84.	Limidi-5	937.50	
85.	EC-1753	941.25	
86.	KG-61-99	946.00	
87.	JH-107	946.50	M_1
88.	K-3	953.00	
89.	K-71	959.02	
90.	EC-21088	1020.25	
91.	U2-1-25	1058.00	
92.	Ah-1716	1068.50	
93.	Spanish-191-1	1124.00	H
94.	Pollachi-1	1136.00	
95.	Limidi-4	1307.75	
96.	JH-313	1323.09	
97.	Sakaria	1421.50	

(i) Mean = 680.65
(ii) Mean - C.D. = 382.31
(iii) Mean + C.D. = 978.99

Table 4 : Treatment means of 97 groundnut genotypes for leaf area arranged in ascending order at N_1 level of nitrogen.

Sl. No.	Genotype	Leaf area (Sq cm)	Status	Sl. No.	Genotype	Leaf area (Sq cm)	Status
1.	EC-21119	462.50		31.	Roiet No.3	950.00	
2.	EC-16675	497.50		32.	Pollachi-1	962.50	
3.	Limidi-5-3	525.00		33.	Tej Amar local	962.50	
4.	Natal common	550.00		34.	Spanhoma	962.50	
5.	Mani Blanco	577.50		35.	US-1	1006.00	
6.	Manfredi-118	675.00		36.	Spanish-5	1006.00	
7.	No. 243	677.88		37.	TMV-7	1006.00	
8.	U2-12-6	690.00		38.	K-35	1006.00	
9.	Exotic-7-3	700.00	L	39.	Local clair	1006.00	
10.	EC-21107	700.00		40.	Sir of Durgapur	1006.00	
11.	RS-60	721.88		41.	No. 276	1008.50	
12.	U-1-2-3	725.00		42.	Ah-811	1025.00	
13.	Kandesh	731.25		43.	Manfredi-84	1028.13	
14.	JH-313	743.75		44.	EG-24447	1037.50	
15.	Small pod	743.75		45.	R-4	1050.00	M_2
16.	K-71	770.00		46.	RB-1	1050.00	
17.	Russian Inter-national-2	775.00		47.	TG-3	1050.00	
				48.	RS-113	1050.00	
				49.	A-15	1050.00	
18.	K-3	831.25		50.	EC-21093	1050.00	
19.	TMV-2	852.70		51.	Local alargel	1050.00	
20.	S-196	871.75		52.	EC-21080	1075.00	
21.	Ah-39	875.00					
22.	U-2-1-8	875.00		53.	EC-21164	1093.50	
23.	NCAC-2742	875.00	M_2	54.	US-16B	1115.63	
24.	Short-1	887.50		55.	Limidi-4	1121.88	
25.	Spanish-191-1	896.50		56.	S-206	1137.00	M_1
26.	EC-21032	918.50		57.	Sterr	1137.50	
27.	Ah-7986	918.75		58.	RS-181	1137.50	
28.	JH-107	918.75		59.	U-2-1-28	1168.50	
29.	Limidi-4	920.50		60.	KG-61-99	1175.00	
30.	Limidi-5	943.75					

Table 4 (Contd.)

Sl. No.	Genotypes	Leaf area (Sq Cm)	Status
61.	No.53	1181.00	
62.	S 40 DR	1181.00	
63.	28-8-2	1181.25	
64.	EC 106985	1181.25	
65.	No.53	1187.50	
66.	TMV-7	1202.88	
67.	US 16B	1215.63	
68.	G-0173	1225.00	
69.	S-277	1225.00	
70.	K-35	1225.00	M_1
71.	RS-12	1225.00	
72.	JH-357	1237.50	
73.	Almel No.1	1266.00	
74.	Mani Blanco	1268.50	
75.	EC-21081	1268.75	
76.	Ah-24439	1287.00	
77.	Khandesh	1312.50	
78.	EC-21073	1312.50	
79.	Dohad No.1	1356.00	
80.	JH-133	1356.25	
81.	NG-337	1362.50	
82.	Taluk Harur local	1375.00	M_1
83.	EC-21128	1387.50	
84.	U-2-1-13	1390.00	
85.	EC-161297	1399.75	
86.	U2-1-25	1400.00	
87.	EC-21088	1400.00	
88.	Non-nodulating	1418.50	H
89.	J-11	1487.00	
90.	Ah-1716	1537.50	
91.	K-3	1612.50	
92.	A-17-1700	1618.75	
93.	KG-61-99	1662.50	
94.	Ah-7116	1725.00	
95.	EC-21105	1825.00	
96.	Jatuti	1837.00	
97.	EC-20957	1900.00	

(i) Mean = 1075.41
(ii) Mean - C.D. = 777.07
(iii) Mean + C.D. = 1373.75

Table 5 : Treatment means of 97 groundnut genotypes for leaf area arranged in ascending order at N_2 level of nitrogen.

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
1.	Limidi-4	360.00		33.	EC-21080	912.50	
2.	EC-20957	362.50		34.	U-1-2-3	931.00	
3.	Russian International-2	425.00		35.	EC-21073	956.00	
				36.	Spanish-191-1	962.25	
4.	S-206	468.50		37.	JH-107	931.25	
5.	No. 243	508.50		38.	NG-337	998.00	
6.	JH-133	512.50		39.	S-277	1025.00	
7.	Limdi-4	562.50		40.	Ah-39	1025.00	
8.	EC-21107	575.00		41.	EC-21164	1025.00	
9.	Khandesh	600.00		42.	NO. 53	1042.25	
10.	EC-1753	606.00		43.	U2-12-6	1071.00	M_2
11.	Starr	606.00		44.	EC-24447	1075.00	
12.	No. 53	606.25		45.	Short-1	1075.00	
13.	Natal common	625.00		46.	EC 21105	1075.00	
14.	Local alarge	675.00		47.	JH-357	1075.00	
15.	U-2-1-8	687.50		48.	K-3	1075.00	
16.	Spanish-5	693.00		49.	EC-161297	1091.00	
17.	RS-60	700.00		50.	EC-21119	1128.75	
18.	EC-21088	725.00					
19.	Local claire	725.00		51.	JH-313	1137.25	
20.	Khandesh	725.00	L	52.	EC-21032	1162.50	
21.	28-8-2	758.63		53.	Limidi-5	1162.50	
22.	Non-nodulating	759.50		54.	Sir of Durgapur	1193.50	
23.	US-16B	787.25		55.	Pollachi-1	1212.50	
24.	U2-1-25	791.33		56.	KG-61-99	1212.73	
25.	Spanhoma	862.50		57.	TMV-2	1216.73	
26.	RS-12	862.50		58.	EC-21128	1217.50	M_1
27.	Sakaria	878.75		59.	Mani Blanco	1225.00	
28.	TG-3	882.50		60.	Dohad No.1	1250.00	
29.	Jatuti	882.80	M_2	61.	Ah-1716	1262.50	
30.	Ah-811	882.80		62.	EC-16674	1262.50	
31.	Limidi-5-3	887.50		63.	Manfredi-84	1262.50	
32.	U-2-1-13	900.00					

Table 5 (Contd.)

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
64.	Ah-24439	1262.50		80.	Almel No.1	1480.33	
65.	EC-16675	1275.00		81.	RS-181	1493.50	
66.	U-2-1-28	1275.00		82.	No. 276	1515.63	
67.	A-15	1287.50		83.	TMV-7	1587.50	
68.	EC-21093	1306.00	M_1	84.	Roiet No.3	1587.50	
69.	RB-1	1307.67		85.	EC-21119	1587.50	
70.	KG-61-99	1312.50		86.	US-16B	1587.50	
71.	Mani Blanco	1318.50		87.	K-35	1678.00	
72.	R-4	1325.00		88.	RS-113	1712.78	H
73.	Manfredi-118	1331.00		89.	Exotic-7-3	1775.00	
74.	J-11	1351.00		90.	Ah-7116	1912.50	
75.	K-71	1362.00		91.	S-40-DR	1962.50	
76.	Tejamar Local	1390.00		92.	EC-21081	1975.00	
77.	Taluk Harur Local	1400.00		93.	US-1	2006.00	
				94.	A-17-1700	2045.00	
78.	G-0173	1437.90		95.	Ah-7986	2058.13	
79.	Small pod	1475.00	H	96.	S-196	2175.00	
				97.	U-2-1-28	2475.00	

(i) Mean = 1135.73
(ii) Mean - CD = 837.07
(iii) Mean + CD = 1434.07

Table 6 : Treatment means of 97 groundnut genotypes for leaf dry weight arranged in ascending order at N_0 level of nitrogen.

Sl. No.	Genotypes	Leaf dry Weight (g)	Status	Sl. No.	Genotypes	Leaf dry Weight (g)	Status
1.	Non-nodulating	3.75		33.	EC-21032	9.25	
2.	Mani Blanco	4.88		34.	EC-21073	9.25	
3.	Ah-7986	5.88		35.	Dohad No.1	9.25	
4.	S-196	6.13		36.	KG-61-99	9.50	
5.	U-2-1-28	6.15		37.	U-2-1-13	9.50	
6.	EC-161297	6.50		38.	Khandesh	9.63	
7.	Jatuti	6.75		39.	A-15	9.75	
8.	No. 53	6.75		40.	A-17-1700	10.00	
9.	JH-357	7.00		41.	EC-20957	10.00	
10.	Kandesh	7.13		42.	EC-21119	10.20	
11.	TMV-2	7.25	M_2	43.	RS-113	10.25	
12.	EC-21128	7.25		44.	EC-16674	10.25	
13.	WC-21105	7.40		45.	Local alarge	10.25	M_2
14.	Manfredi-84	7.40		46.	Taluk Harur Local	10.25	
15.	KG-61-99	7.50		47.	Natal common	10.28	
16.	28-8-2	7.75		48.	No. 243	10.50	
17.	U-1-2-3	7.75		49.	RB-1	10.50	
18.	RS-181	7.75		50.	Sir of Durgapur	10.50	
19.	Small pod	7.75					
20.	No. 53	8.00		51.	Manfredi-118	10.75	
21.	NCAC-2742	8.00		52.	Spanish-5	10.75	
22.	EC-21081	8.13		53.	Limidi-5	10.75	
23.	TMV-7	8.13		54.	Limidi-5-3	10.75	M_1
24.	K-35	8.25		55.	EC-1753	11.00	
25.	EC-106985	8.25		56.	Ah-244439	11.00	
26.	EC-16675	8.38		57.	US-16B	11.00	
27.	EC-21164	8.50		58.	Local claire	11.15	
28.	TG-3	9.00		59.	Ah-811	11.25	
29.	U-2-1-8	9.00		60.	RS-12	11.25	
30.	EC-21107	9.00		61.	Ah-39	11.38	
31.	Ah-7116	9.05		62.	Short-1	11.38	
32.	G-0173	9.13		63.	Spanhoma	11.50	

Table 6 (Contd.)

Sl. No.	Genotypes	Leaf dry Weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
64.	S-40-DR	11.50		80.	EC-21088	12.75	
65.	No. 276	11.63		81.	U2-12-6	13.00	
66.	Russian International-2	11.75		82.	U2-1-25	13.15	
				83.	K-3	13.25	
67.	S-277	11.75		84.	Exotic-7-3	13.88	
68.	NG-337	11.75		85.	EC-24447	14.25	
69.	EC-21093	11.75	M_1	86.	Spanish-191-1	14.25	
70.	US-16B	11.75		87.	Tejamar local	14.40	
71.	Pollachi-1	12.00		88.	Mani Blanco	14.75	
72.	JH-133	12.13		89.	JH-313	14.75	M_1
73.	Limidi-4	12.13		90.	J-11	15.25	
74.	EC-21080	12.13		91.	S-206	15.50	
75.	Roiet No. 3	12.15		92.	US-1	15.75	
76.	K-71	12.50		93.	Starr	15.75	
77.	Almel No.1	12.50		94.	RS-60	16.75	
78.	R-4	12.75		95.	Ah-1716	16.75	
79.	JH-107	12.75		96.	Limidi-4	17.00	
				97.	Sakaria	20.50	H

(i) Mean = 10.59
(ii) Mean - CD = 3.52
(iii) Mean + CD = 17.66

Table 7 : Treatment means of 97 groundnut genotypes for leaf dry weight arranged in ascending order at N_1 level of nitrogen.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	Mani Blanco	5.25		31.	Manfredi-84	10.00	
2.	A-15	6.50		32.	S-40-DR	10.00	
3.	U2-12-6	6.50		33.	Ah-7986	10.25	
4.	Manfredi-118	6.50		34.	Tejamar local	10.25	
5.	Short-1	6.50		35.	JH-107	10.25	
6.	Roiet No.3	6.50		36.	S-206	10.25	
7.	TMV-2	7.00		37.	Russian International-2	10.50	
8.	Limidi-5-3	7.00					
9.	JH-313	7.50		38.	RB-1	10.50	
10.	K-71	7.50	M_2	39.	US-1	10.50	
11.	Small pod	7.75		40.	Limidi-5	10.50	
12.	RS-60	8.00		41.	No. 276	10.75	
13.	RS-181	8.00		42.	RG-3	11.00	M_2
14.	Exotic-7-3	8.25		43.	Local claire	11.00	
15.	U-1-2-3	8.50		44.	EC-21164	11.00	
16.	EC-21107	8.50		45.	Non-nodulating	11.25	
17.	NGAC-2742	8.75		46.	EC-21093	11.25	
18.	Taluk Harur local	9.00		47.	Limisi-4	11.50	
				48.	Local alarge	11.50	
19.	EC-21080	9.00		49.	US-16B	11.50	
20.	Sakaria	9.00		50.	A-17-1700	11.75	
21.	EC-16675	9.13		51.	EC-21032	11.75	
22.	Natal common	9.25		52.	Spanhoma	11.75	
23.	Ah-39	9.25		53.	U-2-1-13	12.00	
24.	EC-16674	9.38		54.	U-2-1-8	12.00	
25.	Kandesh	9.38		55.	28-8-2	12.50	
26.	Pollachi-1	9.50		56.	Dohad No.1	12.50	
27.	Spanish-5	9.50		57.	JH-357	12.50	
28.	S-196	9.50		58.	Mani Blanco	12.50	
29.	Spanish-191-1	9.50		59.	R-4	12.75	
30.	EC-24447	10.00		60.	EC-21119	12.88	M_1

Table 7 (Contd.)

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
61.	S-277	13.00		80.	TMV-7	15.50	
62.	EC-21088	13.00		81.	EC-21073	15.50	
63.	No. 53	13.00		82.	KG-61-99	15.88	
64.	Almel No.1	13.25		83.	J-11	16.25	
65.	RS-113	13.25		84.	NG-337	16.50	
66.	Sir of Durgapur	13.30		85.	No. 243	17.00	
67.	EC-1753	13.50		86.	EC-21128	18.00	M_1
68.	WX-106985	13.50		87.	JH-133	18.00	
69.	Ah-1716	14.00		88.	KG-61-99	18.00	
70.	RS-12	14.00		89.	Starr	18.00	
71.	K-3	14.00	M_1	90.	US-16B	18.00	
72.	G-0173	14.50		91.	Ah-7116	19.25	
73.	Limidi-4	14.50		92.	EC-21005	19.50	
74.	Ah-24439	14.50		93.	EC-21081	20.00	
75.	U-2-1-28	14.75		94.	U2-1-25	20.25	
76.	Ah-811	15.00		95.	No. 53	22.25	H
77.	Khandesh	15.00		96.	Jatuti	22.75	
78.	K-35	15.25		97.	EC-20957	27.75	
79.	EC-161297	15.50					

(i)	Mean	=	12.66
(ii)	Mean - CD	=	5.19
(iii)	Mean + CD	=	19.33

Table 8 : Treatment means of 97 groundnut genotypes for leaf dray weight arranged in ascending order at N_2 level of nitrogen.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	EC-20957	5.75	L	33.	Spanhoma	11.25	
2.	EC-21107	6.50		34.	EC-21073	11.38	
3.	U-2-1-8	7.25		35.	No. 243	11.50	
4.	No. 53	7.50		36.	S-277	11.50	
5.	Limidi-5-3	7.50		37.	RS-181	11.50	
6.	Kandesh	7.70		38.	Ah-24439	11.50	
7.	Mani Blanco	7.75		39.	EC-21080	11.63	
8.	EC-21088	7.75	M_2	40.	Russian International-2	11.75	
9.	Ah-811	8.00		41.	EC-21081	11.75	
10.	Non-nodulating	8.25		42.	Local alarge	11.75	M_2
11.	JH-133	8.50		43.	EC-21105	11.75	
12.	US-16 B	9.00		44.	US-16 B	11.75	
13.	Limidi-5	9.13		45.	NG-337	12.00	
14.	U-1-2-3	9.13		46.	A-15	12.13	
15.	U2-12-6	9.25		47.	J-11	12.13	
16.	JH-107	9.25		48.	A-196	12.25	
17.	Sir of Durgapur	9.63		49.	EC-16675	12.25	
18.	Ah-39	9.75		50.	KG-61-99	12.50	
19.	RS-12	9.75		51.	Small pod	12.50	
20.	Ah-7986	9.88		52.	JH-357	12.50	
21.	Pollachi-1	10.00		53.	Almel No.1	12.75	
22.	U2-1-25	10.00					
23.	K-71	10.00		54.	RS-60	13.00	
24.	U2-1-28	10.13		55.	JH-313	13.00	
25.	Sakaria	10.25		56.	U-2-1-13	13.00	
26.	RB-1	10.50		57.	EC-16674	13.00	
27.	Limidi-4	10.50		58.	K-3	13.00	
28.	TG-3	10.75		59.	Mani Blanco	13.25	M_1
29.	Natal common	10.78		60.	Limidi-4	13.25	
30.	EC-21164	10.88		61.	KG-61-99	13.50	
31.	Starr	11.00		62.	Manfredi-84	13.50	
32.	EC-21119	11.00		63.	R-4	13.75	

Table 8 (Contd.

Sl. No.	Genotypes	Leaf dry Weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
64.	EC-161297	13.75		82.	Manfredi-118	16.50	
65.	K-71	14.00		83.	Dohad No.1	16.50	
66.	EC-21128	14.00		84.	US-1	16.75	
67.	Spanish-5	14.00		85.	Tejamar Local	17.00	
68.	Spanish-191-1	14.00		86.	EC-24447	17.50	
69.	EC-21093	14.00		87.	Exotic-7-3	19.00	
70.	No. 276	14.63		88.	Ah-7116	19.25	M_1
71.	S-206	14.88		89.	Taluk Harur local	19.75	
72.	TMV-2	15.25		90.	A-17-1700	20.00	
73.	Jatuti	15.25					
74.	Local Claire	15.25		91.	S-40-DR	20.15	
75.	No. 53	15.50	M_1	92.	Short-1	20.25	H
76.	Roiet No.3	15.50		93.	TMV-7	20.50	
77.	G-0173	16.00		94.	K-35	20.50	
78.	EC-21032	16.00		95.	NGAC-2742	22.50	
79.	Khandesh	16.00		96.	RS-113	23.25	
80.	EC-106985	16.13		97.	EC-1753	23.50	
81.	28-8-2	16.50					

(i) Mean = 12.95
(ii) Mean - C.D. = 5.88
(iii) Mean + C.D. = 20.02

weight (Tables 9, 10 and 11). Increased level of nitrogen slightly increased genotypes coming under 'H' but not for 'L' status. For pod yield, majority of the genotypes were with M_1 and M_2 status (Tables 12, 13 and 14) across the soil nitrogen enrichment.

On the whole, only leaf area and final pod yield showed almost similar response to nitrogen status of the soil. This was also implicit in their mean performances and range of values (Table 15). Leaf area was changed from 680.65 cm^2 at N_0 to 1135.73 cm^2 at N_2 level of nitrogen with higher magnitude of range from N_0 to N_2 (310.8 to 1421.5 cm^2 at N_0, 360 to 2475 cm^2 at N_2). For pod yield there was a change from 21.37 g at N_0 to 30.64 g at N_2. The magnitude of range was 9-41.22 g at N_0, 11.5-60.43 at N_1 and 8.88 to 53.05 at N_2 level of nitrogen. To estimate the preformance of a genotype over the characters observed under three levels of soil, nitrogen conditions a system of scoring was developed. In this system the categories L, M_2, M_1 and H were assigned a values of 1, 2, 3 and 4 respectively. For each genotype total score was calculated by summing up the score values of all the characters viz., shoot dry weight, leaf dry weight, leaf area and final pod yield across three nitrogen levels.

In Table 16 all the 97 groundnut genotypes were arranged in the ascending order of score values. The genotype with the poorest performance scored a value 21 to that of highest one of 36. These score values were utilized for the selection of genotypes for the next cycle of evaluation.

Experiment II:

This experiment is almost duplication of the Experiment - I with less number of genotypes and observations on more number of

Table 9 : Treatment means of 97 groundnut genotypes for shoot dry weight arranged in ascending order at N_0 level of nitrogen.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl. No.	Genotypes	Shoot dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	Non-nodulating	8.00		31.	Dohad No.1	18.00	
2.	Mani Blanco	9.75		32.	U-2-1-8	18.00	
3.	No. 53	12.00		33.	EC-21107	18.00	
4.	S-196	12.00		34.	h-7116	18.10	
5.	U-2-1-28	12.60		35.	EC-21032	18.50	
6.	RS-60	13.00		36.	EC-21073	18.50	
7.	EC-161297	13.00		37.	KG-61-99	19.00	
8.	Jatuti	13.50		38.	Khandesh	19.25	
9.	KG-61-99	14.00		39.	A-15	19.38	M_2
10.	EC-21128	14.00		40.	Local alarge	19.50	
11.	JH-357	14.00		41.	A-17-1700	20.00	
12.	TMV-2	14.50		42	EC-20957	20.00	
13.	TMV-7	14.75		43.	RS-113	20.00	
14.	EC-21105	14.80		44.	EC-16674	20.00	
15.	Manfredi-84	14.80		45.	WC-21119	20.50	
16.	Ah-7986	15.00		46.	No. 243	21.00	
17.	K-35	15.00		47.	RB-1	21.00	
18.	U-12-3	15.50	M_2	48.	Spanish-5	21.00	
19.	RS-181	15.50		49.	Sir of Durgapur	21.00	
20.	Small pod	15.50		50.	S-206	21.00	
21.	28-8-2	16.00		51.	Kandesh	21.00	
22.	EC-21081	16.00		52.	Limidi-5	21.50	
23.	EC-16675	16.00		53.	Limidi-5-3	21.50	M_1
24.	No. 53	16.00		54.	Natal common	21.60	
25.	NCAC-2742	16.00		55.	Manfredi-118	22.00	
26.	EC-106985	16.50		56.	EC-1753	22.00	
27.	EC-21164	17.00		57.	Local Claire	22.00	
28.	G-0173	18.00		58.	Ah-24439	22.00	
29.	TG-3	18.00		59.	US-16B	22.00	
30.	U-2-1-13	18.00		60.	No. 276	22.50	

Table 9 (Contd.)

1	2	3	4	1	2	3	4
61.	Rs-12	22.50		80.	EC-21088	25.50	
62.	Ah-39	22.75		81.	Russian International-2	26.00	
63.	Short-1	22.75		82.	R-4	26.00	
64.	Ah-811	23.00		83.	U2-12-6	26.00	
65.	Spanhoma	23.00		84.	Limidi-4	26.00	
66.	S-40-DR	23.00		85.	K-3	26.50	
67.	NG-337	23.50		86.	U2-1-25	26.80	
68.	EC-21093	23.50		87.	Exotic-7-3	28.00	
69.	US-16-B	23.50	M_1	88.	EC-24447	28.50	
70.	S-277	24.00		89.	Spanish-191-1	28.50	
71.	EC-21080	24.00		90.	Tejamar Local	28.80	
72.	JH-133	24.25		91.	JH-313	29.50	M_1
73.	Ah-1716	24.25		92.	Mani Blanco	30.00	
74.	Limidi-4	24.25		93.	Taluk Harur Local	30.50	
75.	Pollachi-1	24.50		94.	J-11	30.50	
76.	Roiet No.3	24.50		95.	Starr	31.50	
77.	K-71	25.00		96.	US-1	32.00	
78.	Almel No.1	25.00					
79.	JH-107	25.50					
				97.	Sakaria	41.00	H

(i) Mean = 20.82
(ii) Mean - C.D. = 7.85
(iii) Mean + C.D. = 33.79

Table 10 : Treatment means of 97 groundnut genotypes for shoot dry weight arranged in ascending order at N_1 level of nitrogen.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl. No.	Genotypes	Shoot dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	Mani Blanco	10.00	L	31.	S-206	19.50	
				32.	Manfredi-84	20.00	
2.	Short-1	13.00		33.	S-40-DR	20.00	
3.	Roiet No. 3	13.00		34.	No. 53	20.50	
4.	Manfredi-118	13.00		35.	JH-107	20.50	
5.	TMV-2	14.00		36.	RB-1	21.00	
6.	U2-12-6	14.00		37.	US-1	21.00	
7.	Limidi-5-3	14.00		38.	Limidi-5	21.00	
8.	KG-61-99	15.00		39.	Natal common	21.10	
9.	K-71	15.00		40.	No. 276	21.50	
10.	Small pod	15.50	M_2	41.	TG-3	22.00	
11.	RS-181	16.00		42.	Local Claire	22.00	
12.	EC-16675	16.00		43.	EC-21164	22.00	
13.	Exotic-7-3	16.50		44.	A-15	22.50	M_2
14.	U-1-2-3	17.00		45.	EC-21093	22.50	
15.	EC-21107	17.00		46.	Limidi-4	23.00	
16.	NCAC 2742	17.50		47.	Local alarge	23.00	
17.	Kandesh	18.00		48.	US-16-B	23.00	
18.	Taluk Harur local	18.00		49.	EC-21032	23.50	
19.	EC-21080	18.00		50.	R-4	24.00	
20.	Limidi-5-3	18.00		51.	Non-nodulating	24.00	
21.	Ah-39	18.50		52.	U-2-1-13	24.00	
22.	EC-16674	18.50		53.	U-2-1-8	24.00	
23.	Pollachi-1	19.00		54.	Almel No.1	24.50	
24.	Spanish-5	19.00					
25.	EC-24447	19.00		55.	JH-313	24.88	
26.	S-196	19.00		56.	28-8-2	25.00	
27.	Spanish-191-1	19.00		57.	Dohad No.1	25.00	M_1
28.	Ah-7986	19.50		58.	JH-357	25.00	
29.	Tejanmar local	19.50		59.	EC-106985	25.25	
30.	Spanhoma	19.50		60.	Russian International-2	26.00	

Table 10 (Contd.)

1	2	3	4	1	2	3	4
61.	S-277	26.00		80.	TMV-7	31.00	
62.	RS-113	26.00		81.	EC-21073	31.00	
63.	EC-21088	26.00		82.	J-11	31.50	
64.	Sir of Durgapur	26.00		83.	A-17-1700	33.00	
65.	EC-21139	26.00		84.	NG-337	33.00	
66.	No. 53	26.00		85.	Ah-1716	33.00	
67.	EC-1753	27.00		86.	Mani Blanco	33.25	
68.	K-3	28.00		87.	No. 243	34.00	
69.	RS-12	28.00	M_1	88.	RS-60	35.50	
70.	G-0173	29.00		89.	EC-21128	36.00	
71.	Limidi-4	29.00		90.	JH-133	36.00	M_1
72.	Ah-24439	29.00		91.	KG-61-99	36.00	
73.	Ah-811	30.00		92.	Starr	36.00	
74.	EC-21081	30.00		93.	US-16-B	36.00	
75.	Khandesh	30.00					
76.	U-2-1-28	30.00		94.	Ah-7116	38.00	
77.	U-2-1-25	30.50		95.	EC-21105	40.00	
78.	K-35	30.50		96.	Jatuti	45.50	
79.	EC-161297	31.00		97.	EC-20957	56.00	

(i)	Mean	=	24.56
(ii)	Mean - C.D.	=	11.59
(iii)	Mean + C.D.	=	37.53

Table 11 : Treatment means of 97 groundnut genotypes for shoot dry weight arranged in ascending order at N_2 level of nitrogen.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl. No.	Genotypes	Shoot dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	EC-20957	11.50	L	31.	EC-21164	21.25	
2.	U-2-1-B	14.00		32.	TG-3	21.50	
3.	No. 53	15.00		33.	EG-21088	22.00	
4.	Kandesh	15.40		34.	EC-21119	22.00	
5.	EC-1753	15.50		35.	EC-21073	22.75	
6.	Mani Blanco	15.50		36.	No. 243	23.00	
7.	EC-21107	15.50		37.	S-277	23.00	
8.	Limidi-5-3	15.50		38.	Ah-24439	23.00	
9.	Ah-S11	16.00		39.	EC-21105	23.25	
10	JH-133	17.00		40.	EC-21080	23.25	M_2
11	Limidi-4	17.50		41.	EC-21081	23.50	
12	US-16B	17.50		42.	US-16 B	23.50	
13	Non-nodulating	18.00		43.	Localalarge	23.75	
14	K-71	18.00	M_2	44.	NG-337	24.00	
15	U-1-2-3	18.00		45.	J-11	24.00	
16	Limidi-5	18.00		46.	EC-16675	24.00	
17	U2-12-6	18.50		47.	JH-357	24.00	
18	JH-107	18.50		48.	K-3	24.50	
19	Ah-1716	18.50		49.	EC-16674	24.80	
20	Local Claire	19.25		50.	RS-60	25.00	
21	No. 53	19.50		51.	Small pod	25.00	
22	Ah-39	19.50		52.	Mani Blanco	25.50	
23	Pollachi-1	20.00		53.	Almel No.1	25.50	
24	U2-1-25	20.00		54.	A-15	27.75	
25	RS-12	20.00		55.	Russian Int-2	26.00	
26	Sakaria	20.50		56.	KG-61-99	26.00	
27	U-2-1-28	20.50		57.	U-2-1-13	26.00	
28	RB-1	21.00		58.	Limidi-4	26.50	M_1
29	Short-1	21.00		59.	JH-313	27.00	
30	Natal common	21.00		60.	Manfredi-84	27.00	

Table 11 (Contd.)

1	2	3	4	1	2	3	4
61.	EC-161297	27.50		80.	28-8-2	33.00	
62.	EC-21128	28.00		81.	RS-181	33.00	
63.	Spanish-5	28.00		82.	Dohad No.1	33.00	
64.	Starr	28.00		83.	Manfredi-118	33.00	
65.	EC-21093	28.00		84.	KG-61-99	33.25	M_1
66.	Ah-7116	28.50		85.	US-1	33.50	
67.	S-206	29.25		86.	EC-24447	35.00	
68.	No. 276	29.25	M_1	87.	Ah-7986	36.50	
69.	R-4	30.00		88.	Exotic-7-3	38.20	
70.	Tejamur local	30.00					
71.	TMV-2	30.50		89.	A-17-1700	40.00	
72.	Jatuti	30.50		90.	Taluk Harur Local	40.00	
73.	Roiet No.3	30.50		91.	S-40-DR	40.50	
74.	Spanish-191-1	31.00		92.	Sir of Durgapur	40.50	
75.	G-0173	32.00		93.	TMV-7	41.00	H
76.	EC-21032	32.00		94.	K-35	41.00	
77.	Khandesh	32.00		95.	S-196	42.00	
78.	EC-106985	32.25		96.	NCAC-2742	45.00	
79.	Spanhoma	32.50					

(i) Mean = 25.94
(ii) Mean - C.D. = 12.97
(iii) Mean + C.D. = 38.91

Table 12 : Treatment means for 97 groundnut genotypes for final pod yield arranged in ascending order at N_0 level of nitrogen.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	Small pod	9.00		31.	EC-106985	18.65	
2.	U2-12-6	9.00	L	32.	Almel No.1	18.70	
3.	KG-61-99	9.82		33.	Manfredi-118	18.71	
4.	Mani Blanco	10.00		34.	EC-16674	18.72	
				35.	U-2-1-13	18.75	
5.	A-17-1700	11.00		36.	Taluk Harur Local	19.00	
6.	Spanish-5	11.18		37.	EC-21105	19.84	
7.	US-1	12.57		38.	Roiet No.3	19.98	
8.	RS-113	12.77		39.	US-16B	20.00	M_2
9.	NCAC-2742	12.84		40.	Non-nodulating	20.29	
10.	RS-12	13.15		41.	Exotic-7-3	20.33	
11.	TMV-7	13.22	M_2	42.	Spanish-191-1	20.34	
12.	Russian Int-2	13.50		43.	Ah-24439	20.41	
13.	Pollachi-1	13.50		44.	Ah-1716	20.81	
14.	EC-21119	13.75		45.	Ah-39	20.82	
15.	EC-21093	13.75		46.	K-71	20.94	
16.	Manfredi-84	13.75		47.	EC-16675	21.00	
17.	R-4	14.29		48.	JH-107	21.11	
18.	Sir of Durgapur	14.98					
19.	NG-3337	15.00		49.	TMV-2	21.50	
20.	Jatuti	15.32		50.	RB-1	21.55	
21.	EC-21107	15.37		51.	EC-161297	21.88	
22.	Dohad No.1	15.69		52.	Starr	22.00	
23.	Limidi-5-3	16.57		53.	J-11	22.08	
24.	Limidi-4	16.57		54.	No. 53	22.08	M_1
25.	JH-313	17.17		55.	S-277	22.08	
26.	Ah-7986	17.28		56.	No. 276	22.20	
27.	U-2-1-8	18.18		57.	KG-61-99	22.50	
28.	K-35	18.55		58.	Ah-811	22.50	
29.	Short-1	18.56		59.	Natal common	22.50	
30.	EC-20957	18.57		60.	No. 243	22.69	

Table 12 (Contd.)

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry weight (g)	Status
61.	Spanhoma	22.75		80.	US-16B	25.50	
62.	S-206	22.80		81.	TG-3	25.57	
63.	K-3	22.92		82.	JH-357	25.68	
64.	EC-21032	22.92		83.	EC-21081	27.06	
65.	Mani Blanco	22.98		84.	EA-60	27.30	
66.	G-0173	23.13		85.	EC-24447	27.86	
67.	A-15	23.70		86.	EC-1753	28.15	M_1
68.	S-196	23.75	M_1	87.	Local Claire	28.50	
69.	S-40-DR	23.85		88.	Limidi-4	28.64	
70.	Khandesh	24.29		89.	28-8-2	28.86	
71.	Local alarge	24.29		90.	Tejamar Local	29.46	
72.	Sakaria	24.33		91.	EC-21073	30.00	
73.	Ah-7116	24.56		92.	U-2-1-28	30.17	
74.	EC-21080	24.59					
75.	Limidi-5	25.00		93.	JH-133	32.73	
76.	Kandesh	25.00		94.	EC-21164	33.56	
77.	U-1-2-3	25.13		95.	RS-181	34.12	H
78.	U2-1-25	25.29		96.	EC-21128	39.43	
79.	No. 53	25.38		97.	EC-21088	41.22	

(i) Mean = 21.37
(ii) Mean - C.D. = 10.77
(iii) Mean + C.D. = 31.97

Table 13 : Treatment means of 97 groundnut genotypes for final pod yield arranged in ascending order at N_1 level of nitrogen.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No	Genotype	Dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	Russian Int-2	11.50		31.	EC-24447	26.50	
2.	No. 243	13.72		32.	Sir of Durgapur	26.61	
3.	KG-61-99	14.50		33.	R-4	27.34	
4.	U2-12-6	15.75		34.	Jatuti	27.63	
5.	K-3	16.36	L	35.	RB-1	27.82	
6.	WX-21119	16.50		36.	TG-3	27.83	
7.	EC-21081	17.07		37.	JH-113	28.22	
8.	Manfredi-118	18.50		38.	EC-1753	28.38	
9.	Manfredi-84	18.57		39.	Spanish-191-1	28.42	
10.	Mani Blanco	18.89		40.	U-2-1-28	28.51	M_2
				41.	Taluk Harur Local	28.59	
11.	EC-21105	19.50		42.	EC-161297	28.80	
12.	Limidi-5-3	20.00		43.	Pollachi-1	28.93	
13.	EC-21093	20.34		44.	Exotic-7-3	29.00	
14.	K-35	20.63		45.	Khandesh	29.11	
15.	A-17-1700	22.60		46.	LocalClaire	29.17	
16.	US-1	22.69		47.	S-196	29.19	
17.	Non-nodulating	23.04		48.	JH-313	29.59	
18.	Mani Blanco	23.17		49.	TMV-7	29.69	
19.	U-2-1-8	23.44	M_2	50.	EC-16675	30.00	
20.	A-15	23.50		51.	EC-16674	30.28	
21.	Roiet No.3	24.50		52.	K-71	30.39	
22.	EC-21164	24.78		53.	EA-113	30.42	
23.	No. 53	25.00		54.	28-8-2	30.46	
24.	No. 53	25.19		55.	Dohad No.1	30.72	
25.	J-11	25.23		56.	TMV-2	30.84	
26.	Limidi-4	25.50		57.	Local alarge	31.34	
27.	EC-21032	25.88		58.	JH-107	31.50	
28.	EC-21088	26.37		59.	Natal common	31.50	
29.	EC-106985	26.37		60.	EC-21128	32.00	
30.	Ah-7116	26.46					

Table 13 (Contd.)

1	2	3	4	1	2	3	4
61.	Tejamar Local	32.59		80.	RS-12	37.13	
62.	Ah-7986	32.66		81.	Sakaria	37.46	
63.	Spanhoma	32.69		82.	Ah-811	37.50	
64.	Almel No.1	33.18		83.	Limidi-5	38.25	
65.	NG-337	33.22		84.	U2-1-25	38.31	M_1
66.	U-1-2-3	33.25		85.	S-206	38.72	
67.	Spanish-5	33.33		86.	Khandesh	38.75	
68.	Limidi-4	33.47	M_1	87.	EC-21073	39.17	
69.	Short-1	33.51		88.	Ah-1716	39.74	
70.	RS-60	34.00					
71.	KG-61-99	34.09		89.	Starr	41.37	
72.	Ah-39	34.97		90.	G-0173	42.65	
73.	U-2-1-13	35.54		91.	S-277	42.86	
74.	EC-21107	35.84		92.	NCAC-2742	43.43	
75.	EC-20957	36.00		93.	S-40-DR	44.17	H
76.	JH-357	36.25		94.	EC-21080	45.66	
77.	Ah-24439	36.34		95.	Small pod	46.00	
78.	US-16B	36.36		96.	No. 276	52.50	
79.	RS-181	36.74		97.	US-16B	60.43	

(i)	Mean	=	30.07
(ii)	Mean - C.D.	=	19.47
(iii)	Mean + C.D.	=	40.67

Table 14 : Treatment means of 97 groundnut genotypes for final pod yield arranged in ascending order at N_2 level of nitrogen.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry weight (g)	Status
1	2	3	4	1	2	3	4
1.	Non-nodulating	8.88		31.	TG-3	26.82	
				32.	U2-12-6	26.93	
2.	No. 243	12.50		33.	Spanhoma	27.22	
3.	EC-16675	12.50		34.	Mani Blanco	27.50	
4.	EC-21105	12.50		35.	TMV-2	27.62	
5.	Russian Int-2	15.00		36.	Short-1	27.67	
6.	S-277	15.19		37.	Small pod	27.94	
7.	JH-107	16.07		38.	Kandesh	28.00	M_2
8.	Limidi-5	16.23		39.	NG 337	28.23	
9.	Pollachi-1	17.36		40.	Jatuti	28.64	
10.	Starr	18.90	L	41.	EC-21107	28.95	
11.	A-15	19.17		42.	U-2-1-8	29.00	
12.	EC-21088	19.55		43.	Ah-1716	29.38	
13.	Natal common	20.00		44.	EC-161297	29.61	
14.	Ah-811	20.60		45.	Sakaria	29.65	
15.	R-4	21.50		46.	EC-21073	30.84	
16.	Local alarge	21.79		47.	EC-21093	31.00	
17.	K-71	21.84		48.	Ah-39	31.09	
18.	EC-16674	22.07		49.	EC-21128	31.11	
19.	U2-1-25	22.08		50.	Tejamar Local	31.25	M_1
20.	U-2-1-13	22.50		51.	EC-1753	31.50	
21.	EC-21081	22.65		52.	U-1-2-3	32.00	
22.	EC-21119	22.78	M_2	53.	RB-1	32.09	
23.	28-8-2	23.34		54.	EC-21164	32.50	
24.	A-17-1700	23.89		55.	K-35	32.19	
25.	Mani Blanco	24.00		56.	Limidi-4	32.22	
26.	KG-61-99	24.50		57.	Manfredi-118	32.48	
27.	G-0173	24.89		58.	KG-61-99	32.82	
28.	JH-133	25.15		59.	EC-20957	32.82	
29.	RS-60	25.25		60.	Ah-7116	33.38	
30.	US-1						

Table 14 (Contd)

1	2	3	4	1	2	3	4
61.	Sir of Durgapur	33.45		80.	S-206	38.25	
62.	Ah-24439	34.67		81.	No. 276	38.27	
63.	Manfredi-84	34.67		82.	Dohad No.1	39.50	
64.	Almel No.1	34.75		83.	No. 53	40.00	
65.	Limidi-5-3	34.77		84.	J-11	40.16	
66.	Khandesh	34.86		85.	U-2-1-28	40.63	M_1
67.	JH-313	34.88		86.	JH-357	40.83	
68.	Spanish-5	35.04		87.	US-16B	40.84	
69.	Ah-7986	35.68		88.	TMV-7	41.00	
70.	US-16B	36.37	M_1	89.	RS-113	41.71	H
71.	Exotic-7-3	36.52		90.	RS-181	43.00	
72.	No. 53	36.93		91.	Local Claire	43.93	
73.	K-3	37.28		92.	Roiet No.3	44.00	
74.	EC-106985	37.50		93.	Spanish-191-1	47.64	
75.	EC-21032	37.73		94.	EC-21080	49.15	
76.	EC-24447	37.73		95.	Limidi-4	50.32	
77.	Taluka Harur Local	37.98		96.	RS-12	51.43	
78.	S-40-DR	38.02		97.	NCAC 2742	53.05	
79.	A-196	38.22					

(i)	Mean	=	30.64
(ii)	Mean - C.D.	=	20.04
(iii)	Mean + C.D.	=	41.24

Table 15 : Mean and range of 97 groundnut genotypes at N_0, N_1 and N_2 levels of nitrogen for different characters.

Nitrogen Level	N_0		N_1		N_2	
Characters	Mean	Range	Mean	Range	Mean	Range
1. Leaf Area (Cm^2)	680.65	310.80-1421.50	1075.41	462.50-1900.00	1135.73	360.00-2475.00
2. Leaf dry weight (g)	10.59	3.75-20.50	12.66	5.25-27.75	12.95	5.75-23.50
3. Shoot dry weight (g)	20.82	8.00-41.00	24.56	10.00-56.00	25.94	11.50-46.50
4. Final pod yield (g)	21.37	9.00-41.22	30.07	11.50-60.43	30.64	8.88-53.05

Table 16 : Total score of 97 groundnut genotypes over the characters across the nitrogen levels arranged in ascending order.

Sl. No.	Genotype	Score	Sl. No.	Genotype	Score	Sl. No.	Genotype	Score
1.	Mani Blanco	21	34.	S-206	29	67.	EC-106985	31
2.	Russian Int-2	22	35.	Limidi-5	29	68.	Jatuti	32
3.	RS-12	22	36	EC-21164	29	69.	EC-1753	32
4.	Non-nodulating	23	37.	No. 53	29	70.	EC-21088	32
5.	U2-12-6	24	38.	JH-357	29	71.	EC-21073	32
6.	EC-16675	24	39.	US-16B	29	72.	Taluka Harur Local	32
7.	Natal common	25	40.	R-4	30	73.	EC-21080	32
8.	EC-21119	25	41.	TMV-2	30	74.	Sakaria	32
9.	U-2-1-8	25	42.	EC-20957	30	75.	IC-3	32
10.	EC-21107	25	43.	JH-133	30	76.	JH-313	33
11.	No.243	26	44.	No. 53	30	77.	A-17-1700	33
12.	KG-61-99	26	45.	Ah-811	30	78.	Tej Amra Local	33
13.	Local alarge	26	46.	NG 337	30			
14.	Khandesh	26	47.	Spanhoma	30	79.	Almel No.1	33
15.	RS-60	27	48.	Spanish-191-1	30	80.	Sir of Durgapur	33
16.	JH-107	27	49.	Local Claire	30			
17.	U-1-2-3	27	50.	Limidi-4	30	81.	Limidi-4	33
18.	Limidi-5-3	27	51.	Small pod	30	82.	Roiet No.3	33
19.	S-277	28	52.	EC-21073	30	83.	Ah-24439	33
20.	Pollachi-1	28	53.	EC-21105	30	84.	G-0173	34
21.	Ah-39	28	54.	NCAC-2742	30	85.	U2-1-25	34
22.	TG-3	28	55.	U-2-1-28	30	86.	Ah-1716	34
23.	Manfredi-118	28	56.	Mani Blanco	31	87.	RS-181	34
24.	A-15	28	57.	28-8-2	31	88.	J-11	34
25.	Dohad No.1	28	58.	EC-161297	31	89.	S 40 DR	34
26.	Manfredi-84	28	59.	Exotic-7-3	31	90.	EC-21128	35
27.	K-71	29	60.	EC-21032	31	91.	TMV-7	35
28.	Ah-7986	29	61.	EC-21081	31	92.	K-35	35
29.	RB-1	29	62.	US-1	31	93.	No.276	35
30.	Spanish-5	29	63.	EC-24447	31	94.	RS-113	36
31.	EC-16674	29	64.	U-2-1-13	31	95.	KG-61-99	36
32.	S-196	29	65.	Starr	31	96.	Ah-7116	36
33.	Short-1	29	66.	Khandesh	31	97.	US-16B	36

characters. These observations were recorded at different stages (60th, 80th and 100th day) of plant growth. To maintain enough diversity for future selection, from experiment one genotypes were selected in the following manner.

The whole range of score values (21 to 36) was divided into four quartets viz, 20-24, 25-28, 29-32 and 33-34. The frequency of genotypes in each quartet is listed below.

Quartet	Class interval	Frequency
I	21 - 24	5
II	25 - 28	20
III	29 - 32	50
IV	33 - 36	22

While selecting genotypes for the next cycle of evaulation from these quartets emphasis was laid on plant types and frequency of occurance in each class. Consequently, one out of 5 genotypes from the first quartet, 6 out of 20 genotypes from second quartet, 33 out of 50 genotypes from third quartet and 10 out of 22 genotypes from the fourth quartet were selected.

Table 17 shows the extent of genetic variability for the characters shoot dry weight, leaf dry weight, pod dry weight, total dry weight, leaf area, nodule number and final pod yield at 60th, 80th and 100th day. None of the characters studied showed any significant variation for soil nitrogen application at any stage of growth period. Nevertheless there were significant and highly significant variations of characters at genotypic level. For shoot dry weight, leaf area and nodule number genotypic differences were significant both at 60th and

Table 17 : Analysis of variance for whole plot (two nitrogen levels) and sub-plot treatments (50 groundnut genotypes) at 3 stages (60, 80 and 100 days) for different characters and for final pod yield.

Sl. No.	Character	Stage	Treat-ment	Mean	Range	'F' Ratio	C.D. 5%	G^2	P^2	GCV	PCV	h^2	GA %
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Shoot dry weight (g)	60	M	4.04	4.01-4.07	NS	0.69						
			S	4.04	3.24-5.38	**	1.62	0.29	1.31	13.23	28.12	22	0.52
			I			NS							
		80	M	6.77	6.47-7.07	NS	3.68						
			S	6.77	4.34-9.83	NS	3.76	0.19	5.70	6.39	35.01	3	1.48
			I			NS							
		100	M	10.81	9.65-11.97	NS	4.22						
			S	10.81	6.49-15.04	**	3.17	8.68	16.52	27.95	38.56	53	4.44
			I			**							
2.	Leaf dry weight (g)	60	M	4.03	3.62-4.44	NS	1.54						
			S	4.03	2.28-6.02	NS	1.94	NE	NE				
			I			NS							
		80	M	8.46	8.61-8.30	NS	4.31						
			S	8.46	6.53-10.97	NS	3.74	NE	NE				
			I			NS							
		100	M	8.90	7.64-10.16	NS	1.89	3.37	9.61	**21.25**	**35.88**	**35**	**2.24**
			S	8.90	5.83-19.24	**	28.91						
			I			**							

Table 17 (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
3.	Pod dry weight (g)	60	M	1.98	1.95-2.01	NS	0.94						
			S	1.98	0.64-3.48	*	2.66	1.02	6.54	59.76	151.32	16	0.84
			I			NS							
		80	M	4.81	5.41-4.21	NS	5.21						
			S	4.78	2.63-7.74	**	2.83	2.01	5.13	29.66	47.38	39	1.82
			I			NS							
		100	M	10.75	10.04-11.45	NS	2.02						
			S	10.75	6.71-17.06	**	5.76	3.88	16.83	18.32	38.16	23	1.94
		60	M	9.70	9.19-10.20	NS	1.85						
			S	9.70	5.89-14.16	**	3.35	1.60	5.98	13.04	25.21	27	1.36
			I			NS							
4.	Total dry weight (g)	80	M	20.62	21.18-20.06	NS	12.75						
			S	20.62	15.76-28.43	*	8.81	5.59	35.90	11.45	29.02	16	1.97
			I			NS							
		100	M	30.93	27.32-34.54	NS	3.31						
			S	30.93	22.67-38.71	*	8.64	10.74	41.19	10.61	20.78	26	3.44
			I			**							

Table

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		60	M	407.11	395.02-419.20	NS	178.82						
			S	407.11	283.51-661.91	**	104.81	7148.88	11437.92	19.23	24.32	63	138.79
			I			**							
5. Leaf area		80	M	1378.97	1404.04-1353.89	NS	734.76						
(Cm2)			S	1378.97	1064.82-2040.01	NS	277.54	NE	NE				
			I			NS							
		100	M	1046.50	902.24-1190.76	NS	1231.75						
			S	1046.50	682.76-1543.98	**	275.54	131542.99	161186.74	35.14	38.90	82	678.18
			I			**							
		60	M	26.39	25.66-27.11	NS	12.57						
			S	26.39	16.20-39.67	**	14.34	32.70	113.01	21.67	40.28	29	6.35
			I			NS							
6. Nodule		80	M	42.99	45.51-40.46	NS	12.33						
Number			S	42.49	32.24-55.06	NS	20.83	NE	NE				
			I			NS							
		100	M	59.85	63.34-56.36	NS	9.19						
			S	59.85	41.88-77.33	*	26.26	NE	NE				
			I			NS							
7. Final pod		120	M	20.48	19.81-21.15	NS	9.51						
yield			S	20.68	13.00-29.55	*	13.74	NE	NE				
			I			*							

* = Significant at 5 % level of significance; ** = Significant at 1% level of significance

M = Main Treatment; S = Sub treatment; I = Interaction

100th day. Pod dry weight and total dry weights showed significant genotypic differences throughout the growth stages (60th, 80th and 100th day). Genotypic difference for final pod yield was also significant. Interaction effect of nitrogen levels with genotype for the characters shoot dry weight, leaf dry weight and leaf area was significant, only at 100th day observation.

None of the characters showed wider magnitude of range about the mean with whole plot treatment (N_0 and N_2), at any stage of plant growth. At sub-plot level, generally, wider ranges were exhibited for 100th day observation, i.e. for shoot dry weight 6.49-15.04 g, for leaf dry weight 5.83-19.24 g,for pod dry weigh 6.7 to 17.06 g, for total dry weight 22.67-38.71 g, for leaf area 682.76-1543.98 cm^2, for nodule number 41.88 to 77.33 and for final pod yield 13-29.55 g. For most of the characters, all genetic parameters could not be estimated owing to larger variance associated with error component. Among the characters studied, there was moderate amount of genotypic coefficient of variation (GCV) with 60th (59.76) and 80th day (29.66) pod dry weights, 100th day shoot dry weight (27.95), 100th day leaf dry weight (21.25) and 60th day nodule number (21.67). All these characters showed only moderate amount of phenotypic coefficient of variability. Moderate amount of heritability estimates were recorded for shoot dry weight at 60th day (22%), pod dry weight at 80th day (39%) and 100th day (23%), total dry weight at 60th (27%) and 100th day (16%) and leaf area at 60th (63%) and 100th day (26%), and nodule number 60th day (29%). However, higher heritability estimates were noticed for shoot dry weight at 100th day (53%) and leaf area at 60th (63%) and 100th (82%). Marginal increase in genetic advances estimate were observed

only at 100th day observation. It was 4.44 g for shoot dry weight, 3.44 g for total dry weight and 678.18 cm^2 for leaf area.

Association analysis among all the observed characters were done at all the three growth stages (Table 18). Correlation of shoot dry weight with leaf dry weight, pod dry weight, total dry weight and leaf area was highly significant for all the growth stages for both nitrogen levels except for the 100th day pod dry weight under N_0 and N_2 even total dry weight at 100th day, under N_0 status. Association of shoot dry weight with nodule number was significant only for N_2 level, at 100th day. Exactly similar mode of association was noticed for leaf dry weight with remaining characters. Pod dry weight was significantly correlated with leaf area for all the stages and nitrogen levels. Its association with total dry weight was significant only at N_2 level of nitrogen for 60th day and 80th day observations. Its association with nodule number was significant only at 80th day for N_2 level of nitrogen. The correlation between total dry weight and leaf area was significant for all stages except for N_0 level at 80th day. Its association with nodule number was non-significant except for the N_2 level at 80th day. Leaf area was significantly associated with nodule number for all the levels and stages of growth but for the 60th day observation at N_2 level, which was non-significant.

In this experiment, like previous experiment, genotypes were assigned to either one of the status; H, M_1, M_2 or L. The Tables 19 to 24 show the arrangement of treatments for shoot dry weight for different nitrogen levels for all growth stages. Except for the N_2 level at 100th day (Table 24) none of the genotypes come under 'L' category. Majority of the genotypes were distributed equally between M_2 and M_1 classes and there were a few genotypes under 'H' class.

Table 18 : Phenotypic correlation between pod dry weight and other characters at two nitrogen levels, at three stages of growth in 50 groundnut genotypes.

Combinations	Days	Nitrogen levels	r	Combinations	Days	Nitrogen levels	r
1,2	60	N_0	0.72**	2,4	60	N_0	0.24
		N_2	0.81**			N_2	0.39**
	80	N_0	1.00**		80	N_0	0.28*
		N_2	1.00**			N_2	0.53**
	100	N_0	1.00**		100	N_0	0.22
		N_2	1.00**			N_2	0.44**
1,3	60	N_0	0.40**	2,5	60	N_0	0.54**
		N_2	0.71**			N_2	0.80**
	80	N_0	0.81**		80	N_0	0.85**
		N_2	0.80**			N_2	0.85**
	100	N_0	0.10		100	N_0	0.50**
		N_2	-0.04			N_2	0.48**
1,4	60	N_0	0.27**	2,6	60	N_0	-0.11
		N_2	0.42			N_2	0.00
	80	N_0	0.28*		80	N_0	0.20
		N_2	0.53**			N_2	0.51**
	100	N_0	0.21		100	N_0	0.07
		N_2	0.44**			N_2	0.36*
1,5	60	N_0	0.54**	3,4	60	N_0	0.14
		N_2	0.63**			N_2	0.40**
	80	N_0	0.85**		80	N_0	0.21
		N_2	0.86**			N_2	0.45**
	100	N_0	0.49**		100	N_0	0.00
		N_2	0.48**			N_2	0.07
1,6	60	N_0	-0.21	3,5	60	N_0	0.60**
		N_2	0.002			N_2	0.65**
	80	N_0	0.20		80	N_0	0.83**
		N_2	0.51**			N_2	0.89**
	100	N_0	0.05		100	N_0	0.30*
		N_2	0.36*			N_2	0.33*

Table 18 (Contd.)

Combinations	Days	Nitrogen Levels	r	Combinations	Days	Nitrogen levels	r
	60	N_0	0.44**		60	N_0	0.05
		N_2	0.65**			N_2	0.06
2,3	80	N_0	0.81**	3,6	80	N_0	0.24
		N_2	0.80**			N_2	0.56**
	100	N_0	0.10		100	N_0	0.13
		N_2	-0.04			N_2	0.07
	60	N_0	0.34*		60	N_0	0.19
		N_2	0.45**			N_2	0.11
4,5	80	N_0	0.24	4,6	80	N_0	-0.16
		N_2	0.48**			N_2	0.27*
	100	N_0	0.33*		100	N_0	0.11
		N_2	0.30*			N_2	0.25
5,6	60	N_0	0.31*	5,6	80	N_0	0.52**
		N_2	0.05			N_2	0.72**
	100	N_0	0.48**				
		N_2	0.35*				

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

1 = Shoot dry weight
2 = Leaf dry weight
3 = Pod dry weight
4 = Total dry weight
5 = Leaf area
6 = Nodule Number

Table 19 : Treatment means of 50 groundnut genotypes for shoot dry weights at 60th day for N_0 Nitrogen level arranged in ascending order.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry weight (g)	Status
1.	K-3	2.68		26.	KG-61-99	3.99	M_2
2.	Local Claire	3.12					
3.	EC-21164	3.23		27.	Taluka Harur Local	4.01	
4.	Mani Blanco	3.28		28.	EC-21073	4.04	
5.	US-1	3.40		29.	Ah-39	4.06	
6.	Jatuti	3.42		30.	Pollachi-1	4.09	
7.	Spanhoma	3.45		31.	Limidi-4	4.10	
8.	RB-1	3.47		32.	G-0173	4.12	
9.	TG-3	3.48		33.	EC-21032	4.12	
10.	Khandesh	3.55		34.	Tejamar local	4.17	
11.	EC-162297	3.56		35.	No. 53	4.23	
12.	Ah-811	3.64		36.	U2-12-6	4.26	
13.	EC-20957	3.65		37.	R-4	4.29	
14.	Ah-7986	3.68	M_2	38.	Limidi-4	4.31	M_1
15.	NCAC-2742	3.73		39.	J-11	4.38	
16.	RS-113	3.76		40.	RS-181	4.40	
17.	Exotic-7-3	3.79		41.	TMV-7	4.41	
18.	EC-106985	3.81		42.	TMV-2	4.46	
19.	Starr	3.84		43.	JH-107	4.46	
20.	EC-21088	3.85		44.	EC-16674	4.52	
21.	28-8-2	3.87		45.	Spanish-191-1	4.60	
22.	Limidi-5	3.22		46.	JH-133	4.63	
23.	EC-21107	3.97		47.	U-2-1-28	4.66	
24.	S-206	3.97		48.	U-1-2-3	4.76	
25.	Roiet No.3	3.99		49.	No. 276	4.76	
				50.	Short-1	6.45	H

(i)	Mean	=	4.01
(ii)	Mean - C.D.	=	2.38
(iii)	Mean + C.D.	=	5.62

Table 20 : Treatment means of 50 groundnut genotypes for shoot dry weight at 60th day for N_2 nitrogen level arranged in ascending order.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry weight (g)	Status
1.	K-3	2.87		26.	TG-3	4.02	
2.	EC-20957	3.00		27.	EC-161297	4.02	M_2
3.	RB-1	3.02		28.	28-8-2	4.07	
4.	EC-21164	3.24					
5.	J-11	3.33		29.	U2-12-6	4.09	
6.	NCAC-2742	3.33		30.	TMV-7	4.12	
7.	Khandesh	3.33		31.	Limidi-4	4.14	
8.	RS-181	3.41		32.	EC-106985	4.17	
9.	EC-16674	3.42		33.	U-2-1-28	4.26	
10.	Starr	3.44		34.	Ah-7986	4.26	
11.	No. 53	3.45		35.	EC-21088	4.29	
12.	Spanhoma	3.59	M_2	36.	Mani Blanco	4.32	
13.	Taluka Harur Local	3.60		37.	Jatuti	4.43	
				38.	RS-113	4.46	M_1
14.	Local claire	3.62		39.	KG-61-99	4.48	
15.	Short-1	3.67		40.	Exotic-7-3	4.51	
16.	Limidi-4	3.68		41.	Tejamar Local	4.53	
17.	EC-21073	3.77		42.	US-1	4.53	
18.	Pollachi-1	3.80		43.	EC-21032	4.73	
19.	R-4	3.85		44.	Spanish-191-1	4.85	
20.	S-206	3.87		45.	EC-21107	4.87	
21.	Ah-39	3,89		46.	No. 276	4.93	
22.	JH-133	3.95		47.	JH-107	5.07	
23.	G-0173	3.97		48.	Roiet No.3	5.12	
24.	Ah-811	3.98					
25.	Limidi-5	3.99		49.	U-1-2-3	6.00	
				50.	TMV-2	6.18	H

(i) Mean = 4.07
(ii) Mean - C.D. = 2.45
(iii) Mean + C.D. = 5.69

Table 21 : Treatment means of 50 groundnut genotypes for shoot dry weight at 80th day for N_0 nitrogen level arranged in ascending order.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl No.	Genotypes	Shoot dry weight (g)	Status
1.	EC-21164	4.57		26.	KG-61-99	6.28	
2.	Mani Blanco	4.65		27.	Roiet No.3	6.34	M_2
3.	28-8-2	4.65					
4.	Khandesh	4.93		28.	EC-20957	6.60	
5.	Starr	4.96		29.	U2-12-6	6.65	
6.	EC-106985	4.98		30.	JH-133	6.66	
7.	TG-3	5.12		31.	R-4	6.74	
8.	G-0173	5.15		32.	No. 276	6.78	
9.	Short-1	5.23		33.	Ah-811	6.85	
10.	Ah-39	5.26		34.	RS-113	6.88	
11.	EC-21032	5.28		35.	Jatuti	6.90	
12.	TMV-7	5.42		36.	Taluka Harur Local	6.98	
13.	EC-21088	5.44	M_2	37.	NCAC-2742	6.99	M_1
14.	EC-161297	5.54		38.	Tejamar local	7.03	
15.	JH-107	5.63		39.	EC-21073	7.24	
16.	J-11	5.80		40.	TMV-2	7.26	
17.	Pollachi-1	5.82		41.	EC-16674	7.39	
18.	K-3	5.91		42.	Limidi-4	7.44	
19.	RB-1	5.96		43.	Ah-7986	7.58	
20.	S-206	6.03		44.	Limidi-4	7.63	
21.	Spanish-191-1	6.03		45.	No. 53	7.72	
22.	EC-21107	6.08		46.	U-2-1-28	9.31	
23.	Local claire	6.08		47.	Exotic-7-3	9.66	
24.	Spanhoma	6.15		48.	U-1-2-3	8.08	
25.	US-1	6.28		49.	Limidi-5	8.69	
				50.	RS-181	10.70	H

(i) Mean = 6.47
(ii) Mean - C.D. = 2.71
(iii) Mean + C.D. = 10.23

Table 22 : Treatment means of 50 groundnut genotypes for shoot dry weight at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl. No.	Genotypes	Shoot dry weight (g)	Status
1.	EC-21164	4.10		26.	US-1	7.09	
2.	EC-16674	4.76		27.	R-4	7.13	
3.	EC-21107	4.95		28.	Tej Amar Local	7.15	
4.	S-206	4.99		29.	J-11	7.32	
5.	EC-106985	5.13		30.	U-2-1-28	7.33	
6.	Limidi-5	5.35		31.	Exotic-7-3	7.38	M_1
7.	28-8-2	5.37		32.	Taluka Harur Local	7.40	
8.	Ah-811	5.55		33.	RS-181	7.49	
9.	EC-21073	5.59		34.	No. 53	7.53	
10.	Spanhoma	5.60		35.	EC-21088	7.61	
11.	JH-107	5.73		36.	RS-113	7.69	
12.	Short-1	5.85		37.	Spanish-191-1	7.69	
13.	EC-161297	6.17	M_2	38.	RB-1	7.75	
14.	U2-12-6	6.29		39.	Pollachi-1	7.82	
15.	Ah-7986	6.30		40.	TG-3	7.94	
16.	Limidi-4	6.33		41.	Jatuti	8.07	
17.	Local claire	6.44		42.	KG-61-99	8.16	
18.	Ah-39	6.45		43.	EC-20957	8.20	
19.	Mani Blanco	6.52		44.	Khandesh	8.23	
20.	TMV-7	6.53		45.	U-1-2-3	8.29	
21.	TMV-2	6.54		46.	No. 276	8.58	
22.	Limidi-4	6.64		47.	EC-21032	8.60	
23.	Starr	6.82		48.	G-0173	10.72	
24.	K-3	6.85					
25.	NCAC-2742	6.97					
				49.	JH-133	11.06	H
				50.	Roiet No. 3	13.31	

(i) Mean = 7.07
(ii) Mean - C.D. = 3.31
(iii) Mean + C.D. = 10.83

Table 23 : Treatment means for 50 groundnut genotypes for shoot dry weight at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Shoot dry weight (g)	Status	Sl. No.	Genotypes	Shoot dry weight (g)	Status
1.	Spanish 191-1	6.19		26.	RB-1	9.67	
2.	EC-21088	6.47		27.	J-11	9.67	
3.	28-8-2	6.67		28.	RS-181	9.83	
4.	EC-106985	6.68		29.	Tejamar local	10.00	
5.	Starr	7.40		30.	Ah-39	10.10	
6.	K-3	7.56		31.	KG-61-99	10.10	
7.	Taluka Harur Local	7.68		32.	No. 53	10.14	
				33.	EC-21073	10.25	
8.	EC-16674	7.82		34.	Roiet No.3	10.30	
9.	JH-133	7.92		35.	EC-21107	10.30	
10.	EC-21164	8.01		36.	Ah-811	10.47	
11.	R-4	8.06	M_2	37.	EC-20957	10.63	M_1
12.	S-206	8.06		38.	No. 276	10.67	
13.	TG-3	8.23		39.	U-2-1-28	10.76	
14.	Short-1	8.32		40.	NCAC-2742	10.89	
15.	Khandesh	8.45		41.	US-1	11.24	
16.	JH-107	8.55		42.	Pollachi-1	11.27	
17.	Ah-7986	8.56		43.	EC-21032	11.50	
18.	Jatuti	8.86		44.	U2-12-6	11.71	
19.	TMV-7	8.99		45.	G-0173	12.25	
20.	Mani Blanco	9.01		46.	RS-113	12.40	
21.	Spanhoma	9.05					
22.	Limidi-5	9.19		47.	Limidi-4	13.31	
23.	Limidi-4	9.23		48.	TMV-2	15.58	H
24.	Exotic-7-3	9.37		49.	U-1-2-3	15.96	
25.	EC-161297	9.43					

(i) Mean = 9.65
(ii) Mean - C.D. = 5.98
(iii) Mean + C.D. =13.13

The pattern was almost similar with leaf dry weight, pod dry weight, total dry weight, leaf area, nodule number and final pod yield (Tables 25 to 56).

Table 57 shows the mean and range of 50 genotypes at N_0 and N_2 level of nitrogen. In totality genotypic means as a whole did not change noticeably with nitrogen enrichment, rather there was slightly depressing effect on leaf dry weight, pod dry weight and total dry weight at 80th day. Increased nitrogen level decreased mean nodule number both at 80th and 100th day. However, there were noticeable change in magnitude of range at N_2 level. On 100th day, for leaf dry weight, total dry weight and leaf area. Even wider magnitude of range was observed for final pod yield. The situation was reversed in the case of nodule number where, at 100th day, compared to N_0 level, range was diminished at N_2.

This entire exercise was aimed at identifying groundnut genotypes for following situations.

(i) High yielding genotypes both at nil and excess soil nitrogen conditions.

(ii) Nitrogen responsive and non-responsive types.

Towards this effort multiple trait selection methodology was employed. As in the case of previous experiment, in this experiment also, similar method of scoring was done on all biomass and yield related characters.

However, while arranging the genotypes based on three types of scores were used (Table 58a). In th Table 58a, genotypes were arranged in ascending ord

Table 24 : Treatment means for 50 groundnut genotypes for shoot dry weight at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Shoot dry weight (g)	Status
1.	EC-106985	6.29	
2.	Jatuti	8.01	L
3.	Mani Blanco	8.01	
4.	EC-21107	8.01	
5.	EC-161297	8.31	
6.	EC-21164	8.63	
7.	J-11	8.90	
8.	S-206	9.02	
9.	Ah-39	9.43	
10.	Spanhoma	9.44	
11.	Ah-7986	9.78	
12.	EC-16674	10.29	
13.	Short-1	10.38	
14.	Starr	10.57	M_2
15.	Ah-811	10.71	
16.	US-1	10.76	
17.	No. 53	10.84	
18.	RS-181	10.88	
19.	Exotic-7-3	10.89	
20.	Limidi-4	11.01	
21.	RB-1	11.19	
22.	NCAC-2742	11.47	
23.	U2-12-6	11.67	
24.	Taluka Harur Local.	11.71	
25.	Khandesh	11.76	
26.	EC-21073	11.78	M_2
27.	G-0173	12.32	
28.	Limidi-5	12.38	
29.	KG-61-99	12.45	
30.	K-3	12.56	
31.	No. 276	12.80	
32.	JH-107	12.81	
33.	U-2-1-28	13.10	
34.	R-4	13.34	
35.	RS-113	13.46	
36.	Local claire	13.58	
37.	U-1-2-3	13.70	M_1
38.	Roiet No.3	13.80	
39.	Spanish-191-1	13.84	
40.	28-8-2	14.06	
41.	TG-3	14.26	
42.	TMV-2	14.51	
43.	TMV-7	14.74	
44.	EC-21032	14.98	
45.	Pollachi-1	15.33	
46.	JH-133	15.34	
47.	EC-20957	15.64	
48.	Tej amar local	15.66	
49.	Limidi-4	16.15	H
50.	EC-21088	17.68	

(i) Mean = 11.97
(ii) Mean - C.D. = 8.30
(iii) Mean + C.D. = 15.64

Table 25 : Treatment means for 50 groundnut genotypes for leaf dry weight at 60th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	K-3	1.510	L	27.	Spanish-191-1	3.657	
				28.	Ah-7986	3.707	
2.	Starr	2.500		29.	Pollachi-1	3.710	
3.	Mani Blanco	2.736		30.	Exotic-7-3	3.730	
4.	EC-21073	2.855		31.	TMV-2	3.757	
5.	US-1	2.910		32.	Limidi-4	3.787	
6.	S-206	2.960		33.	RB-1	3.833	
7.	KG-61-99	3.015		34.	JH-133	3.837	
8.	EC-16674	3.090		35.	RS-113	3.853	
9.	Khandesh	3.137		36.	G-0173	3.873	
10.	Ah-811	3.163		37.	R-4	3.890	
11.	Short-1	3.170		38.	Roiet No.3	3.913	
12.	EC-161297	3.191		39.	J-11	4.003	
13.	Local Claire	3.203	M_2	40.	No. 53	4.057	M_1
14.	Jatuti	3.203		41.	JH-107	4.100	
15.	EC-21032	3.290		42.	Limidi-5	4.120	
16.	Tej amar local	3.307		43.	U2-12-6	4.167	
17.	EC-21088	3.307		44.	Taluka Harur Local	4.235	
18.	28-8-2	3.337		45.	TMV-7	4.367	
19.	Spanhoma	3.423		46.	Ah-39	4.375	
20.	EC-106985	3.460		47.	No.276	4.387	
21.	EC-20957	3.467		48.	U-2-1-28	4.417	
22.	JH-133	3.470		49.	EC-21107	4.613	
23.	NCAC-2742	3.477					
24.	RS-181	3.560					
25.	Limidi-4	3.570		50.	U-1-2-3	6.573	H
26.	TG-3	3.577					

(i) Mean = 3.62
(ii) Mean - C.D. = 1.68
(iii) Mean + C.D. = 5.56

Table 26 : Treatment means for 50 groundnut genotypes for leaf dry weight at 60th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	K-3	3.040		27.	28-8-2	4.493	
2.	J-11	3.420		28.	Ah-811	4.507	
3.	EC-21164	3.440		29.	Pollachi-1	4.513	
4.	*No. 53*	*3.463*		*30.*	*EC-106985*	*4.537*	
5.	Spanhoma	3.475		31.	JH-133	4.553	
6.	Khandesh	3.580		32.	RB-1	4.557	
7.	G-0173	3.607		33.	Limidi-4	4.557	
8.	NCAC-2742	3.645		34.	EC-20957	4.567	
9.	S-206	3.757		35.	U2-12-6	4.647	
10.	EC-161297	3.793		36.	Limidi-5	4.673	
11.	Short-1	3.807		37.	Exotic-7-3	4.683	M_1
12.	R-4	3.833	M_2	38.	Spanish-191-1	4.693	
13.	EC-21073	3.923		39.	Tej amar local	4.173	
14.	Mani Blanco	4.127		40.	U-2-1-28	4.717	
15.	Starr	4.163		41.	TMV-7	4.797	
16.	RS-113	4.177		42.	EC-21107	4.800	
17.	JH-107	4.193		43.	EC-21088	4.850	
18.	Jatuti	4.200		44.	Roiet No. 3	4.923	
19.	Local claire	4.223		45.	EC-21032	5.120	
20.	EC-16674	4.280		46.	Limidi-4	5.137	
21.	Ah-7986	4.280		47.	US-1	5.277	
22.	RS-181	4.293		48.	TG-3	5.483	
23.	Taluka Harur Local	4.307		49.	TMV-2	7.383	H
24.	Ah-39	4.307		50.	No. 276	7.647	
25.	KG-61-99	4.375					
26.	U-1-2-3	4.390					

(i) Mean = 4.44
(ii) Mean - C.D. = 2.50
(iii) Mean + C.D. = 6.38

Table 27 : Treatment means of 50 groundnut genotypes for leaf dry weight at 80th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	US-1	6.063		26.	EC-20957	8.510	
2.	Spanish-191-1	6.177		27.	U2-12-6	8.590	M_2
3.	EC-21088	6.350					
4.	G-0173	6.703		28.	Local Claire	8.693	
5.	EC-106985	6.757		29.	TMV-2	8.777	
6.	Starr	6.783		30.	Limidi-4	8.847	
7.	EC-21164	6.833		31.	Jatuti	8.963	
8.	TG-3	7.037		32.	RS-113	9.080	
9.	JH-107	7.190		33.	Spanhoma	9.150	
10.	Short-1	7.195		34.	R-4	9.193	
11.	Ah-39	7.230		35.	EC-16674	9.250	
12.	28-8-2	7.280		36.	KG-61-99	9.540	
13.	Mani Blanco	7.363	M_2	37.	NCAC-2742	9.610	M_1
14.	EC-21107	7.367		38.	Ah-7986	9.710	
15.	EC-21032	7.380		39.	K-3	9.800	
16.	Pollachi-1	7.627		40.	Taluka Harur Local	9.890	
17.	J-11	7.683		41.	JH-133	9.943	
18.	Tej amar local	7.840		42.	EC-21073	9.983	
19.	Roiet No.3	7.857		43.	No. 276	10.183	
20.	RB-1	7.913		44.	U-1-2-28	10.360	
21.	Khandesh	7.980		45.	Limidi-4	10.673	
22.	TMV-7	8.053		46.	Limidi-5	10.727	
23.	Ah-811	8.080		47.	U-1-2-3	10.730	
24.	S-206	8.127		48.	Exotic-7-3	11.147	
25.	EC-161297	8.397		49.	No. 53	12.130	
				50.	RS-181	13.550	H

(i) Mean = 8.61
(ii) Mean - C.D. = 3.71
(iii) Mean + C.D. = 13.51

Table 28 : Treatment means of 50 groundnut genotypes for leaf dry weight at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	EC-21107	5.685		26.	Ah-39	8.370	
2.	EC-21164	6.190		27.	RS-181	8.393	
3.	EC-16674	6.197		28.	EC-21032	8.450	
4.	Short-1	6.470		29.	JH-133	8.473	
5.	Limidi-4	6.700		30.	Starr	8.580	
6.	S-206	6.713		31.	EC-20957	8.590	
7.	EC-161297	6.917		32.	RS-113	8.750	
8.	EC-106985	6.923		33.	Taluka Harur Local	8.750	
9.	28-8-2	6.973					
10.	JH-107	7.040		34.	Ah-7986	8.753	
11.	Spanhoma	7.075		35.	U-1-2-3	8.905	
12.	Ah-811	7.153	M2	36.	Jatuti	9.063	
13.	EC-21073	7.210		37.	Pollachi-1	9.100	
14.	TMV-2	7.357		38.	EC-21088	9.103	
15.	Mani Blanco	7.437		39.	Khandesh	9.137	M1
16.	Limidi-5	7.780		40.	U2-12-6	9.143	
17.	K-3	7.825		41.	RB-1	9.205	
18.	Tejamar local	7.860		42.	Spanish-191-1	9.480	
19.	Limidi-4	7.927		43.	KG-61-99	9.655	
20.	TMV-7	8.023		44.	NCAC-2742	9.713	
21.	No. 53	8.197		45.	Exotic-7-3	9.837	
22.	Local claire	8.215		46.	US-1	9.840	
23.	U-2-1-28	8.227		47.	TG-3	9.890	
24.	J-11	8.227		48.	G-0173	10.433	
				49.	No. 276	11.030	
25.	R-4	8.370	M1	50.	Roiet No.3	11.813	

(i) Mean = 8.30
(ii) Mean - C.D. = 4.10
(iii) Mean + C.D. = 13.20

Table 29 : Treatment means of 50 groundnut genotypes for leaf dry weight at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	EC-21088	3.677		26.	Jatuti	7.500	
2.	Short-1	4.620		27.	J-11	7.550	M_2
3.	TMV-7	4.787		28.	Limidi-4	7.580	
4.	28-8-2	5.123		29.	Ah-811	7.603	
5.	EC-16674	5.490					
6.	No. 53	5.633		30.	ARoiet No. 3	7.707	
7.	JH-107	5.810		31.	Pollachi-1	7.780	
8.	G-0173	6.282		32.	EC-21032	7.817	
9.	RS-181	6.287		33.	U-1-2-3	8.200	
10.	Spanhoma	6.340		34.	EC-21164	8.237	
11.	Ah-7986	6.473		35.	Ah-39	8.237	
12.	TG-3	6.477		36.	EC-21073	8.253	
13.	TMV-2	6.567	M_2	37.	US-1	8.290	
14.	Exotic-7-3	6.650		38.	Mani Blanco	8.307	
15.	EC-106985	6.880		39.	Khandesh	8.467	
16.	Limidi-4	6.900		40.	No. 276	8.767	M_1
17.	KG-61-99	6.920		41.	Spanish-191-1	8.847	
18.	RS-113	7.057		42.	Local claire	8.880	
19.	Tej amar local	7.147		43.	EC-161297	9.613	
20.	EC-20957	7.147		44.	RB-1	9.820	
21.	Limidi-5	7.320		45.	EC-21107	9.870	
22.	S-206	7.340		46.	U-2-1-28	10.140	
23.	Taluka Harur Local	7.367		47.	NCAC-2742	10.593	
24.	R-4	7.447		48.	JH-133	11.250	
25.	K-3	7.497		49.	Starr	11.487	
				50.	U2-12-6	12.970	H

(i) Mean = 7.64
(ii) Mean - C.D. = 3.64
(iii) Mean + C.D. = 11.64

Table 30 : Treatment means of 50 groundnut genotypes for leaf dry weight at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf dry weight (g)	Status	Sl. No.	Genotypes	Leaf dry weight (g)	Status
1.	EC-21107	3.330		26.	Limidi-4	9.873	
2.	S-206	6.090	L	27.	TMV-7	9.907	
				28.	RS-181	9.943	M_2
3.	U2-12-6	6.547		29.	Ah-39	9.957	
4.	EC-21164	6.860		30.	EC-20957	10.013	
5.	Ah-811	6.900		31.	KG-61-99	10.153	
6.	EC-21073	7.367					
7.	Jatuti	7.600		32.	RB-1	10.293	
8.	28-8-2	7.790		33.	TG-3	10.670	
9.	Starr	7.833		34.	Pollachi-1	10.877	
10.	EC-21088	7.977		35.	Local Claire	11.117	
11.	R-4	7.983		36.	JH-133	11.317	
12.	K-3	8.010		37.	No. 276	11.430	
13.	RS-113	8.527	M_2	38.	NCAC-2742	11.563	
14.	TMV-2	8.317		39.	U-1-2-3	11.620	
15.	Mani Blanco	8.660		40.	Tejamar local	11.977	M_1
16.	JH-107	8.660		41.	Exotic-7-3	11.987	
17.	Spanish-191-1	8.677		42.	U-2-1-8	12.217	
18.	EC-16674	8.850		43.	EC-161297	12.320	
19.	Limidi-5	8.950		44.	EC-21032	13.040	
20.	Taluka Harur Local	9.320		45.	Ah-7986	13.250	
				46.	Khandesh	13.990	
21.	Roiet No.3	9.487		47.	G-0173	13.990	
22.	J-11	9.487					
23.	EC-106985	9.593		48.	Limidi-4	15.050	
24.	Spanhoma	9.610		49.	US-1	18.530	H
25.	No. 53	9.680		50.	Short-1	20.960	

(i) Mean = 10.16
(ii) Mean - C.D. = 6.16
(iii) Mean + C.D. = 14.16

Table 31 : Treatment means of 50 groundnut genotypes for pod dry weight at 60th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Pod dry weight (g)	Status	Sl. No.	Genotypes	Pod dry weight (g)	Status
1.	RB-1	0.55		26.	Pollachi-1	1.80	
2.	US-1	0.59		27.	U-1-2-3	1.80	
3.	Ah-39	0.73		28.	JH-107	1.83	M_2
4.	Tej amar local	0.75		29.	Short-1	1.92	
5.	TG-3	0.78		30.	EC-106985	1.93	
6.	KG-61-99	0.80					
7.	Limidi-4	1.13		31.	EC-21088	1.97	
8.	JH-133	1.14		32.	EC-21107	1.97	
9.	TMV-2	1.22		33.	R-4	2.10	
10.	Khandesh	1.22		34.	J-11	2.10	
11.	Rs-113	1.30		35.	Taluka Harur local	2.20	
12.	EC-16674	1.30		36.	TMV-7	2.28	
13.	Ah-811	1.34		37.	No. 53	2.26	
14.	Spanhoma	1.34	M_2	38.	Starr	2.32	
15.	Limidi-4	1.39		39.	K-3	2.50	
16.	RS-181	1.40		40.	Spanish-191-1	2.51	
17.	Limidi-5	1.48		41.	U2-12-6	2.64	
18.	U-2-1-28	1.49		42.	NCAC-2742	2.67	M_1
19.	Mani Blanco	1.52		43.	Ah-7986	2.91	
20.	Exotic-7-3	1.58		44.	No. 276	2.95	
21.	S-206	1.60		45.	Roiet No.3	2.98	
22.	Jatuti	1.62		46.	EC-21164	3.05	
23.	Local claire	1.67		47.	EC-21073	3.42	
24.	EC-20957	1.72					
25.	28-8-2	1.80		48.	EC-21032	4.36	
				49.	EC-161297	4.48	
				50.	G-0173	5.20	H

(i) Mean = 1.95
(ii) Mean - C.D. = 0.38
(iii) Mean + C.D. = 3.52

Table 32 : Treatment means of 50 groundnut genotypes for dry weight at 60th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Dry weight (g)	Status	Sl. No.	Genotypes	Dry Weight (g)	Status
1.	EC-21088	0.45		26.	Mani Blanco	2.07	M_2
2.	EC-16674	0.61					
3.	RS-181	0.82		27.	U-2-1-28	2.09	
4.	Spanhoma	0.86		28.	Roiet No.3	2.10	
5.	Ah-39	1.05		29.	G-0173	2.11	
6.	No. 53	1.13		30.	JH-107	2.15	
7.	28-8-2	1.16		31.	Limidi-4	2.15	
8.	JH-133	1.16		32.	KG-61-99	2.22	
9.	Khandesh	1.16		33.	Starr	2.22	
10.	Spanish-191-1	1.22		34.	Tejamar local	2.26	
11.	Short-1	1.22		35.	Limidi-5	2.35	
12.	Local Claire	1.23		36.	US-1	2.41	M_1
13.	U-1-2-3	1.37	M_2	37.	RS-113	2.41	
14.	S-206	1.50		38.	EC-21164	2.44	
15.	TMV-7	1.56		39.	Jatuti	2.45	
16.	EC-21107	1.65		40.	U2-12-6	2.47	
17.	K-3	1.68		41.	EC-106985	2.50	
18.	RB-1	1.71		42.	EC-161297	2.56	
19.	Taluka Harur Local	1.76		43.	TMV-2	2.90	
				44.	EC-21032	2.90	
20.	R-4	1.77		45.	No. 276	2.92	
21.	EC-20957	1.89		46.	EC-21073	2.92	
22.	Limidi-4	1.89		47.	Ah-811	3.08	
23.	J-11	1.92		48.	Ah-7986	3.41	
24.	TG-3	2.00		49.	NCAC-2742	3.57	
25.	Pollachi-1	2.01					
				50.	Exotic-7-3	5.59	H

(i) Mean = 2.01
(ii) Mean - C.D. = 0.44
(iii) Mean + C.D. = 3.58

Table 33 : Treatment means of 50 groundnut genotypes for pod dry weight at 80th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Pod dry Weight (g)	Status	Sl. No.	Genotypes	Pod dry Weight (g)	Status
1.	Short-1	2.86		26.	RB-1	5.14	
2.	TMV-7	3.09		27.	U-2-1-28	5.19	M_2
3.	EC-161297	3.51		28.	Tej amar local	5.31	
4.	Local Claire	3.59					
5.	EC-21032	3.80		29.	EC-16674	5.55	
6.	Ah-39	3.95		30.	Spanhoma	5.65	
7.	U2-12-6	3.98		31.	Jatuti	5.67	
8.	EC-21164	4.12		32.	TMV-2	5.71	
9.	Mani Blanco	4.16		33.	Ah-811	5.72	
10.	Starr	4.17		34.	EC-20957	5.95	
11.	EC-21107	4.17		35.	KG-61-99	6.16	
12.	JH-133	4.27		36.	J-11	6.19	
13.	TG-3	4.39		37.	US-1	6.21	
14.	Spanish-191-1	4.40	M_2	38.	R-4	6.42	
15.	EC-21088	4.41		39.	No. 276	6.57	
16.	Pollachi-1	4.44		40.	Taluka Harur local	6.62	M_1
17.	Khandesh	4.46		41.	NCAC-2742	6.78	
18.	Ah-7986	4.51		42.	U-1-2-3	7.01	
19.	EC-106985	4.51		43.	No. 53	7.06	
20.	Roiet No.3	4.55		44.	Exotic-7-3	7.24	
21.	JH-107	4.69		45.	Limidi-5	7.29	
22.	Limidi-4	4.72		46.	EC-21073	7.68	
23.	K-3	4.81		47.	Limidi-4	7.71	
24.	RS-181	4.95		48.	RS-113	7.82	
25.	28-8-2	5.10					
				49.	G-0173	8.35	H
				50.	S-206	9.68	

(i) Mean = 5.41
(ii) Mean - C.D. = 2.58
(iii) Mean + C.D. = 8.24

Table 34 : Treatment means of 50 groundnut genotypes for pod dry weight at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Pod dry weight (g)	Status	Sl. No.	Genotypes	Pod dry weight (g)	Status
1.	EC-16674	1.69		26.	EC-21032	4.22	
2.	EC-161297	2.04		27.	EC-106985	4.25	
3.	TMV-7	2.16		28.	U-2-1-28	4.26	
4.	Local Claire	2.48		29.	G-0173	4.41	
5.	Limidi-4	2.50		30.	EC-20957	4.43	
6.	No. 53	2.73		31.	Ah-7986	4.43	
7.	EC-21107	2.86		32.	US-1	4.57	
8.	Limidi-5	2.94		33.	Khandesh	4.58	
9.	Ah-811	3.04		34.	Mani Blanco	4.59	
10.	U2-12-6	3.15		35.	RB-1	4.67	
11.	Short-1	3.21		36.	TMV-2	4.72	
12.	EC-21164	3.24	M_2	37.	Pollachi-1	4.73	M_1
13.	28-8-2	3.32		38.	TG-3	4.73	
14.	U-1-2-3	3.37		39.	Spanish-191-1	4.77	
15.	NCAC-2742	3.42		40.	Spanhoma	4.87	
16.	Starr	3.54		41.	JH-133	4.96	
17.	S-206	3.72		42.	JH-107	5.01	
18.	EC-21088	3.77		43.	Exotic-7-3	5.04	
19.	RS-181	3.80		44.	J-11	5.23	
20.	Limidi-4	3.92		45.	Tejamar local	5.29	
21.	Ah-39	4.03		46.	Jatuti	5.54	
22.	Taluka Harur Local	4.06		47.	RS-113	5.68	
23.	K-3	4.07		48.	R-4	5.92	
24.	EC-21073	4.07		49.	No. 276	7.58	H
25.	KG-61-99	4.12		50.	Roiet No.3	10.92	

(i) Mean = 4.21
(ii) Mean - C.D. = 1.38
(iii) Mean + C.D. = 7.04

Table 35 : Treatment means of 50 groundnut genotypes for pod dry weight at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Pod dry weight (g)	Status
1.	JH-133	6.12	
2.	KG-61-99	6.28	
3.	Limidi-5	6.61	
4.	EC-21088	6.72	
5.	Mani Blanco	7.78	
6.	Limidi-4	7.89	
7.	Limidi-4	7.89	
8.	US-1	8.04	
9.	TMV-7	8.08	
10.	Ah-39	8.11	
11.	EC-161297	8.19	
12.	No. 276	8.35	M_2
13.	EC-20957	8.37	
14.	Ah-7986	8.57	
15.	J-11	8.65	
16.	JH-107	8.69	
17.	R-4	8.79	
18.	Starr	8.98	
19.	No. 53	8.98	
20.	Limidi-4	9.00	
21.	TG-3	9.06	
22.	U-2-1-28	9.09	
23.	U2-12-6	9.10	
24.	K-3	9.20	
25.	EC-21032	9.41	
26.	EC-106985	9.52	
27.	EC-21073	9.63	
28.	TMV-2	9.66	M_2
29.	Pollachi-1	10.12	
30.	Manfredi-118	10.12	
31.	NCAC-2742	10.31	
32.	Spanish-191-1	10.32	
33.	Ah-811	10.36	
34.	Jatuti	10.39	
35.	28-8-2	10.48	
36.	EC-16674	10.61	
37.	Tejamar local	10.69	M_1
38.	Short-1	11.22	
39.	Exotic-7-3	11.34	
40.	RB-1	11.67	
41.	Taluka Harur Local	11.75	
42.	S-206	11.88	
43.	RS-113	11.91	
44.	Spanhoma	12.38	
45.	RS-181	12.43	
46.	U-1-2-3	12.43	
47.	Roiet No.3	12.87	
48.	G-0173	13.21	
49.	EC-21107	14.41	
50.	EC-21164	16.32	H
51.	Local Claire	17.06	

(i)	Mean	=	10.04
(ii)	Mean - C.D.	=	6.10
(iii)	Mean + C.D.	=	13.98

Table 36 : Treatment means of 50 groundnut genotypes for pod dry weight at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Pod dry weight (g)	Status	Sl. No.	Genotypes	Pod dry weight (g)	Status
1.	EC-161297	6.67		26.	TMV-2	11.26	
2.	EC-21088	6.69		27.	No. 276	11.29	M_2
3.	28-8-2	8.82		28.	R-4	11.35	
4.	EC-21107	8.38					
5.	Ah-39	8.66		29.	No. 53	11.47	
6.	EC-21073	8.69		30.	Spanhoma	11.55	
7.	Ah-811	8.81		31.	J-11	11.97	
8.	JH-133	9.06		32.	S-206	12.08	
9.	Ah-7986	9.17		33.	Limidi-4	12.23	
10.	RS-181	9.19		34.	JH-107	12.38	
11.	Starr	9.47		35.	EC-20957	12.54	
12.	Limidi-4	9.53		36.	U-1-2-3	12.57	M_1
13.	US-1	9.55	M_2	37.	Limidi-5	12.61	
14.	EC-16674	9.79		38.	TMV-7	12.84	
15.	EC-106985	9.97		39.	Exotic-7-3	12.89	
16.	Mani Blanco	10.04		40.	Tejamal local	13.00	
17.	U2-12-6	10.04		41.	NCAC-2742	13.06	
18.	RS-113	10.04		42.	Spanish-191-1	13.90	
19.	EC-21164	10.12		43.	Taluka Harur Local	13.91	
20.	Pollachi-1	10.49		44.	KG-61-99	14.09	
21.	K-3	10.69		45.	RB-1	14.17	
22.	G-0173	10.93		46.	Short-1	14.85	
23.	Khandesh	10.98		47.	EC-21032	16.44	
24.	Jatuti	11.10		48.	TG-3	16.88	
25.	U-2-1-28	11.15		49.	Local Claire	17.06	H
				50.	Roiet No. 3	18.40	

(i) Mean = 11.45
(ii) Mean - C.D. = 6.01
(iii) Mean + C.D. = 16.89

Table 37 : Treatment means of 50 groundnut genotypes for total dry weight at 60th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry weight (g)	Status	Sl. No.	Genotypes	Total dry weight (g)	Status
1.	K-3	4.403	L	26.	Pollachi-1	9.360	
				27.	EC-16674	9.383	
2.	No. 53	6.363		28.	28-8-2	9.393	
3.	US-1	6.983		29.	Ah-7986	9.433	
4.	KG-61-99	7.333		30.	JH-133	9.547	
5.	TG-3	7.420		31.	NCAC-2742	9.570	
6.	Mani Blanco	7.487		32.	Roiet No.3	9.840	
7.	RB-1	7.650		33.	G-0173	9.850	
8.	Khandesh	7.810		34.	TMV-2	10.033	
9.	Local Claire	7.930		35.	J-11	10.053	
10.	S-206	8.147		36.	US-2-1-28	10.107	
11.	Tej Amar Local	8.210	M_2	37.	JH-107	10.137	
12.	Spanhoma	8.253		38.	EC-21073	10.240	
13.	Ah-811	8.360		39.	Short-1	10.313	M_1
14.	Ah-39	8.383		40.	Taluka Harur Local	10.363	
15.	Jatuti	8.477		41.	U2-12-6	10.550	
16.	Limidi-4	8.767		42.	Limidi-4	10.573	
17.	EC-106985	8.913		43.	U-1-2-3	10.580	
18.	EC-21088	8.960		44.	Spanish Int-1	10.633	
19.	Exotic-7-3	8.960		45.	EC-21107	10.693	
20.	EC-20957	8.963		46.	TMV-7	10.707	
21.	RS-181	9.083		47.	Starr	10.803	
22.	EC-161297	9.093		48.	R-4	10.880	
23.	EC-21164	9.187		49.	EC-21032	11.220	
24.	RS-133	9.210		50.	No. 276	11.743	
25.	Limidi-5	9.267	M_1				

(i)	Mean	=	9.19
(ii)	Mean - C.D.	=	5.84
(iii)	Mean + C.D.	=	12.54

Table 38 : Treatment means of 50 groundnut genotypes for total dry matter at 60th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry weight (g)	Status
1.	K-3	7.373	
2.	Khandesh	7.873	
3.	Limidi-4	7.893	
4.	No. 53	7.947	
5.	EC-21164	8.073	
6.	RS-181	8.243	
7.	EC-161297	8.540	
8.	Spanhoma	8.720	
9.	Short-1	8.770	
10.	S-206	8.873	
11.	Taluka Harur Local	8.910	
12.	R-4	9.233	
13.	EC-16674	9.280	
14.	J-11	9.297	M_2
15.	G-0173	9.357	
16.	Starr	9.453	
17.	Local Claire	9.600	
18.	Ah-39	9.653	
19.	NCAC-2742	9.723	
20.	28-8-2	9.727	
21.	KG-61-99	9.737	
22.	JH-133	9.837	
23.	Limidi-5	9.867	
24.	U-1-2-3	9.980	
25.	U-2-1-28	10.130	
26.	Limidi-4	10.260	
27.	*Mani Blanco*	*10.280*	
28.	RB-1	10.357	
29.	JH-107	10.460	
30.	TMV-7	10.510	
31.	EC-21073	10.517	
32.	RS-133	10.687	
33.	Jatuti	10.763	
34.	EC-106985	10.773	
35.	Spanish Int-1	10.800	
36.	Exotic-7-3	10.820	
37.	Ah-811	10.833	
38.	EC-20957	11.010	
39.	Ah-7986	11.133	M_1
40.	U2-12-6	11.213	
41.	Pollachi-1	11.270	
42.	EC-21088	11.373	
43.	Tej amar local	11.483	
44.	EC-21107	11.660	
45.	Roiet No.3	11.827	
46.	TMV-2	12.053	
47.	TG-3	12.230	
48.	US-1	12.267	
49.	EC-21032	12.680	
50.	No. 276	16.570	H

(i) Mean = 10.20
(ii) Mean - C.D. = 6.85
(iii) Mean + C.D. = 13.55

Table 39 : Treatment means of 50 groundnut genotypes for total dry weight at 80th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry weight (g)	Status	Sl. No.	Genotypes	Total dry weight (g)	Status
1.	Short-1	15.523		26.	US-1	20.973	
2.	EC-21088	16.047		27.	Tej Amar Local	21.003	M_2
3.	Ah-39	16.603		28.	G-0173	21.077	
4.	Mani Blanco	16.917					
5.	EC-106985	17.030		29.	Local Claire	21.043	
6.	Starr	17.180		30.	Limidi-4	21.937	
7.	TMV-7	17.347		31.	EC-20957	21.970	
8.	EC-21032	17.430		32.	JH-133	22.003	
9.	Spanish	17.463		33.	TMV-2	22.630	
10.	EC-21164	17.463		34.	Jatuti	22.733	
11.	TG-3	17.480		35.	Ah-7986	22.853	
12.	Khandesh	18.063		36.	Spanhoma	22.947	M_1
13.	28-8-2	18.320		37.	EC-16674	22.950	
14.	EC-161297	18.327		38.	KG-61-99	23.227	
15.	EC-21107	18.377		39.	R-4	23.410	
16.	S-206	18.640		40.	Taluka Harur Local	23.590	
17.	Pollachi-1	18.650		41.	NCAC-2742	24.570	
18.	JH-107	18.870		42.	No. 53	25.083	
19.	U-2-1-28	18.947		43.	No. 276	25.513	
20.	RB-1	19.757		44.	RS-133	25.797	
21.	Roiet No.3	19.630		45.	EC-21073	25.867	
22.	U2-12-6	19.683		46.	Limidi-4	26.947	
23.	Ah-811	20.320		47.	U-1-2-3	27.493	
24.	K-3	20.570		48.	Limidi-5	28.023	
25.	J-11	20.577		49.	Exotic-7-3	29.327	
				50.	RS-181	30.367	H

(i)	Mean	=	21.18
(ii)	Mean - C.D.	=	12.37
(iii)	Mean + C.D.	=	29.99

Table 40 : Treatment means of 50 groundnut genotypes for total dry weight at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry weight (g)	Status	Sl. No.	Genotypes	Local dry weight (g)	Status
1.	EC-161297	12.403		26.	Ah-7986	20.237	
2.	EC-16674	13.0707		27.	U-2-1-28	20.520	
3.	EC-21104	13.973		28.	RS-181	20.630	
4.	EC-21167	14.053		29.	Tej Amar Local	20.697	
5.	S-206	15.940		30.	U-1-2-3	20.787	
6.	28-8-2	16.423		31.	NCAC-2742	20.917	
7.	Ah-811	16.447		32.	Taluk Harur Local	21.097	
8.	Limidi-5	16.650					
9.	EC-10698	17.037		33.	EC-21088	21.333	
10.	TMV-7	17.060		34.	Khandesh	21.487	
11.	Local Claire	17.303		35.	RB-1	21.590	
12.	EC-21073	17.497		36.	J-11	21.620	M_1
13.	Short-1	17.570		37.	KG-61-99	21.857	
14.	Limidi-4	17.617		38.	EC-20957	21.990	
15.	Limidi-4	17.793		39.	R-4	22.163	
16.	Starr	17.990	M_2	40.	Pollachi-1	22.317	
17.	No. 53	18.053		41.	US-1	22.440	
18.	JH-107	18.750		42.	RS-133	22.870	
19.	Spanhoma	18.757		43.	Exotic-7-3	22.987	
20.	Mani Blanco	19.000		44.	Jatuti	23.527	
21.	K-3	19.280		45.	TG-3	23.613	
22.	TMV-2	19.317		46.	Spanish/Itl	24.093	
23.	U2-12-6	19.570		47.	JH-133	24.293	
24.	Ah-39	19.587		48.	No. 276	25.507	
25.	EC-21032	19.590		49.	G-0173	26.530	
				50.	Roiet No.3	37.223	H

(i)	Mean	=	20.06
(ii)	Mean - C.D.	=	11.25
(iii)	Mean + C.D.	=	28.87

Table 41 : Treatment means of 50 groundnut genotypes for total dry matter at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry matter (g)	Status	Sl. No.	Genotypes	Total dry matter (g)	Status
1.	EC-21088	17.547	L	26.	Khandesh	27.833	
				27.	EC-161297	28.247	
2.	K-3	21.060		28.	S-206	28.277	
3.	KG-61-99	21.593		29.	Spanhoma	28.367	
4.	R-4	22.350		30.	Taluka Harur Local	28.430	
5.	TMV-7	22.653		31.	Exotic-7-3	28.473	
6.	JH-107	22.670		32.	Limidi-4	28.603	
7.	28-8-2	23.113		33.	RB-1	28.663	
8.	Limidi-5	23.893		34.	No. 276	28.713	
9.	Mani Blanco	24.003		35.	Tej Amar Local	28.750	M_1
10.	Ah-7986	24.083		36.	Starr	28.857	
11.	EC-21164	24.240		37.	TMV-2	29.307	
12.	EC-16674	24.343		38.	Ah-811	29.367	
13.	No. 53	24.963	M_2	39.	G-0173	29.910	
14.	Short-1	25.040		40.	EC-21032	29.937	
15.	EC-106985	25.047		41.	Pollachi-1	29.947	
16.	JH-133	25.187		42.	U-2-1-28	30.590	
17.	Spanish/Itl	26.023		43.	U-12-6	30.607	
18.	Limidi-4	26.143		44.	Local Claire	31.033	
19.	TG-3	26.547		45.	RS-181	31.170	
20.	EC-20957	26.850		46.	EC-21107	31.220	
21.	Ah-39	27.173		47.	RS-133	32.213	
22.	J-11	27.283		48.	U-1-2-3	32.867	
23.	Jatuti	27.593					
24.	Us-1	27.640	M_1	49.	NCAC-2742	33.513	H
25.	EC-21073	27.803		50.	Roiet No. 3	35.997	

(i) Mean = 27.32
(ii) Mean - C.D. = 18.68
(iii) Mean + C.D. = 35.96

Table 42 : Treatment means of 50 groundnut genotypes for total dry matter at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Total dry matter (g)	Status	Sl. No.	Genotypes	Total dry matter (g)	Status
1.	RS-133	25.373	L	26.	No.53	33.273	M_2
2.	EC-16674	26.152		27.	RB-1	34.727	
3.	EC-106985	16.193		28.	Khandesh	35.030	
4.	Jatuti	26.500		29.	K-3	35.733	
5.	EC-21073	26.863		30.	JH-107	36.147	
6.	EC-21088	27.887		31.	Exotic-7-3	36.677	
7.	EC-161297	27.943		32.	U2-12-6	36.760	
8.	Mani Blanco	28.333		33.	Spanhoma	37.413	
9.	S-206	29.860		34.	No. 276	37.533	M_1
10.	Taluka Harur Local	29.860		35.	EC-21032	38.040	
				36.	KH-61-99	38.070	
11.	Starr	30.103	M_2	37.	Limidi-5	38.187	
12.	NCAC-2742	30.137		38.	JH-133	38.713	
13.	G-0173	30.267		39.	EC-20957	39.333	
14.	Spanish/Itl	30.633		40.	TMV-7	40.050	
15.	EC-21107	30.747		41.	U-1-2-3	40.307	
16.	Tej Amar Local	30.983		42.	Limidi-4	40.993	
17.	28-8-2	31.113		43.	Roiet No.3	41.420	
18.	Limidi-4	31.213		44.	Local Claire	41.480	
19.	J-11	31.343		45.	EC-21164	41.797	
20.	Rs-181	31.360		46.	US-1	42.017	
21.	Ah-39	31.637					
22.	TG-3	32.030		47.	U-2-1-28	43.307	
23.	R-4	32.543		48.	Ah-7986	44.480	H
24.	Ah-811	32.920		49.	Pollachi-1	44.687	
25.	TMV-2	33.090		50.	Short-1	45.603	

(i)	Mean	=	34.54
(ii)	Mean - C.D.	=	25.90
(iii)	Mean + C.D.	=	43.18

Table 43 : Treatment means of 50 groundnut genotypes for leaf area at 60th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf area (Sq.Cm.)	Status	Sl. No.	Genotypes	Leaf Area (Sq.Cm.)	Status
1.	K-3	258.50	L	26.	RB-1	396.63	M_2
				27.	KG-61-99	393.43	
2.	*Mani Blanco*	*300.90*					
3.	US-1	320.54		28.	U-1-2-3	398.79	
4.	EC-21032	322.67		29.	EC-106985	400.73	
5.	EC-21073	324.10		30.	Spanish-191-1	401.73	
6.	S-206	326.04		31.	Pollachi-1	408.25	
7.	Short-1	339.31		32.	Exotic-7-3	410.45	
8.	Khandesh	346.43		33.	Limidi-4	416.33	
9.	Ah-811	348.26		34.	JH-133	422.33	
10.	EC-161297	351.34		35.	RS-113	424.38	
11.	Local Claire	352.15		36.	G-0173	427.46	
12.	Jatuti	352.59		37.	R-4	428.27	
13.	TG-3	356.91		38.	Roiet No.3	430.69	M_1
14.	EC-21088	363.73		39.	J-11	441.25	
15.	Tej amar local	364.25	M_2	40.	U-2-1-28	447.19	
16.	Starr	366.08		41.	No. 53	450.05	
17.	Ah-7986	372.99		42.	Ah-39	451.00	
18.	EC-16674	374.73		43.	JH-107	451.22	
19.	28-8-2	376.57		44.	Limidi-5	453.49	
20.	Spanhoma	376.93		45.	U2-12-6	459.29	
21.	EC-21164	382.65		46.	TMV-2	467.78	
22.	NCAC-2742	382.80		47.	Taluka Harur Local	473.51	
23.	EC-20957	384.78		48.	TMV-7	480.63	
24.	RS-181	392.11		49.	No. 276	482.09	
25.	Limidi-4	392.77					
				50.	EC-21107	507.76	H

(i) Mean = 395.02
(ii) Mean - C.D. = 290.21
(iii) Mean + C.D. = 499.83

Table 44 : Treatment means for 50 groundnut genotypes for leaf area at 60th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf Area (Sq. Cm.)	Status
1.	K-3	334.69	
2.	EC-21164	378.06	
3.	No. 53	381.04	L
4.	NCAC-2742	383.90	
5.	Spanhoma	384.89	
6.	Khandesh	394.61	
7.	J-11	409.82	
8.	S-206	411.69	
9.	EC-161297	418.00	
10.	Short-1	418.95	
11.	R-4	422.84	
12.	EC-16674	434.39	
13.	EC-21073	441.69	
14.	RS-181	447.04	
15.	U-1-2-3	453.82	
16.	Mani Blanco	454.08	M_2
17.	RS-113	459.74	
18.	Starr	460.61	
19.	Local Claire	462.07	
20.	Jatuti	464.86	
21.	Ah-7986	471.24	
22.	G-0173	470.51	
23.	Taluka Harur Local	473.73	
24.	JH-133	490.28	
25.	Limidi-4	494.71	
26.	28-8-2	494.93	
27.	Ah-811	496.10	
28.	Pollachi-1	496.83	
29.	EC-106985	498.96	
30.	RB-1	501.67	
31.	EC-20957	502.46	
32.	Limidi-4	504.17	
33.	Roiet No.3	512.53	
34.	Limidi-5	514.43	
35.	Exotic-7-3	515.53	
36.	Spanish-191-1	516.41	
37.	U-2-1-28	519.27	M_1
38.	Ah-39	520.30	
39.	TMV-7	523.60	
40.	JH-107	524.99	
41.	EC-21088	531.52	
42.	KG-61-99	538.52	
43.	U2-12-6	540.83	
44.	EC-21107	545.78	
45.	Tej Amar Local	555.50	
46.	EC-21032	563.13	
47.	US-1	567.01	
48.	TG-3	603.90	
49.	TMV-2	812.50	H
50.	No. 276	841.72	

(i)	Mean	=	419.20
(ii)	Mean - C.D.	=	314.39
(iii)	Mean + C.D.	=	524.01

Table 45 : Treatment means of 50 groundnut genotypes for leaf area a at 80th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
1.	US-1	989.22		26.	EC-20957	1388.39	
2.	Spanish-191-1	1007.71		27.	U2-12-6	1401.44	M2
3.	EC-21088	1035.99					
4.	G-0173	1093.63		28.	TMV-2	1431.90	
5.	EC-106985	1102.34		29.	Limidi-4	1442.32	
6.	Starr	1106.69		30.	Jatuti	1462.35	
7.	EC-21164	1114.84		31.	Local Claire	1418.30	
8.	TG-3	1148.02		32.	RS-113	1481.39	
9.	JH-107	1173.03		33.	Spanhoma	1492.80	
10.	Short-1	1174.12		34.	R-4	1499.87	
11.	Ah-39	1179.56		35.	EC-16674	1509.12	
12.	28-8-2	1187.72	M2	36.	KG-61-99	1556.43	
13.	Mani Blanco	1201.31		37.	NCAC-2742	1567.85	
14.	EC-21107	1201.82		38.	Ah-7986	1584.17	
15.	EC-21032	1204.03		39.	K-3	1598.85	
16.	Pollachi-1	1244.28		40.	Taluka Harur Local	1613.53	
17.	J-11	1258.52					
18.	Tejamar local	1279.02		41.	JH-133	1622.23	M1
19.	Roiet No.3	1281.80		42.	EC-21073	1628.86	
20.	RB-1	1291.04		43.	No. 276	1661.39	
21.	Khandesh	1301.92		44.	U-2-1-28	1690.21	
22.	TMV-7	1313.89		45.	Limidi-4	1741.33	
23.	Ah-811	1318.24		46.	Limidi-5	1750.03	
24.	S-206	1325.85		47.	U-1-2-3	1750.58	
25.	EC-161297	1369.90		48.	Exotic-7-3	1818.55	
				49.	No. 53	1978.99	
				50.	RS-181	2201.65	

(i)	Mean	=	1404.04
(ii)	Mean - C.D.	=	594.04
(iii)	Mean + C.D.	=	2214.04

Table 46 : Treatment means of 50 groundnut genotypes for leaf are at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
1.	EC-21107	927.77		26.	Ah-39	1365.55	
2.	EC-21164	1009.89		27.	EC-21032	1378.60	
3.	*EC-16674*	*1010.97*		*28.*	*JH-133*	*1382.41*	
4.	Short-1	1082.24		29.	Starr	1399.81	
5.	Limidi-4	1093.09		30.	EC-20957	1401.44	
6.	S-206	1095.27		31.	RS-113	1427.55	
7.	EC-161297	1128.44		32.	Ah-7986	1428.09	
8.	EC-106985	1129.53		33.	Taluka Harur Local	1428.09	
9.	28-8-2	1137.68					
10.	JH-107	1148.56		34.	U-1-2-3	1453.10	
11.	Spanhoma	1154.55		35.	Jatuti	1478.67	
12.	Ah-811	1167.05		36.	Pollachi-1	1484.65	
13.	EC-21073	1176.30		37.	EC-21088	1485.19	
14.	TMV-2	1200.23		38.	Khandesh	1490.63	M_1
15.	Mani Blanco	1213.28	M_2	39.	U2-12-6	1491.72	
16.	TMV-7	1243.73		40.	RB-1	1502.05	
17.	Limidi-5	1269.29		41.	Spanish-191-1	1546.64	
18.	K-3	1276.90		42.	KH-61-99	1575.47	
19.	Tej amar local	1282.34		43.	NCAC-2742	1584.71	
20.	Limidi-4	1293.22		44.	Exotic-7-3	1604.83	
21.	No. 53	1337.27		45.	US-1	1605.38	
22.	Local Claire	1340.53		46.	TG-3	1613.54	
23.	J-11	1342.16		47.	G-0173	1702.18	
24.	U-2-1-28	1346.17		48.	No. 276	1799.52	
				49.	RS-181	1869.36	
25.	R-4	1365.55	M_1	50.	Roiet No.3	1927.32	

(i) Mean = 1353.89
(ii) Mean - C.D. = 543.89
(iii) Mean + C.D. = 2163.89

Table 47 : Treatment means of 50 groundnut genotypes for leaf area at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf Area (Sq. Cm)	Status	Sl. No.	Genotypes	Leaf Area (Sq.Cm.)	Status
1.	EC-21088	430.72		26.	K-3	878.63	
2.	Short-1	541.23	L	27.	J-11	884.48	
3.	TMV-7	560.76		28.	Limidi-4	888.00	M_2
4.	28-8-2	600.76		29.	Ah-811	890.73	
5.	EC-16674	643.15		30.	Roiet No.3	902.84	
6.	No. 53	659.93		31.	Pollachi-1	911.43	
7.	JH-107	680.64		32.	EC-21032	915.72	
8.	G-0173	735.90		33.	US-1	917.17	
9.	RS-181	736.48		34.	EC-21164	964.93	M_1
10.	Spanhoma	742.73		35.	Ah-39	964.93	
11.	TG-3	758.74		36.	EC-21073	966.88	
12.	Ah-7986	760.30		37.	U-1-2-3	971.17	
13.	TMV-2	769.29		38.	Mani Blanco	973.13	
14.	Exotic-7-3	779.05	M_2	39.	Khandesh	991.87	
15.	EC-106985	805.99		40.	Local Claire	1000.00	
16.	Limidi-4	808.33		41.	No. 276	1027.01	
17.	KG-61-99	810.68					
18.	RS-113	826.69		42.	Spanish-191-1	1036.39	
19.	EC-20957	837.23		43.	EC-161297	1126.20	
20.	Tej Amra local	837.23		44.	RB-1	1150.41	
21.	Limidi-5	857.54		45.	EC-21107	1156.27	
22.	S-206	859.88		46.	NCAC-2742	1241.01	H
23.	Taluka Harur Local	863.01		47.	JH-133	1317.94	
				48.	Starr	1345.66	
24.	R-4	872.38		49.	U-2-1-28	1513.19	
25.	Jatuti	878.24		50.	U-2-12-6	1519.44	

(i)	Mean	=	902.24
(ii)	Mean - C.D.	=	626.7
(iii)	Mean + C.D.	=	1177.98

Table 48 : Treatment means of 50 groundnut genotypes for leaf area at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Leaf Area (Sq Cm)	Status
1.	EC-21107	390.11	
2.	S-206	713.44	
3.	U2-12-6	766.94	
4.	EC-21164	803.65	
5.	Ah-811	808.34	
6.	EC-21073	863.01	L
7.	No. 53	866.13	
8.	Jatuti	890.34	
9.	28-8-2	912.26	
10.	Starr	917.67	
11.	EC-21088	934.47	
12.	R-4	935.25	
13.	K-3	938.37	
14.	Ah-7986	958.68	
15.	RS-113	974.30	
16.	TMV-2	998.90	
17.	JH-107	1014.52	
18.	Mani Blanco	1014.52	M_2
19.	Spanish-191-1	1016.47	
20.	EC-16674	1036.78	
21.	Limidi-5	1048.49	
22.	Taluka Harur Local	1091.84	
23.	J-11	1111.36	
24.	Roiet No.3	1111.36	
25.	Spanhoma	1125.85	
26.	Limidi-4	1156.66	
27.	RS-181	1164.86	
28.	Ah-39	1166.42	M_2
29.	EC-20957	1173.06	
30.	KG-61-99	1189.46	
31.	RB-1	1205.86	
32.	TG-3	1249.99	
33.	Pollachi-1	1274.40	
34.	Local Claire	1302.12	
35.	JH-133	1325.75	
36.	No. 276	1339.02	M_1
37.	NCAC-2742	1354.64	
38.	U-1-2-3	1361.28	
39.	Tej amra local	1403.07	
40.	Exotic-7-3	1404.24	
41.	U-2-1-28	1431.18	
42.	EC-161297	1443.29	
43.	EC-21032	1527.64	
44.	TMV-7	1577.23	
45.	EC-106985	1577.62	
46.	G-0173	1638.93	H
47.	Khandesh	1638.93	
48.	Limidi-4	1763.11	
49.	US-1	2170.79	
50.	Short-1	2455.46	

(i)	Mean	=	1190.76
(ii)	Mean - C.D.	=	915.22
(iii)	Mean + C.D.	=	1466.30

Table 49 : Treatment means of 50 groundnut genotypes for nodule number at 60th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	US-1	12.00		26.	Jatuti	25.20	
2.	Starr	13.67		27.	R-4	25.33	
3.	No. 53	15.00		28.	Pollachi-1	25.37	
4.	EC-21164	15.87		29.	EC-21073	25.40	
5.	28-8-2	16.95		30.	RS-113	25.40	
6.	EC-106985	17.53		31.	G-0173	25.47	
7.	K-3	18.13		32.	Local Claire	26.07	
8.	Ah-811	18.40		33.	EC-21032	27.60	
9.	RB-1	19.53		34.	Khandesh	27.80	
10.	Spanhoma	19.73		35.	Mani Blanco	28.80	M_1
11.	Pollachi-1	19.77		36.	U-2-1-28	29.40	
12.	RS-181	20.40		37.	EC-16674	29.40	
13.	TG-3	21.27	M_2	38.	JH-133	29.87	
14.	J-11	21.33		39.	Roiet No.3	30.00	
15.	Limidi-5	21.60		40.	Tej Amra Local	30.73	
16.	U-1-2-3	22.13		41.	No. 276	32.10	
17.	Spanish-191-1	22.47		42.	JH-107	32.87	
18.	Short-1	22.63		43.	EC-161297	34.73	
19.	TMV-2	23.00		44.	Limidi-4	34.80	
20.	EC-20957	23.27		45.	Ah-39	35.07	
21.	S-206	23.30		46.	NCAC-2742	37.07	
22.	TMV-7	23.33		47.	Exotic-7-3	37.40	
23.	Limidi-4	23.40					
24.	EC-21088	24.60		48.	U2-12-6	40.20	
25.	EC-21107	25.13		49.	Taluka Harur Local	41.10	H
				50.	Ah-7986	41.60	

(i)	Mean	=	25.66
(ii)	Mean - C.D.	=	11.33
(iii)	Mean + C.D.	=	40.01

Table 50 : Treatment means of 50 groundnut genotypes for nodule number at 60th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	K-3	14.27		26.	EC-161297	26.67	
2.	EC-16674	15.87		27.	No. 53	26.80	
3.	TMV-7	16.73		28.	Mani Blanco	27.10	M_2
4.	Ah-811	18.07		29.	EC-21107	27.17	
5.	28-8-2	18.13		30.	Ah-7986	27.67	
6.	J-11	18.27		31.	U-2-1-28	27.93	
7.	Khandesh	20.60		32.	Jatuti	29.47	
8.	Ah-39	21.13		33.	No. 276	29.53	
9.	Limidi-4	21.60		34.	EC-21088	29.73	
10.	RS-181	22.20		35.	EC-20957	30.60	
11.	Pollachi-1	22.27	M_2	36.	G-0173	30.80	M_1
12.	Limidi-5	22.33		37.	S-206	31.27	
13.	Spanhoma	22.80		38.	Exotic-7-3	31.47	
14.	EC-161297	22.80		39.	Spanish-191-1	31.73	
15.	U-1-2-3	23.40		40.	US-1	32.40	
16.	EC-21164	24.27		41.	RS-113	33.67	
17.	Local Claire	24.53		42.	EC-21073	34.13	
18.	JH-107	24.53		43.	RB-1	34.27	
19.	JH-133	24.80		44.	Limidi-4	34.53	
20.	Short-1	24.80		45.	NCAC-2742	34.87	
21.	KG-61-99	25.03		46.	Roiet No.3	35.47	
22.	Starr	25.83		47.	TMV-2	35.73	
23.	Taluka Harur Local	25.87		48.	TG-3	36.60	
24.	Tej amra local	26.27		49.	U2-12-6	39.13	
25.	EC-106985	26.60		50.	EC-21032	43.60	H

(i) Mean = 27.11
(ii) Mean - C.D. = 12.77
(iii) Mean + C.D. = 41.45

Table 51 : Treatment means of 50 groundnut genotypes for nodule number at 80th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	28-8-2	26.20		26.	US-1	45.17	
2.	R-4	30.11		27.	S-277	45.17	
3.	Spanhoma	33.11		28.	EC-106985	45.89	
4.	Mani Blanco	36.89		29.	JH-107	45.89	
5.	EC-21032	36.87		30.	TMV-2	46.11	
6.	EC-21088	37.33		31.	KG-61-99	46.22	
7.	U2-12-6	37.56		32.	EC-161297	48.00	
8.	RB-1	38.65		33.	Roiet No.3	48.11	
9.	Ah-811	39.00		34.	Limidi-4	48.33	
10.	G-0173	39.67		35.	EC-21107	48.67	
11.	Taluka Harur local	39.78		36.	RS-113	48.89	
				37.	EC-20957	48.89	
12.	Tej amra local	39.80	M_2	38.	Limidi-4	49.67	M_1
13.	U-2-1-28	40.83		39.	TMV-7	49.78	
14.	EC-16674	42.78		40.	Limidi-5	51.34	
15.	S-206	43.55		41.	Pollachi-1	51.67	
16.	Exotic-7-3	43.55		42.	TG-3	52.22	
17.	Spanish-191-1	43.65		43.	JH-133	53.11	
18.	Local Claire	43.67		44.	Khandesh	53.33	
19.	EC-21164	43.89		45.	NCAC-2742	53.55	
20.	Ah-39	44.18		46.	EC-21073	54.33	
21.	U-1-2-3	44.34		47.	K-3	57.00	
22.	Jatuti	44.78		48.	No. 276	57.44	
23.	Ah-7986	45.00		49.	RS-181	57.89	
24.	Short-1	45.00		50.	Starr	63.55	
25.	J-11	45.11					

(i)	Mean	=	45.51
(ii)	Mean - C.D. 5%	=	24.68
(iii)	Mean + C.D. 5%	=	66.34

Table 52 : Treatment means of 50 groundnut genotypes for nodule number at 80th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	S-206	25.45		26.	28-8-2	40.78	
2.	RB-1	25.83		27.	Starr	40.89	
3.	EC-21073	28.67		28.	RS-181	41.00	
4.	EC-21107	28.67		29.	KG-61-99	41.50	
5.	JH-133	29.44		30.	Ah-7986	43.56	
6.	EC-21164	29.67		31.	Ah-39	43.56	
7.	Limidi-4	30.64		32.	K-3	43.78	
8.	No 53	32.00		33.	Tej amra local	43.78	
9.	EC-16674	32.00		34.	Ah-811	43.89	
10.	TMV-7	33.33		35.	US-1	44.00	
11.	Pollachi-1	33.33	M_2	36.	Khandesh	44.66	
12.	EC-21088	33.33		37.	U-2-1-28	44.67	
13.	Limidi-4	34.11		38.	Short-1	45.50	M_1
14.	EC-106985	36.44		39.	Local Claire	45.84	
15.	JH-107	36.78		40.	Taluka Harura Local	45.89	
16.	TMV-2	37.44		41.	R-4	46.31	
17.	Spanhoma	37.67		42.	Mani Blanco	46.89	
18.	Limidi-5	38.00		43.	NCAC-2742	47.11	
19.	Exotic-7-3	38.22		44.	G-0173	47.55	
20.	RS-113	39.56		45.	EC-20957	48.11	
21.	J-11	39.66		46.	TG-3	49.11	
22.	EC-161297	39.78		47.	EC-21032	49.87	
23.	Spanish-191-1	40.22		48.	No. 276	52.67	
24.	Jatuti	40.22		49.	Roiet No.3	56.34	
25.	U2-12-6	40.55	M_1	50.	U-1-2-3	65.00	H

(i) Mean = 40.46
(ii) Mean - C.D. = 19.63
(iii) Mean + C.D. = 61.29

Table 53 : Treatment means of 50 groundnut genotypes for nodule number at 100th day for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	KG-61-99	41.70		26.	Ah-7986	64.93	
2.	EC-21088	44.67		27.	JH-133	65.00	
3.	Spanhoma	47.80		28.	TMV-2	65.47	
4.	Pollachi-1	47.87		29.	Ah-39	65.53	
5.	RB-1	49.80		30.	G-0173	66.10	
6.	EC-16674	50.33		31.	U-1-2-3	66.40	
7.	Limidi-5	51.73		32.	Limidi-4	66.80	
8.	EC-21107	53.60		33.	Khandesh	67.53	
9.	EC-20952	54.67		34.	RS-113	68.13	
10.	Spanish-191-1	54.70	M_2	35.	EC-21032	68.40	
11.	No. 53	55.07		36.	Roiet No.3	68.67	
12.	28-8-2	56.87		37.	EC-21073	69.13	
13.	Mani Blanco	56.87		38.	Starr	69.25	
14.	Limidi-4	57.80		39.	TG-3	70.00	M_1
15.	Jatuti	58.20		40.	EC-21164	70.20	
16.	RS-181	58.70		41.	Taluka Harur Local	70.40	
17.	K-3	60.60		42.	Exotic-7-3	70.50	
18.	Ah-811	60.93		43.	R-4	70.70	
19.	Tej amra local	61.60		44.	J-11	70.80	
20.	EC-161297	62.53		45.	Short-1	71.40	
21.	Local Claire	62.70		46.	US-1	71.50	
22.	U2-12-6	63.40		47.	JH-107	71.70	
23.	EC-106985	63.87		48.	S-206	81.30	
24.	U-2-1-28	64.20	M_1	49.	NCAC-2742	82.93	
25.	TMV-7	64.47		50.	No. 276	89.73	H

(i) Mean = 63.34
(ii) Mean - C.D. = 37.08
(iii) Mean + C.D. = 89.6

Table 54 : Treatment means of 50 groundnut genotypes for nodule number at 100th day for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Nodule Number	Status	Sl. No.	Genotypes	Nodule Number	Status
1.	Spanish-191-1	36.53		26.	RB-1	56.60	
2.	EC-21164	37.00		27.	U-2-1-28	57.00	
3.	EC-21088	39.10		28.	Limidi-4	57.07	
4.	Ah-7986	39.90		29.	aRs-113	57.50	
5.	EC-161297	43.40		30.	EC-20957	57.60	
6.	EC-21073	43.40		31.	Starr	58.67	
7.	Ah-39	44.30		32.	K-3	59.40	
8.	TG-3	44.53		33.	Mani Blanco	62.10	
9.	JH-107	45.20		34.	Local Claire	62.70	
10.	Jatuti	45.90		35.	Khandesh	63.80	
11.	TMV-2	48.00		36.	Tej amra local	63.93	
12.	Ah-811	48.07	M_2	37.	No. 53	74.10	M_1
13.	R-4	48.70		38.	28-8-2	64.40	
14.	Exotic-7-3	49.13		39.	EC-21107	65.00	
15.	U2-12-6	49.60		40.	No. 276	65.00	
16.	Taluka Harur local	50.40		41.	Limidi-4	65.67	
17.	Limidi-5	52.13		42.	EC-21032	68.33	
18.	NCAC-2742	52.40		43.	RS-181	68.70	
19.	JH-133	52.90		44.	U-1-2-3	68.80	
20.	G-0173	53.00		45.	US-1	70.20	
21.	Spanhoma	53.50		46.	J-11	70.93	
22.	S-206	54.00		47.	Pollachi	71.00	
23.	EC-16674	54.87		48.	Roiet No.3	77.70	
24.	EC-106985	55.60		49.	Short-1	79.33	
25.	KG-61-99	55.60					

(i)	Mean	=	56.36
(ii)	Mean - C.D. 5%	=	30.10
(iii)	Mean + C.D. 5%	=	82.62

Table 55 : Treatment means of 50 groundnut genotypes for final pod yield at harvest for N_0 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Final pod yield	Status	Sl. No.	Genotypes	Final pod yield	Status
1.	LImidi-5	12.12		26.	28-8-2	19.78	
2.	G-0173	12.22		27.	No. 53	19.78	M_2
3.	RB-1	12.63		28.	EC-21164	19.85	
4.	J-11	13.14		29.	TMV-2	20.13	
5.	U-2-1-28	14.38		30.	U2-12-6	20.20	
6.	EC-106985	14.60		31.	S-206	20.41	
7.	Exotic-7-3	14.81		32.	Ah-811	20.57	
8.	R-4	15.13		33.	NCAC-2742	20.62	M_1
9.	Spanish-191-1	15.53		34.	EC-20957	20.90	
10.	TMV-7	16.07		35.	No. 276	21.03	
11.	Ah-39	16.59		36.	Khandesh	21.61	
12.	KG-61-99	16.82		37.	Spanhoma	22.36	
13.	Limidi-4	16.89		38.	Short-1	23.17	
14.	Jatuti	16.92	M_2	39.	Pollachi-1	23.20	
15.	Taluka Harur Local	16.99		40.	Ah-7986	23.32	
				41.	TG-3	24.06	
16.	U-1-2-3	17.00		42.	EC-161297	24.38	
17.	Tej amra local	17.30		43.	JH-107	24.88	
18.	Local Claire	17.42		44.	K-3	25.48	
19.	Mani Blanco	17.43		45.	EC-21073	25.67	
20.	EC-21088	17.60		46.	EC-21032	25.74	
21.	Roiet No.3	17.92		47.	EC-16674	25.78	
22.	Limidi-4	18.31		48.	US-1	26.53	
23.	Starr	18.62					
24.	RS-181	19.25		49.	RS-113	32.70	H
25.	JH-133	19.65		50.	EC-21107	32.78	

(i) Mean = 19.81
(ii) Mean - C.D. = 6.96
(iii) Mean + C.D. = 32.66

Table 56 : Treatment means of 50 groundnut genotypes for final pod yield at harvest for N_2 level of nitrogen arranged in ascending order.

Sl. No.	Genotypes	Final pod yield	Status	Sl. No.	Genotypes	Final pod yield	Status
1.	EC-106985	11.40		26.	Roiet No.3	20.38	
2.	U-2-1-28	11.79		27.	JH-133	20.44	
3.	Taluka Harur Local	13.17		28.	Short-1	20.60	
				29.	U2-12-6	20.83	
4.	Ah-7986	14.46		30.	Mani Blanco	21.10	
5.	J-11	15.26		31.	Spanish-191-1	21.35	
6.	Limidi-4	15.46		32.	Exotic-7-3	21.39	
7.	Khandesh	15.83		33.	Ah-39	21.76	
8.	TG-3	16.00		34.	U-1-2-3	22.06	
9.	TMV-2	16.14		35.	EC-20957	23.37	
10.	28-8-2	16.68		36.	Starr	23.56	
11.	EC-21164	16.78		37.	S-206	24.03	
12.	RB-1	16.98	M_2	38.	NCAC-2742	24.81	M_1
13.	K-3	17.61		39.	TMV-7	24.90	
14.	Limidi-5	17.77		40.	KG-61-99	25.25	
15.	G-0173	17.91		41.	Jatuti	26.67	
16.	EC-161297	13.08		42.	EC-21107	27.33	
17.	RS-181	18.12		43.	Spanhoma	27.44	
18.	Tej amra local	18.17		44.	Local Claire	27.86	
19.	EC-21088	18.56		45.	EC-21032	28.10	
20.	RS-113	18.69		46.	R-4	28.25	
21.	Pollachi-1	18.87		47.	No. 53	31.67	
22.	Limidi-4	19.06		48.	US-1	32.56	
23.	Ah-811	19.28		49.	JH-107	33.09	
24.	EC-16674	20.02		50.	No. 276	36.11	H
25.	EC-21073	20.32	M_1				

(i) Mean = 21.15
(ii) Mean - C.D. = 8.30
(iii) Mean + C.D. = 34

Table 57 : Mean and range of 50 groundnut genotypes at N_0 and N_2 levels of nitrogen for different characters.

Sl. No.	Character	Days	N_0		N_2	
			Mean	Range	Mean	Range
1.	Shoot dry weight (g)	60	4.00	2.68-6.45	4.07	2.87-6.18
		80	6.47	4.57-10.70	7.07	4.10-13.31
		100	9.65	6.19-15.96	11.97	6.29-17.68
2.	Leaf dry weight (g)	60	3.62	1.51-6.57	4.44	3.04-7.65
		80	8.61	6.06-13.55	8.30	5.69-11.81
		100	7.64	3.68-12.97	10.16	3.33-20.96
3.	Pod dry weight (g)	60	1.95	0.55-5.20	2.01	0.24-5.39
		80	5.41	2.86-9.68	4.21	1.69-10.92
		100	10.04	6.12-16.32	11.45	6.67-18.40
4.	Total dry weight (g)	60	9.19	4.40-11.74	10.20	7.37-16.57
		80	21.18	15.52-30.37	20.06	12.40-37.22
		100	27.32	17.65-35.99	34.54	25.37-45.60
5.	Leaf area (Cm^2)	60	395.02	258.50-507.76	419.20	334.69-841.72
		80	1404.04	989.22-2201.60	1353.89	927.77-1927.3
		100	902.24	930.72-1519.40	1190.76	390.11-2455.4
6.	Nodule number	60	25.66	12.0-41.60	27.11	14.27-43.60
		80	45.51	26.2-63.55	40.46	25.45-65
		100	63.34	41.7-269.2	56.36	36.53-79.53
7.	Final pod yield (g)	120	19.81	12.12-32.78	21.15	11.40-36.11

Table 58A: Arrangement of groundnut genotypes in different quarters under different methods of scoring in ascending order.

Sl. No.	Quar-tets	Scoring based on all parameters	Quar-tets	Scoring based on biomass at 60th 80th & 100th days	Quar-tets	Scoring based on biomass at harvest
		1		2		3
1.	I	K-3	I	EC-21164	I	EC-21088
2.		28-8-2		Ah-39		Mani Blanco
3.		S-206		K-3		25-8-2
4.		EC-21164	II	Mani Blanco		Ah-39
5.		Ah-811		28-8-2		TG-3
6.		Spanhoma		EC-161297		RS-113
7.		EC-16674		EC-21088		EC-16674
8.		Mani Blanco		Limidi-4		Spanish-191-1
9.		EC-21088		EC-106985		Limidi-4
10.		EC-106985		S-206		EC-106985
11.	II	Ah-39		Ah-811		EC-21164
12.		No. 53		TG-3		No. 53
13.		Starr		EC-16674	II.	K-3
14.		Short-1		Starr		R-4
15.		Limidi-4		No. 53		TMV-2
16.		J-11		EC-21107		EC-161297
17.		TMV-7		U-2-1-28		EC-20957
18.		Limidi-5	III.	G-0173		JH-133
19.		Jatuti		Tej Amra Local		Jatuti
20.		Tej Amra Local		JH-107		G-0173
21.		Local Claire		TMV-7		Ah-811
22.		JH-107		US-1		Tej Amra Local
23.		TG-3		Spanhoma		JH-107
24.		RS-181		KG-61-99		TMV-7
25.		EC-21107		Spanish-191-1		Starr
26.	III	R-4		Local Claire		S-206
27.		EC-161297		Short-1		EC-21073
28.		KG-61-99		Khandesh		RS-181
29.		Khandesh		Limidi-5		Limidi-5
30.		EC-21073		J-11		Taluka Harur Local
31.		Spanish-191-1		NCAC-2742		J-11

Table 58A (Contd.)

Sl. No.	Quar-tets	Scoring based on all parameters	Quar-tets	Scoring based on biomass at 60th, 80th & 100th days	Quar-tets	Scoring based on biomass ar harves
32.		Taluka Harur Local		R-4		NCAC-2742
33.		EC-20957		TMV-2	III	EC-21107
34.		RB-1		EC-20957		U-2-1-28
35.		NCAC-2742		U2-12-6		U-2-12-6
36.		Ah-7986		JH-133		Ah-7986
37.		G-0173		Jatuti		RB-1
38.		Limidi-4		RB-1		Exotic-7-3
39.		U2-12-6		EC-21032		EC-21032
40.		JH-133		RS-113		US-1
41.		Pollachi-1		EC-21073		Spanhoma
42.		US-1		RS-113		US-1
43.		RS-113		Taluka Harur Local		No. 276
44.		TMV-2	IV	Limidi-4		Short-1
45.	IV	EC-21032		U-1-2-3		Khandesh
46.		U-2-1-28		Ah-7986		Limidi-4
47.		Exotic-7-3		Exotic-7-3		U-1-2-3
48.		U-1-2-3		Pollachi-1	IV	Pollachi-1
49.		Roiet No.3		No. 276		KG-61-99
50.		No. 276		Roiet No.3		Roiet No.3

Table 58 B : Correlations among different methods of genotypes scoring

	Genotypic scoring	
	2	3
1	0.82*	0.59**
2		0.71**

** = Significant at 1% level of significance

1 = Scoring based on all parameters at 60th, 80th and 100th days at N_0 and N_2 levle of Nitrogen.

2 = Scoring based only on biomass at 60th, 80th and 100th days at N_0 and N_2 level of Nitrogen.

3 = Scoring based only on biomass at harvest at N_0 and N_2 levels.

scores of genotypes obtained considering all the parameters observed across three growth stages (60th, 80th and 100th day) and two nitrogen levels (N_0 and N_2). Arrangement of genotypes in the second column is based on the scores obtained only on total biomass of individual genotype across the growth stages (60th, 80th and 100th day) and nitrogen levels (N_0 and N_2). The third column contains the genotypes arranged according to score obtained on biomass only at harvest.

Generally selection is exercised only on economic yield or total biomass at harvest. However, here observations were recorded on shoot dry weight, leaf dry weight, pod dry weight, total dry weight, leaf area, nodule number and final pod yield at different stages of growth. It is known that higher biomass is essential for realizing higher economic yield. Consequently to understand relative importance of selection based on multiple trait over that one based on biomass, above said three categories of selections were exercised.

Table 58b shows the correlations among the those three types of selection. All of them are significantly associated among themselves. This outcome infers that all these methods of selection are equally effective in identifying the genotype performance.

Subsequent to the arrangement of genotypes in the ascending order (Table 58a) they were placed in quartet in each method of selection. Quartets were identified, in each type of scoring, taking into range value and dividing it into four equal class interval. This was done to examine the extent to which common genotypes appear in I, II, III and IV Quartets when all the three methods are compared. Higher the degree of similarity, then one can use any one of these methods as a method of selecting desirable genotypes.

In the present investigation, there was, to some extent exists tendency of some genotypes to fall in the same quartet when all the methods are compared. Genotypes appearing in the first quartet are of poor performance type and that at the fourth quartets are of superior performing type. Thus, the first quartet helps in identifying genotypes which are inferior and non-responsibe to nitrogen application. Similarly fourth quartet helps in identifying genotypes which can perform better both under nil and excess soil nitrogen conditions.

To select these types of genotypes, out of three methods of scoring, the scoring methodology based on all parameters across the growth stages was used. This was done keeping in mind that economic yield of any crop plant in general and legume in specific is a series of physiological, genetical and biochemical process spanning over the entire growth period. Hence, to select a genotype of superior performance, this methodology helps in identifying true performance of such genotype throughout the growth period. Such genotypes may be more stable and reliable in their performance. The methodology described in Table 58a, the genotypic performance both at nil nitrogen and adequately fertilized condition was summed up to arrive at a final score. Hence, such methodology did not reveal directly the genotypic response to added nitrogen.

To understand such response, genotypic performance of all the 50 genotypes at 60th, 80th and 100th days were compared separately at N_0 and N_2 (as shown in Table 59 for selected genotypes). For each character under each nitrogen level its response over growth stages was calculated as follows:

Each character was assigned L, M_2, M_1, or H category at each growth stage (60th, 80th and 100th days) from the previous exercise.

Table 59: Response of selected groundnut genotypes to nitrogen for **different** characters at 3 stages of growth (60, 80 and 100 days).

1. Genotype: Mani Blanco L to L type

Sl. No.	Characters	Base Status (No.)				Response to nitrogen application			
		60 Days	80 Days	100 Days	Final Status	60 Days	80 Days	100 Days	Final Status
1.	Shoot dry weight	M_2	M_2	M_2	L	M_2	M_2	L	L
2.	Leaf dry weight	M_2	M_2	M_1	L	M_2	M_2	M_2	L
3.	Pod dry weight	M_2	M_2	M_2	L	M_2	M_2	M_1	L
4.	Total dry weight	M_2	M_2	M_2	L	M_1	M_2	M_2	L
5.	Leaf area	M_2	M_2	M_1	L	M_2	M_2	M_2	L
6.	Nodule number	M_1	M_2	M_2	L	M_2	M_1	M_1	H
7.	Final pod yield			M_2	L			M_1	H

2. Genotype : US-1 L to H type

1.	Shoot dry weight	M_2	M_2	M_1	L	M_1	M_2	L	L
2.	Leaf dry weight	M_2	M_2	M_1	L	M_1	M_1	H	H
3.	Pod dry weight	M_2	M_1	M_2	L	M_1	M_2	M_2	L
4.	Total dry weight	M_2	M_2	M_1	L	H	M_2	H	H
5.	Leaf area	M_2	M_2	M_1	L	M_1	M_1	M_1	H
6.	Nodule number	M_2	M_2	M_1	L	H	M_2	L	L
7.	Final pod yield			M_1	H			M_1	H

Table 59 (Contd.)

Sl. No.	Characters	Base Status (NO)				Response to nitrogen application			
		60 Days	80 Days	100 Days	Final Status	60 Days	80 Days	100 Days	Final Status
	3. Genotype : RS-113 H to L types								
1.	Shoot dry weight	M_2	M_1	M_1	H	M_1	M_2	L	L
2.	Leaf dry weight	M_1	M_1	M_2	H	M_2	M_2	L	L
3.	Pod dry weight	M_2	M_1	M_1	H	M_2	M_2	L	L
4.	Total dry weight	M_1	M_1	M_1	H	M_2	M_2	M_2	L
5.	Leaf area	M_1	M_1	M_2	H	M_2	M_2	M_2	L
6.	Nodule number	M_2	M_1	M_1	H	M_1	L^2	L	L
7.	Final pod yield			H	H			L	L
	4. Genotype : No. 276								
1.	Shoot dry weight	M_1	M_1	M_1	H	M_2	M_1	M_2	L
2.	Leaf dry weight	M_1	M_1	M_1	H	H	M_2	M_2	H
3.	Pod dry weight	M_1	M_1	M_2	H	M_2	M_2	M_1	L
4.	Total dry weight	M_1	M_1	M_1	H	H	M_2	M_1	H
5.	Leaf area	M_1	M_1	M_1	H	H	M_2	M_2	H
6.	Nodule number	M_1	M_1	H	H	M_2	L^2	L^2	L
7.	Final pod yield			M_1	H			H	H

To arrive at a final status in each nitrogen level all the three values of growth stages were combined in the following manner. If each character records minimum of two M_2 or lesser category (L), out of three stages, final status would be designated as L meaning overall. Poor performance. On the contrary a minimum of two M_1's or higher status (H) out of three stages resulted in H in the final status indicating overall better performance.

With all these exercises at the end following four groundnut genotypes were selected viz., Mani Blanco, US-1, RS-113 and No. 276. Performance of Mani blanco was very poor both at N_0 (base status) and N_2 (applied nitrogen condition). There were quite a few such genotypes behaving similar to Mani Blanco. Amongst them, seed filling was found very good with Mani Blanco. This genotype was selected under the category of 'LL' mentioned previously, contrary to earlier definition of L status, both under N_0 and N_2 for all characters, there were H status for final pod yield and nodule number at N_2 level of nitrogen for this genotype. However, when looked into absolute value of final yield (Table 60) for Mani Blanco, its performance was poorer to other selected genotypes.

Genotype US-1 was designated as 'LH' type. Table 59 revealed that this genotype scored 'L' for all the characters studied at N_0 except for final pod yield and H status for leaf dry weight, total dry weight, pod dry weight and final pod yield at N_2 level of nitrogen.

Genotype RS-113 (Table 59) showed a positive response to nitrogen application. All the characters at N_0 were 'L' types but the same characters scored H at N_2 level, hence designated as LH type.

Table 60 : Treatment means of selected groundnut genotypes for different characters across growth stages with different nitrogen levels.

Sl. No.	Character	Days	Nitrogen levels	Mani Blanco (LL)	US-1 (LH)	RS-113 (HL)	No. 276 (HH)
1.	Shoot dry weight (g)	60	N_0	3.28	3.40	3.76	4.76
			N_2	4.32	4.53	4.46	4.93
		80	N_0	4.65	6.28	6.68	6.78
			N_2	6.52	7.09	7.69	8.58
		100	N_0	9.01	11.24	12.40	10.68
			N_2	8.01	10.76	13.46	12.80
2.	Leaf dry weight (g)	60	N_0	2.74	2.91	3.85	4.39
			N_2	4.12	5.28	4.18	7.65
		80	N_0	7.36	6.06	9.08	10.18
			N_2	7.44	9.84	8.75	11.03
		100	N_0	8.31	8.29	7.06	8.77
			N_2	8.66	18.53	8.53	11.43
3.	Pod dry weight (g)	60	N_0	1.52	0.59	1.30	2.95
			N_2	2.07	2.41	2.41	2.92
		80	N_0	4.16	6.21	7.82	6.57
			N_2	4.59	4.57	5.68	7.58
		100	N_0	7.78	8.04	11.91	8.35
			N_2	10.04	9.55	10.04	11.29
4.	Total dry weight (g)	60	N_0	7.49	6.98	9.21	11.74
			N_2	10.28	12.27	10.69	16.57
		80	N_0	16.92	20.97	25.80	25.51
			N_2	19.00	22.44	22.87	25.51
		100	N_0	24.00	27.60	32.21	28.71
			N_2	28.33	42.02	25.37	37.53

Table 60 (Contd.)

	60	N_O	300.90	320.54	424.38	482.09
		N_2	454.08	567.01	459.74	841.72
5. Leaf area	80	N_O	1201.31	989.22	1481.39	1661.39
		N_2	1213.28	605.38	1427.55	1799.52
(Cm^2)	100	N_O	973.13	917.17	826.69	1027.01
		N_2	1014.52	2170.79	974.30	1339.02
	60	N_O	25.46	12.00	25.40	32.10
		N_2	27.13	32.40	33.67	29.53
6. Nodule number	80	N_O	36.55	45.17	48.89	57.44
		N_2	46.56	44.00	39.56	52.67
	100	N_O	56.90	71.50	68.13	89.73
		N_2	45.43	70.93	57.50	65.00
7. Final pod yield (g)	120	N_O	17.43	26.53	32.70	21.03
		N_2	21.10	32.56	18.69	36.11

The genotype No. 276 scored highest in the scoring chart (Table 58a). Its performance was extremely good with all characters at N_0 level of nitrogen, and with N_2 still it retained 'H' status for leaf dry weight, total dry weight, pod dry weight and final pod yield, fitting this genotype into 'HH' category. This selection was justified (Table 60) when the absolute figures of these genotypes were compared for all the characters. When economic yields were considered, which would be the ultimate goal of improvement, there was a clear cut distinction among the genotypes across the nitrogen levels. Mani Blanco (LL) showed a specific yield level of 17.43-21.10 g from N_0 to N_2. It was 26.53 to 32.56 g for US-1, 32.70-18.69 g for RS-113 and 21.03-36.11 g for No.276, thus exactly fitting into their respective categories.

Experiment III

There were several reasons and hypotheses advocated to explain the negative and positive responses of legumes to applied nitrogen viz., local effect of nitrogen on nodule development and function, toxic effect of NO^-_3 on enzyme nitrogenase and lack of carbohydrate translocation to nodule during active period of function etc. This experiment was aimed at finding out the possible reasons for the responses of above said 4 classes of genotypes with these parameters, in addition many physiological and morphological characters were also recorded to find out the subtle differences among themselves. The four selected genotypes (G) were tried at following four environmental conditions, under pot culture experiment, (1) Control condition (C); Here all the four genotypes were not provided with either nitrogen or Rhizobium treatment. They were given other essential nutrients only

through nutrient solution, (2) Nitrogen treatment (N); Here all the four genotypes were supplied sufficient quantity of nitrogen, along with other essential nutrients, but not Rhizobium. (3) Rhizobium (R); Here all the genotypes were treated with soil rhizobia and supplied with all the essential nutrients excluding nitrogen regularly, and (4) Rhizobium + Nitrogen (N + R); Here all the genotypes were treated with soil rhizobia and supplied with all the essential nutrients including nitrogen regularly.

These four environmental conditions (E) were supplied to help in pin pointing the probable cause of differential response observed hitherto.

Tables 61 to 63 show the variance component and other genetic parameters observed for many physiological and related characters at 60, 80 and 100 days of growth period. Effect of 4 environmental conditions, genotypes and interaction between these two were significant for shoot length, leaf dry weight, total dry weight at60th day (Table 61). For leaf area interactions with environment was not significant. For nodule number and shoot dry weight only environmental effects were significant. At 80th day, there was no significant genotypic difference for any of the characters observed except for root dry weight (Table 62). Environmental influence on root dry weight, shoot dry weight, leaf dry weight, total dry weight,leaf area and nodule number was significant. Shoot length, root dry weight, leaf dry weight and leaf area showed significant interaction effects.

At 100th day, all the characters exhibited significant environmental effect (Table 63) and none of these characters had a significant genotypic effect. Interaction effect was significant only for pod dry weight.

Shoot length, root dry weight, shoot dry weight, total dry weight, and leaf area showed higher GCV and h^2 coupled with higher

Table 61 : Two way analysis of variance for difference biomass characters at 60th day under pot culture experiment.

Sl. No.	Character	Treat-ment	Mean	Range	Variance	C.D. 5%	h^2	G.A. 5%
1.	Root length (Cm)	E	8.07	7.20-9.18	NS	-	19.52	1.09
		G	8.07	6.99-9.01	NS	-		
		I			NS			
2.	Shoot length (Cm)	E	11.16	5.25-13.37	**	2.78	64.46	7.73
		G	11.16	8.84-14.47	**	2.49		
		I			*			
3.	Shoot/Root	E	1.80	1.56-2.01	NS	-	NE	NE
		G	1.80	1.68-1.88	NS	-		
		I			NS			
4.	Root dry weight (mg)	E	333.87	232.19-437.50	NS	-	50.15	379.76
		G	333.87	165.00-468.75	**	186.27		
		I			NS			
5.	Shoot dry weight (mg)	E	1332.81	793.75-1575	*	503.60	31.59	624.00
		G	1332.81	993.75-1793.75	NS	-		
		I			NS			
6.	Leaf dry weight (mg)	E	1077.34	550.00-1593.75	**	443.68	16.93	212.48
		G	1077.34	562.50-1687.50	**	350.64		
		I			*			
7.	Total dry weight (mg)	E	2647.50	1790.63-3219.69	*	931.80	42.68	1652.06
		G	2647.50	1821.25-33534.37	*	1020.99		
		I			**			
8.	Leaf area (Cm^2)	E	129.23	66.00-191.25	**	53.11	78.21	202.11
		G	129.23	67.50-202.50	**	42.03		
		I			NS			
9.	Nodule number	E	14.56	6.19-31.81	**	5.34	18.50	3.88
		G	14.56	11.88-18.94	NS	-		
		I			NS			

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

Table 62 : Two way analysis of variance for different biomass characters at 80th day under pot culture experiment.

Sl. No.	Character	Treat-ment	Mean	Range	Variance	C.D. 5%	h^2	G.A. 5%
		E	7.66	7.46-7.85	NS	-		
1.	Root length (Cm)	G	7.66	6.82-8.52	NS	-	11.78	0.62
		I			NS			
		E	12.72	11.51-14.13	NS	-		
2.	Shoot length (Cm)	G	12.72	12.18-13.54	NS	-	**9.67**	**0.45**
		I			*			
		E	1.79	1.65-1.98	NS	-		
3.	Shoot/Root	G	1.79	1.56-1.94	NS	-	11.76	0.14
		I			NS			
		E	421.69	290.63-525.00	*	136.48		
4.	Root dry weight (mg)	G	421.69	325.00-508.00	*	108.65	42.70	175.9
		I			**			
		E	2259.53	1575.00-2650.63	*	764.23		
5.	Shoot dry weight (mg)	G	2259.53	2055.00-2587.50	NS	-	NE	NE
		I			NS			
		E	1808.59	1109.38-2425.00	**	453.47		
6.	Leaf dry weight (mg)	G	1808.59	1556.25-2206.25	NS	-	21.82	391.9
		I			*			
		E	4413.13	3209.38-5221.25	**	757.50		
7.	Total dry weight (mg)	G	4413.13	3867.50-4981.25	NS	-	18.18	553.76
		I			NS			
		E	234.61	146.72-312.83	**	57.99		
8.	Leaf area (Cm^2)	G	234.61	200.71-284.61	NS	-	22.01	50.81
		E	31.02	7.31-83.50	**	11.84		
9.	Nodule number	G	31.02	17.00-41.31	NS	-	19.40	12.91
		I			NS			

* = Significant at 5% level of significance; ** = Significant at 1% level of significance
E = Environments; G = Genotypes; I = Interaction effect

Table 63 : Two way analysis of variance for different biomass characters at 100th day under pot culture experiment.

Sl. No.	Character	Treat-ment	Mean	Range	Varia-nce	C.D. 5%	h^2	G.A. 5%
1.	Root length (cm)	E	26.16	18.46-30.00	*	7.42		
		G	26.16	22.02-28.04	NS	-	26.39	4.60
		I			NS			
2.	Shoot length (Cm)	E	22.10	20.89-23.41	*	2.56		
		G	22.10	21.43-23.24	NS	-	NE	NE
		I			NS			
3.	Shoot/Root	E	1.04	0.78-1.62	*	0.59		
		G	1.04	0.80-1.43	NS	-	37.50	0.58
		I			NS			
4.	Root dry weight (mg)	E	2270.31	1487.50-2837.50	**	442.59	-	-
		G	2270.31	2018.75-2568.75	NS	-		
		I			NS			
5.	Shoot dry weight (mg)	E	10848.44	7943.75-13050.0	**	2641.85		
		G	10848.44	9418.75-11637.5	NS	-	6.87	
		I			NS			
6.	Leaf dry weight (mg)	E	5587.50	3981.25-8018.75	**	1150.72		
		G	5587.50	5137.5-6143.75	NS	-	-	
		I			NS			
7.	Total dry weight (mg)	E	21154.69	15750-25584.38	**	3275.07		
		G	21154.69	19350-22453.13	NS	-	-	
		I			NS			
8.	Leaf area (Cm^2)	E	720.22	513.56-1034.42	**	147.77		
		G	720.22	662.72-792.54	NS	-	-	
		I		NS				
9.	Nodule number	E	89.25	63.38-224.44	*	77.70		
		G	89.25	80.00-104.75	NS	-	-	
		I			NS			
10.	Pod dry (mg)	E	2431.25	1690.63-3340.63	**	675.53		
		G	2431.25	2093.75-2753.13	NS	-	7.69	171.81
		I			*			

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

genetic advance at 60th day. In 80th day observation only nodule number showed moderate GCV (45.88). Moderate heritability (42.70) was observed for root dry weight. Genetic advance was moderate for root dry weight (175.92 g) and nodule number (12.91).

None of the genetic parameters were noteworthy at 100th day observation. Only shoot/root ratio showed moderate amount of GCV (44.06) and heritability (37.50).

Study of carbohydrate translocation to different parts

To study the translocation pattern among selected genotypes across the environment, isotopic carbon (^{14}C) was fed to whole plant and how it was apportioned to leaves, shoot, root and pods were studied. This ^{14}C translocation was expressed at three scales of measurements viz, counts per minute per gram (cpm/g), cpm/organ dry weight and ^{14}C per cent in different plant parts.

As shown in the Tables 64 - 66 genotypes/environment/interaction effects were not significant for most of the characters. In the case of specific ^{14}C activity (cpm/g), on 60th day interaction effect for root and environmental influence on shoot were significant. On 80th day, genotype and environmental effect in the case of root, genotype effect on shoot and genotypic and interaction effects of shoot and pods were significant. However, at 100th day observation only environmental and interaction effect of shoot was significant.

Activity based on organ weight (cpm/organ) did not exhibit much variation for characters studied. Environmental effect of roots on 60th day, genotypic effect of root on 80th day and environmental and interaction effect of root on 100th day were significantly different.

Table 64 : Two way analysis of variance for ^{14}C activity in different plant parts at 60th day under pot culture experiment.

Character	Treatment	Mean cpm/gram	Range	Variance	C.D. 5%	h^2	G.A. %
Root	E	11617.18	8512.5-15900	NS	-		
	G	11617.18	9275.0-14375	NS	-	8.00	1099.6
	I			*			
	E	12340.63	8850.0-14412.5	*	4166.12		
Shoot	G	12340.63	8587.5-15350.0	NS	-	47.83	6778.7
	I			NS			
Leaves	E	10481.25	8300.0-11850	NS	-		
	G	10481.25	6887.5-13725	NS	-	9.62	1552.3
	I			NS			
		cpm/organ					
Root	E	6710.31	3950.0-10216.25	*	1776.05		
	G	6710.31	4889.3-9439.38	NS	-	-	-
	I			NS			
Shoot	E	23486.25	13200.0-29221.2	NS	-		
	G	23486.25	12717.5-33545.0	NS	-	26.65	1.22 x 10
	I			NS			
Leaves	E	12779.38	9791.25-16527.5	NS	-		
	G	12779.38	9327.50-16800.0	NS		-	-
	I			NS			
		$\%^{14}C$ activity					
Root	E	14.36	12.69-17.19	*	1.64		
	G	14.36	12.65-19.14	NS	-	37.70	7.80
	I			NS			
Shoot	E	29.39	26.50-33.85	NS	-		
	G	29.39	25.48-32.51	NS		-	-
	I			NS			
Leaves	E	22.15	18.04-24.41	NS	-		
	G	22.15	20.03-24.18	NS	-		
	I			NS			

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

Table 65 : Two way analysis of variance for ^{14}C activity in different plant parts at 80th day under pot culture experiment.

Character	Treatment	Mean $^{14}C/g$	Range	Variance	C.D. 5%	h^2	GA%
Root	E	140842.20	113531.3-163875.0	*			
	G	140842.20	37562.5-240656.3	**	81644.76	85.34	3.46×10^5
	I			NS			
Shoot	E	165140.64	105250.00-80968.75	NS			
	G	165140.64	99968.75-329687.5	*	173650.2	58.42	2.97×10^5
	I			NS			
Leaves	E	276601.58	248156.3-2919687.5	NS			
	G	276601.58	129812.5-455843.8	**	104201.1	88.89	5.25×10^5
	I			*			
Peg	E	342656.28	23900.00-396093.8	NS			
	G	342656.28	128968.8-578625.0	**	90276.96	95.46	7.60×10^5
	I			*			
			^{14}C/organ				
Root	E	76870.16	60718.75-106862.5	NS			
	G	76870.16	63381.25-111421.3	*	56394.87	69.25	1.33×10^5
	I			NS			
Shoot	E	493875.83	372943.8-64538.8	NS			
	G	493875.83	2848881.3-826981.3	NS	-	39.64	4.55×10^5
	I			NS			
Leaves	E	806725.73	590018.8-13456	NS			
	G	806725.73	656193.8-1529259	NS	-	61.64	1.38×10^5
	I			NS			

Table 65 (Contd.)

Peg	E	259159.4	160475-298493.8	NS			
	G	259159.4	108359.4-396484.4	NS	-	47.84	2.70×10^5
	I			NS			
			% ^{14}C activity				
Root	E	8.53	7.93-9.31	NS			
	G	8.53	6.23-11.19	*	3.34	56.76	5.45
	I			NS			
Shoot	E	21.70	17.89-23.98	NS			
	G	21.70	19.56-23.31	NS	-	-	-
	I			NS			
Leaves	E	28.31	22.49-32.09	NS			
	G	28.31	26.87-29.73	NS	-	-	-
	I			NS			

Table 66 : Two way analysis of variance for ^{14}C activity in different plant parts at 100th day under pot culture experiment.

Character	Treat-ment	Mean	Range	Varia-nce	C.D.5%	h2	GA%
			Cpm/g				
Root	E	62406.25	53968.75-72312.5	NS			
	G	62406.25	42906.25-90906.25	NS		54.72	6.79×10^4
	I			NS			
Shoot	E	81148.44	41625.00-121250.0	**			
	G	81148.44	67500.00-101343.8	NS	**14530.6**	78.95	4.56×10^5
	I			NS			
Leaves	E	120070.33	80125.00-28750.0	NS			
	G	120070.33	79937.50-174718.8	NS		43.00	9.70×10^4
	I			NS			
Pod	E	138515.64	8768.75-160375.0	NS			
	G	138515.64	1071625-162250	NS		18.28	2.65×10^4
	I			NS			
		Cpm/Organ					
Root	E	64644.54	46418.75-76281.25	NS			
	G	64644.54	44703.13-84631.25	NS	-	-	-
	I			NS			
Shoot	E	756303.03	387996.9-1127544	**			
	G	756303.03	561193.8-1105612	NS	90225.6	51.81	6×10^5
	I			NS			

Table 66 (Contd.)

Leaves	E	558657.05	438306.3-861665.60	NS			
	G	558657.05	418659.4-736212.50	NS	-	-	-
	I			NS			
Pod	E	367580.88	265959.4-452795.3	NS			
	G	367580.88	250193.8-516554.70	NS	-	51.26	2.83×10^5
	I			NS			
			% ^{14}C activity				
Root	E	7.83	6.42-8.74	NS			
	G	7.83	6.82-9.54	NS	-	8.29	0.57
	I			NS			
Shoot	E	23.10	17.78-29.89	*			
	G	23.10	21.56-27.29	NS	-	7.06	0.98
	I			NS			
Leaves	E	22.99	19.64-28.08	NS			
	G	22.99	20.03-24.66	NS	-	-	-
	I			NS			
Pod	E	19.37	16.95-22.70	NS			
	G	19.37	18.41-20.35	NS	-	-	-
	I			NS			

* = Significant at 5% level of significance
** = Significant at 1% level of Significance

For ^{14}C per cent estimates in different parts, environmental effect of root on 60th day, genotypic effect of root on 80th day and and environmental effect of shoot on 100th day showed significant differences.

Genotypes with higher GCV coupled with higher heritability estimates are useful in plant breeding programme. For specific activity (cpm/g) on 60th day, only in shoot higher GCV with higher heritability coupled with higher genetic advance (GA) was noticed. However, on 80th day and 100th day all the characters showed higher GCV, h^2 and GA for specific ^{14}C activity.

Study of per cent nitrogen (N%) in different plant parts and enzyme activity

Environmental effect on per cent N in leaves on 60th day and on root and leaves on 80th day was significant. On 100th day, effect of environment, genotype and interaction effect on shoot N content was significant (Tables 67 -69).

When nitrogenase activity was considered per hour (μ mol $C_2H_4 pl^{-1} h^{-1}$), they were significantly different among environments on 60th and 100th day (Tables 67 - 69). However, when nitrogenase activity was measured on plant top weight basis (μ mol C_2H_4 top $wt^{-1}h^{-1}$, it was significantly different among environments on 60th, 80th and 100th day. In addition it was significantly different among genotypes on 60th day.

Nitrate reductase is an enzyme involved in the uptake of soil nitrogen. Its activity was significant only for different environments on all the growth stages (60th, 80th) (Tables 67 - 68). Nitrate reductase activity was absent on 100th day in all the genotypes studied. Per cent nitrogen in root, shoot and leaves did not show much

Table 67 : Two way analysis of variance for per cent N in different plant parts, nitrogenase and nitrate reductase activity at 60th day under pot culture experiment.

Characters	Treat-ments	Mean	Range	Vari-ance	C.D. 5%	h2	G.A. %
% N							
Root	E	7.45	7.14-7.94	NS	-		
	G	7.45	6.90-7.87	NS	-	27.4	0.48
	I			NS			
Shoot	E	5.90	5.07-6.41	NS	-		
	G	5.90	5.34-6.31	NS		**22.4**	**0.52**
	I			NS			
Leaves	E	9.30	8.81-10.18	**	0.35		
	G	9.30	9.10-9.46	NS	-		
	I			NS			
Nitrogenase (μ mol. C_2H_2 pl^{-1} h^{-1} activity)	E	31.61	9.27-71.52	**	9.88		
	G	31.61	26.19-35.51	NS	-		
	I			NS			
μ mol C_2H_4/ organ wt h^{-1}	E	13.88	4.28-27.91	*	9.92		
	G	13.88	12.35-19.72	*	7.80		
	I			NS		57.95	13.18
(μ mol./g/NO_2 fresh weight h^{-1}) (Nitrate reductase activity)	E	0.92	0.78-1.04	*	0.09		
	G	0.92	0.83-1.02	NS			
	I			NS			

* = Significant at 5% level of significance; ** = Significant at 5% level of significance

Table 68 : Two way analysis of variance for per cent N in different plant parts, nitrogenase and nitrate reductase activity at 80th day under pot culture experiment.

Character	Treat-ment	Mean	Range	Vari-ance	C.D. 5%	h^2	G.A. %
% N Root	E	7.31	6.78-7.71	*	0.45		
	G	7.31	6.90-7.87	NS	-	-	-
	I			NS			
Shoot	E	5.90	5.07-6.41	NS			
	G	5.90	5.34-6.31	NS	-		
	I			NS			
Leaves	E	9.30	8.81-10.18	*	0.50		
	G	9.30	7.97-9.46	NS	-	-	-
	I			NS			
Nitrogenase activity	E	21.09	0.96-45.67	NS	-		
(µ mol C_2H_4	G	21.09	15.96-28.31	NS	-	-	-
pl^{-1} h^{1})	I			NS			
µ mol C_2H_4/	E	4.62	0.31-11.05	*			
	G	4.62	3.31-5.58	NS	2.15	10.91	0.99
top wt/h	I			NS			
(µ mol. NO_2/g fresh wt./h) Nitrate reductase activity)	E	0.48	0.16-1.01	**	0.12		
	G	0.48	0.36-0.56	NS	-	-	-
	I			NS			

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

Table 69 : Two way analysis of variance for per cent N in different plant parts nitrogenase activity at 100th day under pot culture experiment.

Characters	Treat-ments	Mean	Range	Vari-ance	C.D. 5%	h	GA %
N % Root	E	6.90	6.54-7.62	NS			
	G	6.90	6.49-7.22	NS	-	-	-
	I			NS			
Shoot	E	6.88	6.50-7.09	**	0.15		
	G	6.88	6.57-7.13	*	0.36	59.26	0.63
	I			**			
Leaves	E	8.67	8.45-9.15	NS			
	G	8.67	8.22-9.03	NS	-	-	-
	I			NS			
Nitrogenase	E	19.25	11.96-30.02	*	6.08		
μ mol C_2H_4	G	19.25	8.87-29.42	NS	-	46.00	18.61
pl^{-1} h^{-1}	I			NS			
μ mol C_2H_4/top	E	1.32	0.56-2.38	**	0.39		
	G	1.32	0.52-1.89	NS	-	43.39	1.23
wt/h	I			NS			

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

genotypic and phenotypic coefficient of variability throughout the growth period. There was a moderate heritability estimate (22.40) for shoot N per cent on 60th day and a higher heritability estimate for shoot N on 100th day.

Specific activity of nitrogenase (μ mol C_2H_4 $pl^{-1}h^{-1}$) did not show any noteworthy genetic effect on 60th and 80th day. On 100th day its GCV (69.51), PCV (102), h^2 (46) and GA (18.61) were quite high. When enzyme activity was considered for plant top weight, high GCV, PCV and h^2 were noticed throughout the growth period. On 60th day, even GA (13.18) was very high.

Correlation analysis

This analysis helps in identifying the characters which have got direct/indirect bearing on final yield of a crop. Sometimes it would be difficult to select directly, for the character of importance. Under such conditions, best way of going for selection would be select for associated, easily observable characters. In this study (Table 70), the characters like root length, shoot length, shoot/root ratio, root dry weight, shoot dry weight, leaf dry weight and leaf area were correlated with total dry weight. Here contribution of different characters to total dry weight was considered to be any indication for higher yield.

As shown in the Table 70, on 60th day, root length, shoot length, root dry weight, shoot dry weight, leaf dry weight, leaf are and nodule number were significantly correlated with total dry weight. On 80th day only shootdry weight, leaf dry weight and leaf area showed significant association with total dry weight. On 100th day, root length, root dry weight, shoot dry weight, leaf dry weight and leaf

Table 70 : Phenotypic correlation of different characters with total dry weight under pot culture experiment.

Combination	Days	r	Combination	Days	r
	60	0.86**		60	0.96**
1, 8	80	0.34	5, 8	80	0.89**
	100	0.79**		100	0.87**
	60	0.66**		60	0.92**
2, 8	80	0.36	6, 8	80	0.94**
	100	0.18		100	0.84**
	60	-0.22		60	0.61*
3, 8	80	-0.02	7, 8	80	0.94**
	100	-0.98**		100	0.84**
	60	0.77**		60	0.57*
4, 8	80	0.15	9, 8	80	0.25
	100	0.85**		100	-0.78**

1 = Root length
2 = Shoot length
3 = Shoot/root
4 = Root dry weight
5 = Shoot dry weight
6 = Leaf dry weight
7 = Leaf Area
8 = Total dry weight
9 = Nodule number

area were positively and significantly associated with total dry weight, however association of shoot/root ratio and nodule number was significant but negative.

Table 71 shows the correlation of some of the characters which has got direct or indirect bearing on plant nitrogen content with the total plant weight. Here, only association of nitrogenase activity with total dry weight on 80th day and nodule number with total dry weight on 60th day were significant. Nodule number exhibited significant negative effect on total dry weight on 100th day.

Comparison of mean performance

Mean performance of genotypes Mani Blanco, US-1, RS-113 and No. 276 under different treatments-control, nitrogen application, Rhizobium treatment and Rhizobium nitrogen combined application, are presented in Table 72. The purpose of such presentation was to find out the subtle differences between varieties for various characters. The ratio between shoot and root was estimated among four varieties across the different treatments - control, nitrogen, Rhizobium and nitrogen + Rhizobium which did not show any appreciable difference among varieties. In all the varieties, however, there were decreased ratio with advances in growth stages. The partitioning of dry matter among root, shoot and leaves were studied over growth period of four genotypes. Generally, with progress in growth stages there was proportionate increase in dry weight for shoot, and decreased partitioning to leaves. Root dry weight was either remained constant or decreased with growth stages under control and applied nitrogen conditions, but it was decreasing for Rhizobium and Rhizobium + nitrogen conditions. Regarding rate of increase of dry matter accumulations,

Table 71 : Phenotypic correlation of different nitrogen fixation character with total dry weight under pot culture experiment.

Combination	Days	r
1, 6	60	-0.11
	80	0.14
	100	-0.08
2, 6	60	0.15
	80	-0.31
	100	-0.48
4, 6	60	0.20
	80	-0.43
	100	0.15
5, 6	60	0.57*
	80	0.27
	100	-0.77*

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

1 = ^{14}C counts (cpm/organ)
2 = % N
3 = μ mol. C_2H_4 $pl^{-1}h^{-1}$
4 = Nitrate reductase activity (NRA) μ mol. NO_2/g fresh weight h^{-1}
5 = Nodule number
6 = Total dry weight

Table 72 : Means for different biomass character under pot culture experiment.

Varieties	Days	Control								
		Root length (Cm)	Shoot length (Cm)	Shoot/ root	Root dry weight (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Total dry weight (mg)	Leaf area (Cm^2)	Nodule number
	60	9.10	12.40	1.36	350	875	1100	2325	132.00	5.25
Mani	80	16.13	14.00	0.87	350	2395	2275	5020	293.48	16.00
Blanco	100	27.25	19.25	0.71	1800	6650	4725	13175	609.53	73.00
	60	8.35	11.60	2.20	100	1525	1600	3225	192.00	15.50
US-1	80	17.83	15.50	0.87	432.5	2532.5	2525	5490	325.73	20.00
	100	28.38	22.65	0.80	2300	11950	5850	20100	754.65	66.75
RS-113	60	8.08	12.35	1.80	100	925	1175	2200	141.00	12.50
	80	16.75	15.60	0.93	300	2575	1450	4325	187.05	19.00
	100	24.33	20.25	0.83	1800	10750	3550	16100	457.95	50.00
No.276	60	11.18	17.13	1.99	875	2750	2500	6125	300.00	16.00
	80	19.13	16.10	0.84	775	3100	3450	7325	445.05	9.50
	100	27.00	21.43	0.79	1825	8925	3400	14150	438.60	63.75

Table 72 (Contd.)

Varieties	Days	Rhizobium Treatment								
		Root length (Cm)	Shoot length (Cm)	Shoot/ root	Root dry weight (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Total dry weight (mg)	Leaf area (Cm^2)	Nodule number
Mani Blanco	60	7.98	14.25	1.79	550	2650	1287.50	4487.50	154.50	126.00
	80	16.40	15.00	0.91	1066	1950	1525.00	4541.00	196.80	93.00
	100	21.60	22.63	1.05	2200	8425	4750.00	15375.00	612.73	283.00
US-1	60	7.83	14.28	1.82	425	1250	1275.00	2950.00	153.00	95.00
	80	19.38	16.25	0.84	1259.70	2650	2175.00	6084.70	280.58	78.25
	100	21.08	16.63	0.79	1375.00	8350	3500.00	13225.00	451.50	193.50
RS-113	60	8.25	12.25	1.48	275.00	825	525.00	1625.00	63.00	121.00
	80	15.75	14.75	0.94	1023.75	2525	1575.00	5123.75	203.18	34.75
	100	21.28	23.38	1.10	1300.00	6125	2950.00	10375.00	380.48	220.00
No. 276	60	9.00	14.00	1.56	500.00	2200	2000.00	4700.00	63.00	167.00
	80	19.88	16.50	0.83	1000.00	2725.00	2225.00	5950.00	287.03	128.00
	100	20.00	25.30	1.27	1075	8875	4725	14675.00	609.53	201.25

Table 72 (Contd.)

Varieties	Days	Rhizobium + Nitrogen treatment								
		Root length (Cm)	Shoot length (Cm)	Shoot/ root	Root dry weight (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Total dry weight (mg)	Leaf area (Cm^2)	Nodule Number
Mani Blanco	60	8.25	15.00	1.82	425.00	1450	775.00	2650.00	93.00	30.00
	80	16.75	16.50	0.99	1088.75	1650	1562.50	4301.25	116.10	7.00
	100	32.08	21.48	0.67	2825.00	13275	5250.00	21350.00	668.25	41.00
US-1	*60*	*8.00*	13.93	1.74	300.00	1275	200	1775.00	24.00	25.00
	80	18.13	15.50	0.85	1178.45	2350	1650	5178.45	219.30	27.75
	100	32.13	23.93	0.74	3175.00	13000	5425	21600.00	699.83	56.75
RS-113	60	5.98	11.43	1.19	206.25	800	250	1256.25	30.00	16.00
	80	18.63	17.20	0.92	1210.95	2125	2162.5	5498.45	345.08	10.75
	100	29.88	24.38	0.82	2550.00	11800	6950.0	21300.00	896.55	61.00
No. 276	60	8.33	13.28	1.59	300.00	1225	975.0	2500.00	117.00	28.00
	80	16.55	18.00	1.09	1075.75	3275	2075.0	6425.75	267.68	23.00
	100	25.93	23.88	0.92	2800.00	9500	6250.00	18550.00	706.25	39.25

Table 72 (Contd.)

Varieties	Days	Nitrogen treatment								
		Root length (Cm)	Shoot length (Cm)	Shoot/ Root	Root dry weight (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Total dry weight (mg)	Leaf area (Cm^2)	Nodule number
Mani Blanco	60	6.08	12.45	2.05	225	1975	1550	3750	186.00	60.00
	80	18.00	15.38	0.85	1206	2225	1525	4956	196.65	17.25
	100	31.25	23.50	0.75	3450	14450	7850	25750	1012.65	22.00
US-1	60	9.53	10.88	1.14	200	950	450	1600	54.00	20.00
	80	18.75	17.00	0.91	1000	1200	762.5	2962.5	112.88	3.75
	100	30.10	22.50	0.75	2450	13050	9800	25300	1264.20	23.50
RS-113	60	5.68	13.05	2.30	78.75	450	300	828.75	36.00	3.00
	80	18.25	16.00	0.88	425.0	1625	1075	3125.00	138.68	4.67
	100	31.23	20.05	0.64	2425.00	14325	7100	23850	915.90	17.50
No. 276	60	7.55	13.28	1.76	200.00	1575	1275	3050	153.00	34.00
	80	16.25	18.00	1.11	300	1250	1075	2625	138.00	4.25
	100	25.13	22.35	0.89	2975	10375	7325	20675	944.93	15.75

RS-113 and No.276 excelled Mani Blanco and US-1 under control. Under nitrogen added conditions none of the varieties showed any significant increase. With Rhizobium treatment it was US-1 and No.276, and for Rhizobium + nitrogen, there were slight increase in dry weights for Mani Blanco and No. 276, and decreased allocation in case of US-1 and RS-113. Decrease in leaf dry weight under control condition was significant for US-1, RS-113 and No. 276. Under applied nitrogen treatment differences were not much noticeable with growth stages. Under Rhizobium treatment US-1 showed a steep decrease from 60th to 100th day, but for other varieties it was either constant or marginal. Rhizobium and nitrogen treatment enhanced leaf dry weight in case of US-1 and RS-113, and marginal decrease in Mani Blanco and No.276. For total dry weight both Mani Blanco and NO. 276 maintained higher weights throughout (60th - 100th day) for all types of treatments compared to US-1 and RS-113. Leaf area and nodule number did not show much differences among varieties across the growth stages with all treatments.

^{14}C translocation studies

Specific activities (cpm/g) of carbon (Table 73) in all the organ increased from 60th to 80th day and decreased afterward in all the treatment combinations. However, with nitrogen application and Rhizobium treatment, specific activities in all the organs increased or remained constant for No.276. Under controlled environment RS-113 maintained highest specific activity at 80th day over rest of the varieties. AT 80th and 100th day, specific activity was highest for RS-113 and No.276. On 60th day differences among varieties was not noticeable. This was, equally true with other situation like applied

Table 73 : Means of different characters for ^{14}C activity under pot culture experiment

Varieties	Days	Control											
		cpm/g				cpm/organ				% cpm			
		Root	Shoot	Leaves	Pod	Root	Shoot	Leaves	Pod	Root	Shoot	Leaves	Pod
		1	2	3	4	5	6	7	8	9	10	11	12
Mani Blanco	60	9.35	16.35	4.70		1.29	29.81	3.73		4	86	10	
	80	13.20	233.00	253.50	280.30	65.70	706.30	720.30	465.33	3	36	37	5
	100	91.00	120.37	421.00	105.50	113.10	752.02	1857.80	294.00	4	25	62	9
US-1	60	11.25	6.00	8.00		5.10	12.37	10.95		18	44	39	
	80	46.00	90.87	13.30	169.75	26.25	300.00	410.40	209.60	3	32	43	22
	100	45.12	76.37	112.87	144.12	76.02	915.68	499.92	294.86	4	51	28	17
RS-113	60	7.60	17.70	20.04		7.98	50.05	3.60		13	81	6	
	80	253.25	421.00	542.50	720.50	100.05	453.20	755.00	196.24	7	30	50	13
	100	91.87	111.50	238.00	218.60	65.68	916.50	846.12	767.47	3	35	33	19
No.276	60	13.00	17.60	14.30		6.17	24.65	3.66		18	71	11	
	80	118.25	145.00	194.25	413.75	50.87	405.52	474.37	336.15	4	32	37	27
	100	23.62	176.75	63.17	117.62	36.60	1925.96	242.76	454.84	1	72	9	18

Table 73 (Contd)

Varieties	Days	Nitrogen											
		1	2	3	4	5	6	7	8	9	10	11	12
Mani Blanco	60	13.80	6.05	3.70		7.26	3.15	12.01		14	62	24	
	80	305.85	132.50	540.00	270.00	121.21	216.15	556.20	150.50	12	21	53	14
	100	86.31	11.12	107.50	104.75	45.85	32.01	411.43	327.07	6	4	50	40
US-1	60	29.00	4.85	10.80		10.17	7.26	4.58		46	33	21	
	80	17.75	380.75	997.50	224.00	10.65	997.75	259.05	149.50	1	70	18	11
	100	23.87	54.50	81.87	52.62	20.31	72.37	443.68	87.07	3	12	71	14
RS-113	60	8.60	5.65	9.05		5.81	10.17	18.20		17	30	53	
	80	234.75	477.25	423.50	374.12	117.85	1199.20	1217.75	370.53	4	41	42	13
	100	100.25	163.37	96.00	261.62	103.50	1260.66	448.98	258.38	5	61	22	12
No.276	60	12.20	18.85	9.65		6.90	53.40	31.32		8	58	34	
	80	36.00	78.75	79.75	550.00	27.20	168.32	120.00	465.70	3	22	15	60
	100	367.50	803.75	771.25	222.50	82.38	186.93	559.25	391.35	7	15	46	32

Table 73 (Contd.)

Varieties	Days	Rhizobium Treatment											
		1	2	3	4	5	6	7	8	9	10	11	12
Mani	60	8.00	15.00	4.50		12.00	15.50	3.99		38	49		
Blanco	80	174.50	176.50	266.50	213.62	139.45	500.90	1044.70	123.28	8	28	58	6
	100	54.00	38.37	46.12	83.87	27.15	253.27	110.10	247.37	4	40	17	39
US-1	60	1.00	12.85	17.15		11.88	19.40	20.96		23	37	40	
	80	65.50	86.50	204.75	932.50	29.65	27.91	652.77	51.57	3	28	64	5
	100	38.00	41.12	27.00	82.00	16.00	338.18	120.00	267.00	2	46	16	36
RS-113	60	22.62	24.70	11.45		15.63	59.57	17.13		17	65	19	
	80	170.12	420.50	354.12	519.62	45.01	1007.57	806.21	403.18	2	44	36	18
	100	88.62	41.12	203.37	83.12	67.37	541.27	1079.75	417.00	3	26	51	20
No.276	60	11.80	15.25	11.55		1.34	9.22	12.22		6	40	54	
	80	44.00	59.00	167.00	129.50	68.57	175.57	509.02	63.85	8	22	62	8
	100	61.12	45.87	126.62	102.87	75.15	561.27	566.00	426.80	5	34	35	26

Table 73 (Contd..)

Varieties	Days	Rhizobium + Nitrogen Treatments											
		1	2	3	4	5	6	7	8	9	10	11	12
Mani Blanco	60	5.95	4.90	14.65		0.59	6.42	17.58		2	26	71	
	80	182.00	153.25	162.50	291.00	119.32	365.77	303.57	345.60	11	32	27	30
	100	49.12	100.12	124.25	247.50	58.06	1207.46	565.60	356.60	3	55	26	16
US-1	60	12.65	10.65	18.95		1.74	11.83	9.47		8	51	41	
	80	21.00	32.00	81.75	27.37	21.55	88.00	453.17	22.76	4	15	77	4
	100	71.12	104.87	111.50	127.75	66.75	1137.75	611.02	351.83	3	53	28	16
RS-113	60	7.65	11.35	5.45		8.32	14.38	5.33		30	51	19	
	80	304.50	294.50	503.25	700.25	179.70	647.90	3338.07	629.32	4	14	70	12
	100	118.87	30.12	31.87	85.62	101.96	251.18	168.75	145.68	15	38	25	22
No.276	60	7.80	9.70	3.40		5.13	20.16	6.78		16	63	21	
	80	148.00	289.25	419.25	503.87	106.87	390.10	1287.00	176.75	5	20	66	9
	100	50.12	102.37	52.87	176.12	78.62	1748.27	4079.75	793.22	3	58	13	26

nitrogen, Rhizobium treated and combined application of nitrogen and Rhizobium.

Under nitrogen applied condition, on 80th day, highest specific activity in root (305.85), shoot (477.25) leaves (997.5) and pod (550) was observed in Mani Blanco, RS-113, US-1 and No.276 respectively. In general, higher ^{14}C specific activity in all the organs was noticed in RS-113, on 80th day and No.276 on 100th day.

With applied Rhizobium, higher ^{14}C specific activity in root, shoot, leaves and pod on 80th day was associated with Mani Blanco (174.5), RS-113 (420.5), RS-113 (354.125) and RS-113 (519.62) respectively. On 100th day only noticeable specific activity was observed with leaves in Rs-113 (354.125).

RS-113 exhibited higher ^{14}C specific activity on 80th day in root (304.5), shoot (294.5), leaves (503.25) and pod (700.25) with simultaneous application of Rhizobium and nitrogen. On 100th day it was RS-113 for root (118.87), US-1 for shoot (104.87) and Mani Blanco for leaves (124.25) and pod (247.5).

Counts per minute/organ

^{14}C counts per gram dry weight of the plant tells only about efficacy of particular organ. But to know about total activity of ^{14}C, cpm/organ is generally followed (Table 73).

On 60th day under control treatment highest activity was observed for root (7.98) and shoot (50.05) in RS-113, and leaves (10.95) in US-1. On 80th day, for root (100.05) in RS-113, shoot (706.8) in Mani Blanco, leaves (720.3) in Mani Blanco, and for pods Mani Blanco (465.337). On 100th day it was Mani Blanco for root (113.15), No.276

for shoot (1925.5), Mani Blanco for leaves (1857.85) and RS-113 for pod (767.47).

Under applied nitrogen treatment, roots did not show much difference among varieties on 60th day. No.276 showed higher activity for shoot (53.4) and leaves (31.32) on 80th day, Mani Blanco showed higher root activity (121.1), RS-113 higher shoot (1199.25) and leaf (1217.95) activity and No.276 higher activity in pod (465.7). At 100th day, higher root (103.5) and shoot (1260.66) activities were observed in Rs-113 and higher activities in leaves (559.25) and pod (391.35) were observed in No.276.

With Rhizobium treatment, on 60th day higher activities for root (15.63) and shoot(59.57) were observed in RS-113 and higher leaf activity (20.96) in US-1. On 80th day Mani Blanco showed higher activity in root (139.45) and leaves (1044.7) and higher shoot (1007.57) and pod activity (403.18) was found in RS-113. On 100th day, No.276 exhibited higher activity in root (75.15) shoot (561.27), and pod (426.8) and higher activity in leaf (1079.75) was found in RS-113.

Under Rhizobium and nitrogen applied condition, on 60th day, difference in activity was not so significant among varieties. On 80th day RS-113 showed higher activities in all the organs. On 100th day higher activity in different organ was observed in No.271.

Per cent ^{14}C in different plant parts

On 60th day, under controlled condition, RS-113 and No.276 had higher ^{14}C accumulation in root and shoot, but RS-1 in root and leaves (Table 73). However, Mani Blanco showed higher accumulation only in shoot. Under nitrogen applied situations, higher root activity was observed only in US-1 (46.0%), Mani Blanco (62%) and No. 276 (58%)

exhibited higher accumulation in shoot, and only RS-113 had higher leaf accumulation (53%). With the treatment of Rhizobium, higher root accumulation (38%) was observed in Mani Blanco, higher shoot accumulation (65%) in RS-113, and higher accumulation in leaves (54%) in No. 276. Under applied Rhizobium + nitrogen situation, higher accumulation in root, shoot and leaves were observed in RS-113 (30%), No.276 (63%) and Mani Blanco (71%) respectively.

On 80th day, under the treatment control genotypes did not differ much in their percentage allocation of ^{14}C in root, shoot and leaves. Only No.276 accumulated higher ^{14}C in pod. With nitrogen applied condition higher accumulation in root, shoot, leaves and pod was observed in Mani Blanco (12%), US-1 (70%), Mani Blanco (53%), and No. 276 (60%). Under Rhizobium treatment there was not much noticeable difference among genotypes for ^{14}C accumulation. Even with Rhizobium + nitrogen application situation pattern was almost same, except in Mani Blanco which showed higher shoot and pod accumulation and lower root accumulation.

On 100th day, under control condition higher shoot and leaves ^{14}C accumulation was observed in No.276 (72%), and Mani Blanco (62%). Genotypes did not differ much in their root and pod accumulation. Genotypes did not show much difference in root accumulation under applied nitrogen condition. However, higher accumulation in shoot, leaves and pod was observed in RS-113 (61%), US-1 (71%) and No.276 (32%) respectively. Under Rhizobium treatment and Rhizobium + nitrogen treatment percentage allocation of ^{14}C to different parts was almost same.

Per cent nitrogen and enzyme activity in different genotypes

In Table 74, per cent N present in different plant parts at 60th, 80th and 100th day was presented. When genotypes were not provided with either external nitrogen or Rhizobium treatment (control), percentage nitrogen in root, shoot, leaves and pod generally decreased with successive growth stages. There was not much differences among genotypes for shoot and pod nitrogen per cent. But for root and shoot nitrogen per cent there were consistently higher percentages in Mani Blanco and No.276 over growth period. Under applied nitrogen conditon, RS-113 and No.276 accumulated, higher nitrogen compared to Mani Blanco and US-1 in all the parts for all the growth stages. Nitrogen accumulation pattern in genotypes were different when they were treated with Rhizobium. Generally, per cent nitrogen in root and shoot decreased from 60th to 80th day. It increased or remained more or less constant in leaves in this period. From 80th - 100th day, there was an increasing trend in root and shoot and decreasing trend in leaves except in No. 276, where it was still increasing. Higher pod N was observed in RS-113 (3.55%) and No.276. Under Rhizobium + nitrogen condition genotypic differences in root, shoot and leaf N was not so significant. However, No.276 maintained higher leaf and pod N over growth period when compared to rest of the genotypes.

Enzyme activity

Nitrogenase and nitrate reductase are the two key enzymes involved in nitrogen fixation/uptake in the plant. Nitrogenase (NRase) and nitrate reductase activity (NRA) are considered as an indication of nitrogen uptake by the plant. Nitrogenase activity was expressed both as a specific activity (plant^{-1} hour^{-1}) and absolute activity

Table 74 : Means of different characters for per cent N content under pot culture experiment.

Varieties	Day	% Nitrogen				NR	NR	NRA
		Root	Shoot	Leaves	Pod	$pl^{-1}h^{-1}$	$top_{h-1}wt^{-1}$	µ mol/g
1	2	3	4	5	6	7	8	9
				Control				
	60	1.68	1.26	3.07		4.28	2.02	0.86
Mani	80	1.78	1.15	3.04		26.69	6.26	0.32
Blanco	100	1.56	1.54	1.94	1.55	9.18	0.55	-
	60	1.95	1.13	3.07		28.45	11.63	0.83
US-1	80	1.17	1.12	2.69		16.11	2.94	0.00
	100	1.20	1.44	2.33	1.69	12.22	0.95	-
RS-113	60	2.16	1.36	3.45		11.42	9.98	0.78
	80	1.20	0.92	2.59		1.62	0.33	0.00
	100	1.24	1.18	2.28	2.00	22.59	1.27	-
No.276	60	1.43	1.26	2.94		0.16	0.04	1.08
	80	1.48	1.14	2.72		73.23	11.91	0.33
	100	1.29	1.02	2.65	1.59	30.01	2.69	-
				Nitrogen				
Mani	60	1.36	1.02	2.49		29.29	5.58	1.37
Blanco	80	1.33	1.25	3.29		2.06	0.47	1.20
	100	1.33	1.38	2.64	1.49	1.49	16.86	-
	60	1.26	1.34	2.54		20.29	15.73	0.47
US-1	80	1.43	1.18	3.69		0.07	0.03	0.92
	100	1.62	1.47	1.35	1.92	8.98	0.04	-
RS-113	60	2.28	1.18	2.59		34.98	26.81	1.23
	80	1.59	1.52	2.82		1.07	0.55	1.12
	100	1.69	1.44	2.27	2.68	18.22	0.79	-
No.276	60	1.43	1.02	2.28		32.91	22.06	1.08
	80	1.71	1.40	3.21		0.64	0.20	0.80
	100	1.18	1.72	3.04	2.20	11.68	0.60	-

Table 74 (Contd.)

1	2	3	4	5	6	7	8	9
				Rhizobium				
Mani	60	2.42	1.22	2.31		63.92	21.27	0.74
Blanco	80	0.48	1.00	2.88		54.99	14.97	0.03
	100	1.40	1.70	2.86	2.38	43.77	3.55	-
US-1	60	2.12	0.74	2.89		83.39	27.12	1.10
	80	0.85	1.48	2.84		41.12	8.08	0.02
	100	1.12	1.49	2.45	1.73	8.92	0.43	-
RS-113	60	1.60	1.37	2.64		64.47	38.71	1.06
	80	0.93	0.84	2.39		49.65	11.40	0.03
	100	1.77	1.66	1.99	3.55	39.36	3.30	-
No.276	60	1.62	1.39	2.33		95.30	24.07	1.04
	80	1.27	1.05	2.43		36.94	9.73	0.12
	100	3.27	1.14	2.91	2.68	28.07	2.24	-
				Rhizobium + Nitrogen				
Mani	60	1.72	1.25	2.21		7.28	3.48	0.79
Blanco	80	2.44	1.32	2.48		0.66	0.29	0.71
	100	0.99	1.58	2.51	2.90	5.47	0.29	-
US-1	60	1.51	0.48	2.26		16.90	7.05	0.92
	80	1.20	1.39	1.59		6.56	1.43	0.49
	100	1.48	1.50	2.57	3.23	13.59	0.71	-
RS-113	60	1.58	0.40	2.21		4.81	3.37	1.00
	80	1.50	1.55	0.26		23.69	4.88	0.77
	100	1.76	1.28	1.96	2.60	37.53	2.23	-
No.276	60	1.32	1.29	2.77		8.11	3.26	0.78
	80	2.25	1.44	2.75		2.44	0.49	0.78
	100	1.22	1.44	1.70	3.62	9.92	0.74	-

(top weight^{-1} hour^{-1}). Specific activity of nitrate reductase was expressed as NRA/gram fresh weight per hour (Table 74). Under the control treatment, both specific and absolute activity were low for Mani Blanco (4.28 and 2.02) and No.276 (0.16 and 0.04) compared to US-1 (25.45 and 11.63) and RS-113 (11.42 and 9.98). However, there was increased activity in Mani Blanco (26.69, 6.26) and No.276 (73.23 and 11.91) by 80th day, while it was decreasing in US-1 (16.11 and 2.94) and RS-113 (1.62 and 0.33). By 100th day, activities were decreasing in all the genotypes. But, at this stage also, No. 276 and RS-113 was showing higher activities over other two genotypes.

When nitrogen was applied there was a decreased activities from 60th to 80th day in all the genotypes and marginal increases from 80th to 100th day. Under Rhizobium treated condition all the genotypes showed highest activities on 60th day and progressive decrease on 80th and 100th day. Incidentally, higher specific activity was observed in US-1 and No.276 on 60th day. Under Rhizobium + nitrogen condition all the genotypes exhibited very low activity compared to rest of the treatments. Here, enzyme activity decreased from 60th to 80th day increased thereafter.

Nitrate reductase activity (NRA)

This is the enzyme responsible for the uptake of soil nitrogen. Its activity is expressed per gram fresh weight per hour (Table 74). In all the treatments and also in all the genotypes, NRA was highest at 60th day, decreased by 80th day and there was no activities at 100th day. When both the stages (60th and 80th) were considered, No.276 showed higher activity under all the four environmental conditions than the rest of the genotypes. NRA was almost same for

control and Rhizobium treatment and also for nitrogen and nitrogen + Rhizobium treatment.

Experiment IV:

Evaluation of hybrids derived from the selected genotypes

One of the purposes of the selection was to evolve a superior ideotype for the crossing programmes, in turn effecting higher heterosis in the F1 and transgressive segregants in subsequent generations. This will enable one to select the parents for any breeding programme. With these notions the four genotypes: Mani Blanco, US-1, RS-113 and No.276 were crossed in all possible combinations, viz.

Mani Blanco x US-1

Mani Blanco x RS-113

Mani Blanco x No. 276

US-1 x RS-113

US-1 x No. 276

RS-113 x No. 276

Enough hybrid seeds were obtained from these corsses and they were raised under two replications. It would be very much pertinent to evaluate the hybrids carefully, to find out which are all the character/s that have changed in the hybrids in positive or negative direction ultimately effecting significant heterosis for yield. For this purpose following characters were measured on 60th day and 80th day.

(1) Root length, (2) Shoot length, (3) Number of internodes on main branch (n), (4) Number of internodes on sub branch (n+1), (5)

length of n internodes, (6) length of n+1 internodes, (7) leaf length, (8) leaf width, (9) nodule number, and (10) NRA.

Following observations were recorded at the time of harvest, viz, shoot dry weight, root dry weight, leaf dry weight, total dry weight, leaf area and pod yield.

Heterosis over better parent (H) and best parent (heterobeltosis) (HB) for these characters under N_0 and N_2 nitrogen conditions are presented in Table 75.

The hybrids between Mani Blanco x US-1, exhibited a negative heterosis for root length, internodes on main and side branch and their lengths, leaf length and width and for nitrate reductase activity on 60th and 80th day for N_0 and N_2 conditions. The positive heterosis, exhibited for few characters either on 60th day or 80th day was marginal. The negative heterosis was most prominent from 60th to 80th day for the characters, n, n+1 internodal number, their length and leaf length under N_2 soil nitrogen condition. Similar effect was observed for NRA, under N_0 soil nitrogen condition. There was a noticeable heterotic effect (47.67) for leaf length under N_0 soil nitrogen condition. On the contrary this cross combination brought about a significant positive heterosis and heretobeltiosis for shoot length, root length, leaf dry weight, total dry weight, leaf are and final pod yield at harvest under N_0 and N_2 nitrogen conditions (Plate 1).

The hybrid progenies of Mani Blanco x RS-113 (Table 75 and 77) on 80th day showed significant heterosis for root length (N_0), length of n and n+1 branches under N_2 soil nitrogen condition. Heterosis was marginal for leaf length (N_0) and nodule number (N_2). For other

Plate 1a: Parents and F_1 of Mani Blanco x US-1 at N_0 soil of nitrogent conditon

Plate 1b: Parents and F_1 of Mani Blanco x US-1 at N_2 soil nitrogen conditon

1a

1b

Table 75 : Estimates of heterosis over better and best parent for different characters of F_1 progenies of selected parental crosses.

Crosses	Days	Root length (Cm)				Shoot length (Cm)				n-internodes			
		N_0		N_2		N_0		N_2		N_0		N_2	
		H	HB	H	HB	H	HB	H	HB	H	HB	H	HB
5 x 40	60	-14.72	-17.39	-1.75	-1.75	-11.15	-11.15	22.64	22.64	0	0	2.70	2.70
	80	-17.89	-18.32	-19.23	-19.23	-20.43	-35.70	-5.70	-5.70	-40.00	-40.00	-61.22	-61.22
50 x 42	60	45.87	41.30	-2.46	-2.46	-26.98	-26.98	8.98	7.50	0	0	-17.65	-24.32
	80	22.51	22.51	-11.11	-11.11	7.49	7.49	30.74	2.32	-10.91	-10.91	58.62	-53.06
5 x 44	60	-10.87	-10.87	-8.77	-8.77	-32.73	-32.73	-6.12	-13.21	-47.06	-47.06	-11.76	-18.92
	80	-25.79	-26.18	-50.67	-57.31	4.60	-34.55	-11.67	-23.19	-38.18	-38.18	44.83	-57.14
40 x 42	60	22.33	22.33	63.84	1.75	-36.36	-37.05	-23.55	-34.29	-35.29	-35.29	-24.32	-24.32
	80	-24.08	-24.08	-32.69	-32.69	-62.38	-62.38	-46.09	-46.09	-12.77	-25.45	-61.22	-61.22
40 x 44	60	9.57	9.57	37.73	6.32	-21.82	-22.66	-32.83	-23.53	-23.53	-23.53	-24.32	-24.32
	80	9.00	2.72	-58.08	-58.08	-7.13	-24.95	-21.74	-21.74	-65.96	-70.91	-64.29	-64.29
42 x 44	60	26.09	26.09	2.27	-21.05	-9.14	-42.81	-19.59	-19.59	-17.65	-17.65	3.06	-75.00
	80	18.85	18.85	16.67	-16.54	3.84	3.84	-1.67	-14.49	193.10	54.55	0	-63.27

Table 75 (Contd.)

Crosses	Days	Leaf width				Nodule Number			
		N_0		N_2		N_0		N_2	
		H	HB	H	HB	H	HB	H	HB
5 x 40	60	-24.72	-24.72	7.37	2.64	-23.91	-23.91	-2.11	-19.83
	80	-6.75	-6.75	-7.20	-7.20	-28.08	-28.08	-43.28	-43.28
5 x 42	60	-22.88	-22.88	5.53	0.88	-15.56	-38.04	12.63	-7.76
	80	-13.06	-15.48	-30.67	-37.50	-31.36	-60.10	20.00	16.42
5 x 44	60	-13.65	-13.65	-7.49	-7.49	-50.37	-63.59	-18.10	-18.10
	80	-6.53	-9.13	-5.88	-9.09	46.81	-32.02	-26.15	-28.36
40 x 42	60	0.81	-9.59	10.84	-0.88	-32.07	-32.07	-29.47	-29.47
	80	-14.68	-14.68	-29.17	-29.17	-90.64	-90.64	29.85	29.85
40 x 44	60	-5.67	-5.67	0.88	0.88	-41.85	-41.85	6.03	6.03
	80	5.16	5.16	-23.48	-23.48	-27.59	-27.59	-25.37	-25.37
42 x 44	60	-27.46	-34.69	-4.85	-4.85	-26.21	-58.70	7.76	7.76
	80	4.35	-12.00	-12.94	-15.91	9.32	-37.00	-30.77	-32.84

Table 75 (Contd.)

Crosses	Days	n + 1 : internode				Length - n (Cm)			
		N_0		N_2		N_0		N_2	
		H	HB	H	HB	H	HB	H	HB
5 x 40	60	-12.90	-12.90	-36.73	-36.73	-33.94	-33.94	0	0
	80	0.00	-29.63	-47.90	-47.90	-7.46	-7.46	-42.02	-43.13
5 x 42	60	0	-9.68	-12.24	-12.24	-17.61	-29.09	-20.00	-23.29
	80	35.19	-35.19	72.22	-43.31	-17.11	-17.11	-26.34	-26.34
5 x 44	60	-41.07	-46.77	-6.12	-6.12	-50.70	-57.58	-30.00	-32.88
	80	-16.67	-16.67	34.69	-60.48	-32.02	-32.02	-5.38	-32.82
40 x 42	60	-74.19	-74.19	-17.50	-32.65	-36.36	-36.36	0	0
	80	-74.07	-74.07	-64.67	-64.67	-14.10	-14.10	-22.52	-22.52
40 x 44	60	-56.45	-56.45	15.79	-10.20	-10.91	-10.91	-36.30	-36.30
	80	85.42	64.81	-7.19	-7.19	-10.55	-14.10	-42.02	-43.13
42 x 44	60	-39.29	-45.16	37.93	18.37	-55.63	-61.82	-34.29	-63.01
	80	-60.42	-64.81	140.74	-22.16	5.26	5.26	-16.13	-40.46

Table 75 (Contd.)

Crosses	Days	Length n + 1				Leaf Length			
		N_0		N_2		N_0		N_2	
		H	HB	H	HB	H	HB	H	HB
5 x 40	60	-21.67	-21.67	7.24	7.24	-29.14	-29.14	8.92	-13.20
	80	-37.61	-42.97	-56.52	-56.52	47.67	8.42	-28.44	-28.44
5 x 42	60	-21.61	-23.15	13.74	-1.97	-26.83	-26.83	31.85	26.67
	80	13.74	-1.97	5.74	-31.37	30.47	25.25	1.02	-25.42
5 x 44	60	-25.13	-26.60	17.56	1.32	-9.01	-9.01	-8.38	-8.38
	80	17.56	1.32	-8.72	-8.72	6.84	6.84	-19.10	-39.36
40 x 42	60	-45.32	-45.32	-11.18	-11.18	-2.58	-13.00	40.35	1.52
	80	-11.18	-11.18	-26.09	-26.09	18.89	1.05	-16.76	-16.76
40 x 44	60	-4.93	-4.93	17.76	17.76	-20.19	-28.72	-5.08	-5.08
	80	17.76	17.76	-54.35	-54.35	18.42	18.42	4.14	4.14
42 x 44	60	-42.11	-45.81	10.69	-4.61	-2.15	-33.12	-9.90	-9.90
	80	10.69	-4.61	-8.14	-52.80	20.00	20.00	-3.77	-27.87

Table 75 (Contd..)

Crosses	Days	NRA µ. mol/g fresh weight/hour			
		N_O		N_2	
		H	HB	H	HB
5 x 40	60	-19.35	-19.35	-34.38	-34.38
	80	-34.48	-45.71	-54.84	-54.84
	100	-23.53	-23.53	18.18	-18.75
5 x 42	60	-16.13	-16.13	-62.50	-62.50
	80	-34.29	-34.29	-51.61	-51.61
	100	-27.45	-27.45	-22.73	-46.88
5 x 44	60	-19.00	-19.00	18.75	18.75
	80	-37.93	-48.57	-38.71	-38.71
	100	-21.57	-21.57	0	-31.25
40 x 42	60	9.00	-23.00	-9.68	-12.50
	80	-54.29	-54.29	5.88	-41.91
	100	-13.16	-35.29	105.26	21.88
40 x 44	60	13.64	-19.35	-3.57	-15.63
	80	68.18	5.71	94.12	6.45
	100	-7.32	-25.49	-28.13	-28.13
42 x 44	60	14.29	-22.58	-41.94	-43.75
	80	0	-17.14	-6.45	-6.45
	100	2.44	-17.65	-46.88	-46.88

H = Heterosis over better parent
HB = Heterosis over best parent.

5 = Mani Blanco
40 = US-1
42 = RS-113
44 = No. 276

Table 76 : Means of 4 parents and 6 F_1's for biomass characters.

	Shoot dry weight (g)		Root dry weight (g)		Leaf dry weight (g)		Total dry weight(g)		Leaf area (Cm^2)		Final pod yield (g)	
	N_O	N_2	N_O	N_2	N_O	N_2	N_O	N_2	N_O	N_2	NO	N2
Parents:												
5	29.44	25.21	1.47	1.07	18.20	13.80	49.11	40.88	2093.00	1587.00	40.06	43.00
40	30.95	19.86	1.77	1.05	19.44	13.67	52.15	52.58	2235.03	1572.05	45.74	26.77
42	34.98	28.45	1.53	1.15	20.56	18.75	57.07	48.35	2364.40	2156.25	50.45	43.44
44	42.21	35.27	2.06	1.53	25.50	17.70	69.77	49.50	2932.50	2034.93	47.44	54.53
Crosses: (F_1)												
5 x 40	60.82	44.55	2.44	2.15	40.79	37.50	104.05	84.20	4690.85	4312.50	72.64	72.50
5 x 42	37.75	46.05	1.62	1.52	25.98	35.10	63.35	82.67	2987.70	4036.50	43.98	66.75
5 x 44	21.13	29.92	1.32	1.36	13.65	20.00	36.10	51.28	1569.75	2300.00	36.87	70.00
40x 42	29.18	26.10	1.75	1.33	21.17	16.20	52.10	43.63	2434.55	1863.00	50.25	50.47
40x 44	43.83	44.98	1.40	1.51	23.30	26.98	68.53	73.47	2679.50	3102.70	76.37	65.40
42x 44	51.94	53.25	1.99	1.51	41.78	33.80	95.71	88.56	4804.70	3887.00	95.00	85.00

5 = Mani Blanco
40 = US-1
42 = RS-113
44 = No. 276

Table 77 : Heterosis over better parent (H) and best parent (HB) in F1 progenies for different biomass characters.

Crosses	Shoot dry weight				Root dry weight				Leaf dry weight			
	N_0		N_2		N_0		N_2		N_0		N_2	
	H	HB	H	HB	H	HB	H	HB	H	HB	H	HB
5 x 40	96.51	44.09	76.72	26.31	37.85	18.45	100.93	40.52	109.83	59.96	153.62	100.00
4 x 42	7.92	-10.57	61.86	30.56	5.88	-21.36	32.17	-0.65	26.36	1.88	87.20	87.20
5 x 44	-49.94	-49.94	-15.17	-15.17	-35.92	-35.92	-11.11	-11.17	-46.47	-46.47	12.99	6.67
40x42	-14.29	-30.87	-8.26	-26.00	-1.13	-15.05	-15.65	-13.07	2.97	-16.98	-13.60	-13.60
40x44	3.84	3.84	27.53	27.53	-32.04	-32.04	-1.31	-1.31	-8.63	-8.63	52.43	43.80
42x44	23.05	23.05	50.98	50.98	-3.40	-3.40	-1.31	-1.31	63.84	63.84	80.27	80.27

H = Heterosis over better parent
HB = Heterosis over best parent

5 = Mani Blanco
40 = US-1
42 = RS-113
44 = No. 276

Table 77 (Contd.)

Crosses	Total dry weight				Leaf area				Final pod yield			
	N_0		N_2		N_0		N_2		N_0		N_2	
	H	HB	H	HB	H	HB	H	HB	H	HB	H	HB
5 x 40	99.52	49.78	60.14	60.14	109.88	59.96	171.74	100.00	58.81	43.98	68.60	32.95
5 x 42	14.51	-6.34	70.98	57.23	26.36	1.88	87.20	87.20	-12.82	-12.82	53.66	22.41
5 x 44	-48.26	-48.26	3.60	-2.47	-46.47	-46.47	13.03	6.67	-22.28	-22.28	28.37	28.37
40x42	-8.71	-25.33	-17.02	-17.02	2.97	-16.98	-13.60	-13.60	-0.40	-0.40	16.18	-7.45
40x44	-1.78	-1.78	39.73	39.73	-8.63	-8.63	52.47	43.89	60.98	51.38	19.93	19.93
42x44	37.18	37.18	78.91	68.43	63.84	63.84	80.27	80.27	88.31	88.31	55.88	55.88

H = Heterosis over the better parent

HB = Heterosis over the best parent

characters on 60th and 80th day heterotic effects were either negative or positive but non-significant. However, this hybrid showed higher heterotic effect for shoot dry weight, root dry weight, leaf dry weight, total dry weight, leaf area and final pod yield only under N_2 soil nitrogen condition (Plate 2).

For all the characters studied, hybrids of Mani Blanco x No.276 exhibited either negative or non-sginifcant positive heterosis throughout the growth perod for both N_0 and N_2 soil nitrogen conditions (Plate 3).

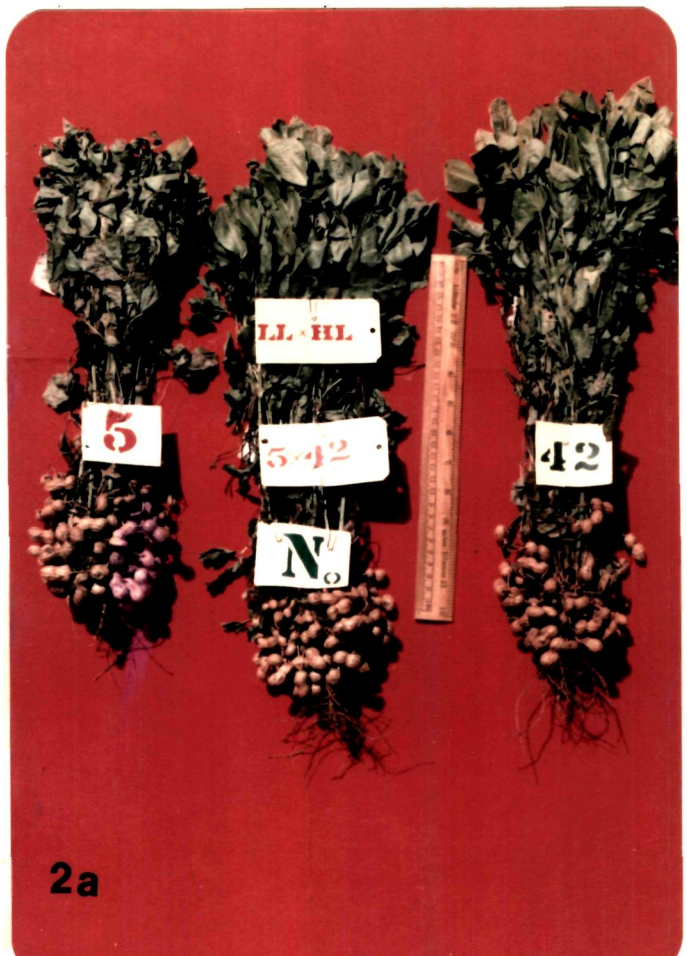
The hybrids between US-1 x RS-113 exhibited (Tables 75 & 77) marginal, positive heterosis for root length (60th day), NRA (100th day) under both N_0 and N_2 soil nitrogen conditions. For nodule number (80th day) heterosis was positive and significant only under N_2 soil nitrogen condition. Higher negative heterotic effect was noticed for shoot length (80th day), number of 'n' internodes , underN_2 (80th day) and number of n + 1 internode (60th and 80th day, N_0 and 80th day, N_2) and nodule number under N_0 (80th day).

For the hybrids US-1 x No.276 (Tables 75 & 77) significant positive heterosis was observed for number of n+1 internodes (80th day - N_0), NRA (80th day - N_0 and N_2), leaf dry weight, total dry weight and leaf area (N_2) and for final pod yield (N_0). Higher negative heterotic effect was also noticed for root length (80th day - N_2), number of n+1 internode (80th day - N_0) and length of 'n' internodes (80th day - N_2) (Plate 4).

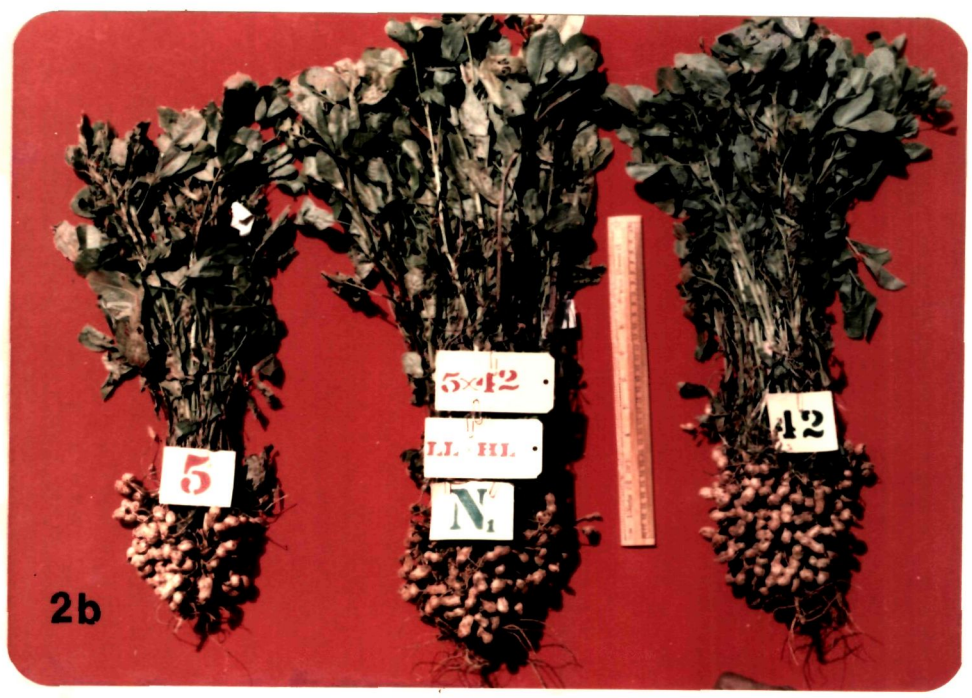
The hybrids between RS-113 x No.276 (Tables 75 & 77) effected marginal heterosis in root length (60th and 80th day - N_2) and shoot dry weight at harvest (N_0). However positive heterotic effect was highly significant for shoot, dry weight, leaf dry weight, total dry

2a: Parents and F_1 of Mani Blanco x RS-113 at N_0 soil nitrogen condition

2b : Parents and F_1 of Mani Blanco x RS-113 at N_1 soil nitrogen conditon



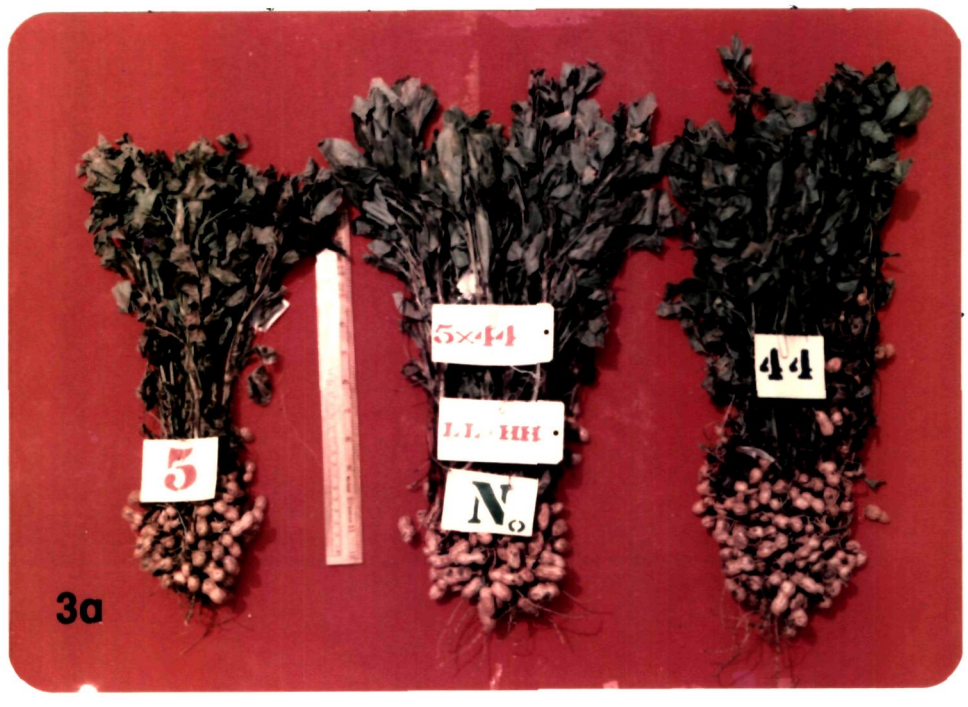
2a



2b

3a: Parents and F_1 of Mani Blanxo x No.276 at N_0 soil nitrogen conditon

3b: Parents and F_1 of Mani Blanco x No.276 at N_2 soil nitrogen conditon

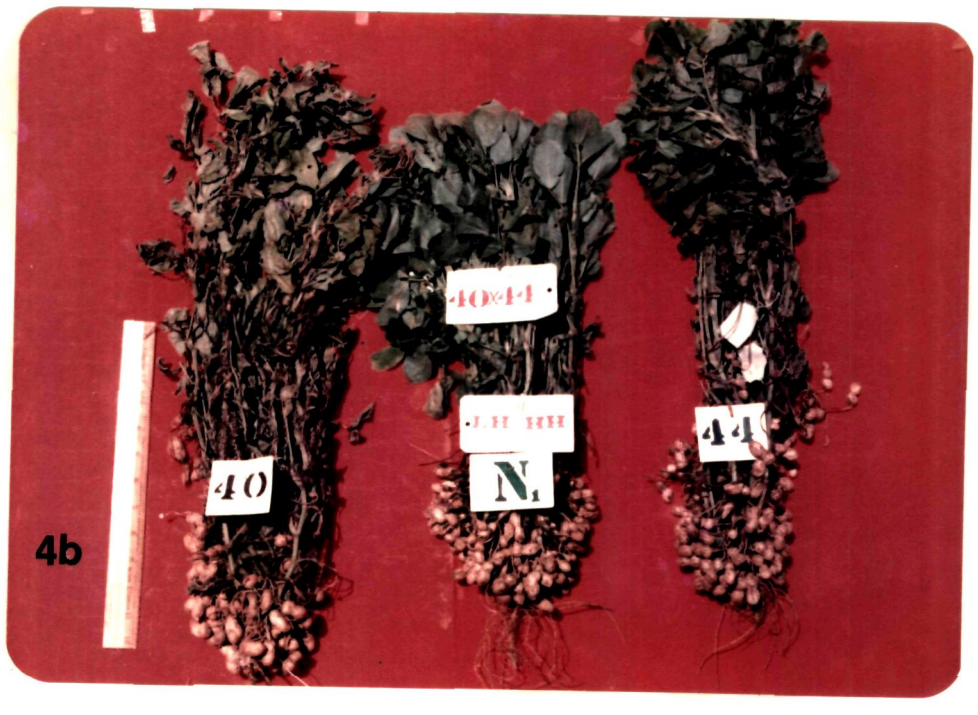

5
5×44
44
No
3a


5
5×44
44
No
3b

4a: Parents and F_1 of US-1 x No.276 at N_0 soil nitrogen condition

4b: Parents and F_1 of US-1 x No.276 at N_2 soil nitrogen condition

4a



4b

5a: Parents and F_1 of RS-113 x No.276 at N_0 soil nitrogen conditon

5b: Parents and F_1 of RS-113 x No.276 at N_a soil nitrogen condition

5a

5b

weight, leaf area and final pod yield both under N_0 and N_2 soil nitrogen conditions. For shoot dry weight higher positive heterotic effect was observed only at N_2 soil nitrogen condition. The negative heterotic effect for remaining characters were generally marginal (Plate 5).

DISCUSSION

V. DISCUSSION

The present investigation is discussed under following headings:

1. Genetic variability study of groundnut genotypes under varied nitrogen levels.
2. Evaluation of selected genotypes with respect to physiological and biochemical characters.
3. Identification of parental combinations to achieve higher degree of heterosis in F_1 and subsequent generations.

1. Genetic variability study

Improvement in any crop mainly depends on the availability of genetic variability in that crop, in the absence of which there will be no response to selection. Lack of genetic variability has been implicated in the relatively limited progress made in the improvement of pulse crops particularly in India (**Ramanujam, 1975**). Hence, the germplasm of the crops collected from diverse geographical tracts is considered to be the best source to undertake such studies. Based on this line of thinking groundnut genotypes of diverse origins - South America, Africa and India, were included and selections were exercised. The data obtained on the extent of variability in the population with regard to some of the physiological characters is briefly discussed.

Experiment I : Genetic variability studies in 97 groundnut genotypes.

None of the characters studied showed any significant variation for nitrogen levels. This does not mean that there were no genotypes responding to nitrogen application. Because of large number of genotypes involved in the study, there might be a confounding effect among the genotypes which resulted in non-significant variations. There were only few instances where relationship between plant growth and nitrogen fixation was linear (Allos and Bartholomen, 1955). In most of the cases higher available nitrogen decreased the fixed nitrogen contribution to plant's development. There were also situations where soybeans which were effectively inoculated or raised in a soil which had been under inoculation in past, did not require any additional nitrogen (**Pal** and **Saxena, 1975**). According to **Hardy** et al., **(1977)** additional nitrogen fertilization at a single time or multiple times did not appear to be an effective approach. The ineffectiveness, they attributed, is due to the compensatory decrease in nitrogen input from fertilizer nitrogen. There was also a lot of discussion regarding time of fertilizer application to legume plant. **Hera (1976)** advocated application of fertilizer nitrogen during planting to realize higher yields. Later application especially after flowering had a better effect on yield than similar amount applied at planting (**Canessa** and **Ramirez, 1984**). In the present investigation nitrogen fertilizer was added, once in 15 days, each time thrice the recommended level thus creating an unusual nitrogen richness in the soil. This toxic level might have hindered the genotypes ability to respond to a threshold level of external nitrogen.

However, when genotypes were tested for their divergence, they showed significant differences in leaf area and final pod yield

(Table 1). These two characters also exhibited higher heritability and genetic advance. The remaining two characters, neither significantly differed among genotypes nor showed any appreciable estimates for genetic parameter studied. There was a non-significant association of these characters with final pod yield (Table 2). However, one should be over-cautious in interpreting results. According to **Grafius (1959)** there cannot be any gene system for yield per se. The yield is a product of multiplicative interaction among yield components. Therefore it has been stressed that in the study of possible use of physiological features for crop improvement, it is necessary to measure a large number of physiological and morphological characters in the same population under the same environmental conditions. This will provide information on all relevant correlations (**Hobbs** and **Mahon, 1982**). Since the first experiment with 97 groundnut genotypes was just an initial evaluation, more detailed estimations were carried out during subsequent seasons, detailed discussion is postponed till then.

As indicated earlier significant genotypic differences were not observed for all the characters studied. It may be unwise to expect significant variation for all the characters studied. Many characters may not be having any direct contribution to economic yield. The present investigation did not reveal any role of shoot or leaf dry weight to economic yield. But higher dry matter production is very essential for higher yield. It is clear that main factor responsible for lower grain yields of most of the pulses are due to poor harvest index (**Jain, 1975**). Hence it may be argued that selection for improved plant type, combining a high harvest index and high dry matter production, amount to selection for economic yield. These aspects seek the

selection for individual genotype with such characters. Though the statistical analysis seldom revealed the significant variation for hitherto discussed characters of importance, it is thought of devising an approach which gives relative importance to all the characters in question while assessing the worth of a genotype. As explained earlier, mean and critical difference values were the parameters used to discriminate the genotypic worth. The use of this method can be justified on the ground that when one uses C.D. values to find out those genotypes which differ among themselves for the characters under question. Similarly here, these genotypes which differ for the characters by a magnitude of mean + C.D. and mean - C.D. are of extreme types. However, one cannot always expect the genotypes to fall in either of the two categories. Hence to cover all the genotypes studied, two more categories were framed viz, medium high and meidum low expression for the characters under study respectively.

Results of Tables 3 - 14 revealed that as soil nitrogen status increased more number of genotypes fall under 'L' and 'H' classes for leaf area and final pod yield. Leaf dry weight and shoot dry weight did not show any change across nitrogen levels. The number of genotypes falling in each category for leaf and shoot dry weight was almost same unlike leaf area and final pod yield. This was quite evident from the mean and range values (Table 15). Genotypes did not differ much in their shoot and leaf dry weight across the nitrogen enrichment. Conversely, there was significant increase in mean and magnitude of range for leaf area and pod yield from N_0 to N_1. But from N_1 to N_2 increase in mean was not so significant, showing detrimental effect of external nitrogen. However, when looked into range for these

two characters, magnitude was very high, indicating there are at least some genotypes which are responsibe to external soil nitrogen. These genotypes could be isolated if each genotype was carefully evaluated for its trait.

When all the 97 genotypes were scored for the characters, leaf area, leaf dry weight, shoot dry weight and final pod yield, there was a range from 21-36 (Table 16). Here the genotypes at the lower strata show the poor performance of genotypes, while at the other end are those with good performance for most of the characters. A more comprehensive analysis of individual genotypes was preconceived from this initial evaluation. Hence retention of maximum variability for further selection is imminent from this analysis. Consequently, genotypes were selected right from the bottom of the scoring chart (Table 16), till the top of it.

Experiment II: Genetic variability studies in selected groundnut genotypes

From the previous experiment only 50 groundnut lines were carried further for more extensive study. Main emphasis was to select genotypes which are responsive to nitrogen application and for genotypes which can withstand higher soil nitrogen. Consequently genotypes were subjected only to N_0 and N_2 soil nitrogen conditions.

Selection of superior plants or parents for breeding programme is generally done at harvesting time, more specifically for economic characters. This may not be an appropriate criterion as there may not be any gene for yield as such, but for its components (**Grafius, 1959**). To achieve a stable yield improvement, its component characters must be improved in desirable directions. It follows that a major improvement of single character may not bring desirable end results because

of the compensation mechanism occuring to other characters. Nevertheless, the process at each level of system should be considered as to whether they could be improved by breeding, bearing in mind that such improvement will only be effective in relation to all the other factors involved (**Apel, 1984**). Hence study of a crop plant throughout its life period may yield more information for breeders to manipulate the crop towards desired direction. For instance, for some legumes an increase in fixation during early development would be beneficial. For crops like soybean, an increase in nitrogen availability during flowering and pod set could contribute to increased yields. Also prolonged period of nitrogen uptake would be of value (**Hardy** et al., **1968; Weber** et al., **1971**). Hence, in this experiment observations were recorded throughout the plant growth period (60th, 80th and 100th days) on many physiological/physiomorphological characters viz., shoot dry weight, leaf dry weight, pod dry weight, total dry weight, leaf area, nodule number and final pod yield.

Analysis of variance (Table 17) for the characters did not show any significant differences for nitrogen application, confirming the results of previous experiment. This is not to say about self-sufficiency for nitrogen requirement of genotypes. According to **Harper (1974)**, 25-60 per cent of the total plant nitrogen was derived from symbiotic nitrogen fixation, the rest was soil derived. Similar conclusions were also expressed by **Postgate (1978), Fred** and **Graul (1916)**. Though groundnut comes under heavy nitrogen feeder category among oilseeds (**Aulakh** et al., **1985**), the time of application and amount of N applied might have hindered the expression of full genetic potential. For groundnut, increase in rate of application of urea

beyond 30 kg ha^{-1} did not increase yield (**Canessa** and **Ramirez, 1984**). In the present investigation 75 kg nitrogen was added once in 15 days, four such applications during life cycle of the plant, bringing the total nitrogen to 300 kg ha^{-1}. This dose of external nitrogen might have hindered the nodule development and related characters (**Streeter, 1982**). This phenomenon is clearly depicted wherein increased N application decreased the character performance Eg., for leaf dry weight mean performance from N_0 to N_2 was 8.61 to 8.3 on 80th day. Similarly for pod dry weight (5.41 to 4.21, 80th day), total dry weight (21.18-20.06, 80th day), leaf area (1404.04 - 1353.89, 80th day) and nodule number (45.51-40.46, 80th day; 63.34 - 56.36, 100th day). This is in concurrence with the results of **Pawar** and **Khuspa (1976)** and **Rabie** et al. (1979), where effect of N was not evident at the initial as well as the later stages of nodulation. There was increase in dry matter production with nitrogen enrichment of the soil. However, as pointed earlier, analysis of this type may not unravel the ability of individual genotype to nitrogen application. There are many reports on nitrogen responsive and/or tolerant legume genotypes. In soybean there are many mutant lines which showed higher nitrate tolerance (**Caroll** et al., **1985**). Similar reports are also available on Arachis hypogaea, Medicago sativa, Trifolium repens and Lotus corniculatus (**Allos** and **Bartholomen, 1955**). To identify such types, a system of scoring was done on all the characters in the present investigation, which will be discussed later.

There was significant variation (Table 17) among genotypes for shoot dry weight, leaf area and nodule number on 60th and 100th day. Pod and total dry weight showed significant differences throughout the growth period across nitrogen levels. Even genotypes were

significantly different for final pod yield. This showed that there was enough genetic variability for the physiological characters and characters related to biomass. This was in accordance with the reports of **Arunachalam** et al. (1984b). According to **Mahon (1983)**, if one considers these morphological characters, and basing a selection on this, it must have a genetic variability in its expression and it must be related to agronomic benefits, because presence of higher variability in these characters permits considerable improvement by selection.

All the genetic parameters could not be studied for all the characters, owing to higher error component associated with the analysis. However, shoot dry weight (100th day) leaf dry weight (100th day), pod dry weight (80th, 100th day) and leaf area (60th and 100th day) showed high GCV with high heritability. Except for leaf area none of the characters showed any significant genetic gains. This shows that only leaf area shows higher additive gene action. Similar observations have been drawn by **Miller** and **Zary (1981)** in cowpea and **Ganeshaiah** and **Shivashankar (1980)** in horsegram. Shoot and pod dry weight exhibited higher heritability with lower genetic advance. According to **Vishnuswarup** and **Chaugale (1962)** high heritability need not necessarily be associated with high genetic advance. According to **Panse (1957)** if heritability is mainly due to non-additive effects (dominance and epistasis), the genetic advance will be low. Hence it could be inferred that the characters, shoot and pod dry weight showed predominance of non-additive gene action. The leaf area was the only character which showed significant variation, h^2, GCV and GA throughout the growth period. Its performance was consistent across

the nitrogen enrichment and seasons (Experiment I & II). Identification of varieties with higher rate of leaf production may be a useful approach, because dry matter production is a function of leaf area and photosynthetic efficiency. High source capacity throughout life cycle of a legume diminishes the competition for photosynthate between nodules and pod. Equally important is higher leaf area at the later period of plant growth which increases per cent mature pods and pods with higher mean weight. Otherwise these pods will go as a waste for want of carbohydrate supply. The source size during the early stages of pod development determines the total and potential mature pod number. Hence, high source size during this stage of pod growth is a desirable character for higher productivity.

This significant difference in dry matter also has a lot of implication in plant improvement. In any given situation, production of dry matter is an absolutely essential prerequisite. It not only signifies photosynthetic ability in a canopy of a genotype, but also signifies other synthetic processes during developmental sequence. In groundnut such differences have been shown to exist amongst genotypes (**Shashidhar** and **Sastry, 1986**). The significance in dry matter is that, keeping harvest index constant, increase in dry matter can increase yield.

Higher nodule number across the nitrogen levels even at 100th day showed that genotypes were tolerant to higher nitrogen application. It is in the line of results obtained by **Aulakh** et al (**1985**). According to **Koermendy** and **Eaglesham (1984)**, older the plants were harvested, higher was the level of starter N required to maximise nodule number, nodule dry weight and acetylene reduction assay. This they interpreted as a large plant with a large N demand, which was met by a burst of

nodulation. Providing, inorganic N during productive period generally decreases nodule number and its activity. This leads to shorter supply of N to developing organs like shoot, leaves and pod, and equally important is the lack of response of legumes to inorganic N at this stage. To this effect, genotypes with higher dry matter and pod yield coupled with the powerful source - high leaf area for CHO and higher nodule number for N - found in the present investigation may be welcoming factors. This would bear a lot of implication for plant breeders. Legumes are generally poor yielders compared to cereal crops. This is attributed to the fact that they were generally cultivated under stress and supposed to have evolved under such conditions, where most important requirement was survival, hence the excessive vegetative growth in the preflowering stage, partitioning less to the economic parts. In order to give high yields legumes have to develope certain agronomic characters which may be of little value under competitive and stress conditions of a wild habitat or a primitive agriculture (**Harlan** and **Martini, 1938**). It is concluded that lower yields of pulses are mainly due to poor harvest index and not their poor photosynthetic capacity or dry matter production. Harvest index is very much related to source-sink relationship of a plant. Indeed, the sink in many of the pulse crops appears to be usually large when one considers flowering potential. This is equally true with groundnut plant also, which produces flower throughout its life span. But because of improper distribution of photosynthate, most of the flowers are shed and pods which do develop are only partially filled. Hence selection for improved plant type combining high harvest

index can be expected to be associated with more uniform distribution of photosynthate during the life of the plant (**Jain, 1975**).

Associated Studies

Correlation analysis of different characters at different growth periods (60th, 80th, 100th day) and nitrogen levels (N_0, N_2) revealed close inter-relationship of most of the characters studied (Table 18).

However, almost all the characters showed a significant correlation with nodule number on 80th and 100th day, but only at N_2 level of nitrogen. This is a welcome change for legume crop. Generally fertilizer nitrogen decreases nodule number. But among genotypes there was a lot of difference in nodule number. Nodules generally degenerate at the active period of pod development. However, higher shoot dry weight and leaf area with higher nodule number may be the selection criteria to identify nitrogen tolerant genotypes at this stage of plant growth. **Caldwell** and **Vest (1977)** opined that the relationship of stages of plant development and nodulation was not well understood. Additional information on the nitrogen nutrition at various stages of plant development would be of value in determining the feasibility of using applied nitrogen to supplement fixed nitrogen.

Except leaf area all other characters did not show any association with pod dry weight at 100th day, both at N_0 and N_2 soil nitrogen conditions. This is the period of pod maturity, and mostof the current photosynthate has to be channelised to pod development. Under such situations increased dry weights either shoot, leaf or total plant, generally decrease pod development, if there were no partitioning coefficient. However, here correlations of shoot, leaf and total dry weights with pod were neither significantly positive nor negative. All

the same, significant correlation of leaf area with pod dry weight at this stage is very essential, as activity of the source generally enhances percentage of mature pods.

Thus, there was enough genetic variability noticed for almost all the characters throughout the growth period. And also all these characters were significantly associated, indicating possibility of simultaneous improvement in dependent and independent characters, not exhibiting any physiological compensation. The sole aim of the experiment was to find out the responsive and non-responsive genotypes across the soil nitrogen in terms of yield and yield related characters. It can be presupposed about the types of genotypic response to nitrogen application: (a) Genotypes which are high yielders both under poor and rich soil nitrogen conditions. These genotypes must be nitrate tolerant and in addition they should respond to nitrogen application. (b) Soil nitrogen is known to inhibit nodulation and nitrogen fixation. Hence, a good performer at poor soil nitrogen status may become a poor yielder at rich soil nitrogen (N_2) condition. Such genotypes can be referred as HL, meaning high yielder at N_0 and poor yielder at N_2. (c) Contrary to previous situation, there can be a genotype having capacity to respond/absorb soil nitrogen, however yielding less or normal at poor soil nitrogen (N_0) condition. These genotypes must be inevitably nitrogen responsive which were referred as LH. (d) Finally, there might be genotypes which are inherently poor in their performance irrespective of the nitrogen status of the soil. These are referred as LL types. To identify these classes of genotypes selection was carried out on individual genotype. A system of classification based on C.D. with mean for each character was considered. Here selection was not precisely based on one or two

characters, but emphasis was laid on all the characters related to growth, nitrogen fixation and yield measured from seedling to harvest. Selection based on a single or few characters at harvest may not bring about desirable effects and most of the time effects were not repeatable. Yield is a highly complex character, and many direct and indirect yield components have been identified (**Arunachalam, 1980**). The harvestable end product is an outcome of interacting genetically controlled physiological processes which precede plant maturity (**Cregan** and **Berkum, 1984**). Hence, selection based only on one or two character may not be a stable one and compensatory mechanism may inhibit any yield improvement. Here this above mentioned method was devised to pool information each genotype, based on large number of yield and yield component characters spanning the entire growth phase of the plant. Such type of scoring (Table 58a) has helped in identifying status of the genotypes when they were arranged in ascending order.

In this Table (58a) genotypes are arranged in ascending order based on three methods of scoring. The genotypic arrangement in the first column is based on score obtained on all parameters studied throughout the growth stages (60th, 80th and 100th day) at N_0 and N_2 soil nitrogen conditions. In the second column, genotypes are arranged based on the scores obtained only on total biomass at 60th, 80th and 100th day at N_0 and N_2 soil nitrogen conditions. The last column contains the genotypic arrangement based on the scores obtained only on biomass at harvest both under N_0 and N_2 soil nitrogen conditions.

Genotypes are presented in these three methods to evaulate the effectiveness of multiple trait selection over the selections based

only on biomass during growth stages or only at harvest. Selection for biomass at harvest is the routinely followed method in plant breeding programme. Generally, goal of the plant breeder is to select a genotype having high biomass together with high harvest index. The goal is also same with multiple trait selection. However, with this type of selection additional advantage was sought regarding the stability of performance of selected genotypes.

The association studies (Table 58b) among these three methods of selection revealed that all of them were significantly correlated with one another. Subsequently, genotypes were compared for their relative positions in these three methods of selection. There is certain amount of similarity in genotypic positions in these three methods. Few genotypes consistently fall in the same quartet in all the three methods. This outcome apparently leads to a conclusion that selection for biomass at harvest is least expensive and rapid over the rest. However, to get an improved plant type together with stable character performance, a multiple trait selection throughout the growth period seems a logical approach. Such stable and improved plant type would more than compensate the advantages realised through other methods. Hence, in the present investigation multiple trait selection methodology was followed to identify desirable genotypes.

In Table 58a genotypes are arranged in ascending order. This was done to identify genotypes with poor and good character performance. Consequently, genotypic performance would be very poor, medium and superior in first, second and third, and fourth quartet respectively. All these exercises were done to identify the divergent genotypes for hybridization programme. Divergent genotypes are expected to give

higher heterotic performance in F_1 generation and trangressive segregants in subsequent generations.

From the scoring method hitherto discussed (Table 58a) genotypes are identified for their overall performance and grouped as poor, medium and superior categories. To select desirable genotypes for crossing programme from these categories, method outlined in Table 59 was followed. This method helps in identifying actual response of individual genotype from one nitrogen level (N_0) to the other level (N_2).

Pot culture experiment:

Here the four selected genotypes, viz., Mani Blanco (LL), US-1 (LH), RS-118 (HL) and No. 276 (HH) were grown under four environmental conditions under pot culture. The environments were control, applied nitrogen, Rhizobium treatment and nitrogen application along with Rhizobium treatment.

In this experiment an attempt was madeto understand the possible reasons behind the differential responses of four classes of genotypes (HH, HL, LH and LL types) previously mentioned. Out of those four classes of genotypes there were two types of responses regarding the utilization of symbiotic and soil nitrogen. There were poor performing genotypes and superior performing genotypes under N_0 and N_2 soil conditions. Answer for differential responses were studied on the following lines of thinking.

A genotype performs poorly under nil soil nitrogen condition (N_0) because:

i) nitrogen fixation was inadequate for normal plant growth and development, or

ii) genotype was genetically inferior, hence fixation was limited by plant growth, or

iii) inspite of the adequate fixation and normal plant growth there was improper distribution of plant assimilate to economic parts.

On the other hand, a genotype performs poorly under abundant soil nitrogen condition (N_2), because:

i) soil nitrogen hinders normal development and functioning of nodule, or

ii) genotype was incapable of utilizing soil nitrogen.

The whole experiment was carried under pot culture condition, inspite of the difficulty of relating the results to the field conditions. However, pot culture experiment was imminent as to control some of the environmental conditions viz., conditions free from rhizobia and nitrogen, only rhizobia or nitrogen conditions. The whole study was subjected to two way analysis of variance technique to find out genotypic difference and environmental effect.

The present study revealed the presence of variability for dry weights, leaf area, ^{14}C movements, per cent N and enzyme activities (Tables 61-66) across different environmental situations. Interestingly, genotypes did not show much difference among themselves for different characters studied. Here, significant differences were therefore specifically introduced by environment and not even by interaction effect. Earlier, there were lot of discussions on the question of whether limitation to nitrogen fixation is general lack of plant growth or is limitation to growth in inadequate fixation.

Question is quite obvious because symbiotic ability of a plant, measured in terms of nitrogen and dry matter produced may be confounded by the basic differences in their genotypic potentials. Present investigation did not show any difference in the genetic potentiality among genotypic dry weight having almost equal mean. Hence, it is reasonable to assume that the legume-Rhizobium symbiosis is nitrogen limited under optimal growing conditions. Such conclusion was also drawn by **Mytton (1976)** and **Phillips** et al, **(1981)**.

Since environment is the principal component which brings variation, phenotype rather than the genotype should be the primary objective of the breeder's attention. Mytton (1976) in his attmpet to describe phenotype from genotype supposed that if we can explain the process by which the genotypes become phenotypes this may be expected to increase the precision of the plant breeding and may also suggest new approach to plant improvement.

Association analyses (Tables 70 and 71) stressed the need for selection of plants during early part of (60-80 days) plant growth. At this time there was highest correlated response among characters studied. **Duhigg** et al. **(1978)** pointed out that plant growth provides a much better assessment of nitrogen fixation than any of the other indirect measures.

Mean performance of the genotypes:

All the four types of genotypes did not differ much in their shoot to root ratio (Table 72). This amounts to the fact that genotypic difference to different nitrogen and Rhizobium treatments has not brought about any change in the root volume relative to shoot. This is in contrary to results of **Allison** and **Ludwig (1934)** who showed

that top to root ratio in legumes increased with varying amount of available N. Even the absolute values of the root and shoot remained same, though there was an increase from 60th to 100th day. Similarly, leaf area and nodule number did not show any significant differences among genotypes within a treatment. However, there was significant increase in nodule number in all the genotypes under Rhizobium treatment. This showed that the primary effect of inorganic nitrogen is to reduce number of nodules at first place. It is in concurrence with the reports of **Streeter (1982).**

When genotypes were compared for root, shoot and leaf dry weights, along with per cent dry matter allocated to each of these parts along the growth period, it is found that, generally plants tend to maintain higher dry matter in shoots than roots or leaves. This may not be a surprise finding as plants tend to maintain higher dry matter in shoots to avoid stress and adverse climatic conditions, which is also an evolutionary outcome (**Harlan** and **Martini, 1938**). Observations on the increased sink capacity of stem with the ageing of the plant till fruiting is reported by **Lawrie** and **Wheeler (1973).** But, within each treatment genotypes are not significantly different from one another. Though nitrogen, Rhizobium, nitrogen + Rhizobium treatments enhanced dry matter production over control, however within each treatment genotypic response was one and the same except for genotype No.276. This genotype exhibited higher dry weights and nodule number at early stage (60th day) of plant growth and maintained higher score throughout the life-cycle. This might be the reason for the success of this genotype over others in maintaining higher productivity both under poor and rich soil nitrogen conditions. More interesting results

were obtained from ^{14}C translocation studies (Table 73), wherein genotype RS-113 showed higher specific activity, activity/organ and high per cent ^{14}C in pods. And No.276 showed higher specific activity, higher ^{14}C activity/organ and higher ^{14}C per cent in pods at later stages of plant life compared to Mani Blanco and US-1. This explains that though the genotypes are not much different in their physio-morphological studies, they differ in their physiological process of carbohydrate translocation. There is ample evidence that symbiotic fixation is demanding energy. Physiological investigations (**Streeter 1974; Hardy** and **Havelka, 1975**) with symbiotically grown soybeans suggested that the nitrogen fixation process is limited by carbon compounds supplied by photosynthesis. Though, this experiment was planned to seek the subtle differences among the genotypes for their differential behaviour over nitrogen enrichment from the earlier four classifications, viz., LL, LH, HL and HH, the results obtained from this experiment reduced the classification into two categories. There can be a genotype performing normally under both nitrogen and Rhizobium treatment condition (HH) or poor performance from the normal with nitrogen enrichment (HL type). Here high yield performance of No.276 and RS-113 may be due to their higher translocation of ^{14}C in developing pods. Though Mani Blanco and US-1 fixed higher ^{14}C in their shoots, root and leaves, but the assimilate translocation to developing pod was generally less. It can be suggested that high yields in No.276 and RS-113 may be due to their better sink capacity and partitioning of photosynthates compared to US-1 and Mani Blanco. Similar results are also reported by Sengupta and **Sharma (1984).** Improvement in the groundnut genotypes in the United States has been

achieved by promotion of partitioning factor during last four decades (**Duncan** et al., **1978**).

Partitioning of nitrogen to different plant parts, enzyme activities

The nitrogen accumulated by the plants as a result of its association with Rhizobium is the most direct method of measuring overall symbiotic effectiveness. Hence a reliable and accurate method of measuring phenotypic variation in nitrogen fixation is essential. In the present investigation genotypes were grown without nitrogen and Rhizobium. Then they were grown separately, only with nitrogen, only with Rhizobium, lastly in a mixture of rhizobia. It is expected to find out genotypic response only to nitrogen and Rhizobium. The differential response, if any, would have indicated whether genotypes are deprived of optimum level of nitrogen for growth and development. Higher N uptake at Rhizobium + nitrogen condition confirms the synergistic effect of NO_3- N and N_2 fixation on plant N requirement. However, selected genotypes did not show any differences for their root, shoot and leaf nitrogen within and between treatments. Nevertheless, No. 276 and RS-113 accumulated higher nitrogen in their pods than Mani Blanco and US-1. This is a welcoming feature, because in legumes, unlike cereals, remobilization of N from vegetative to reproductive parts is relatively less. However, large seed N in RS-113, and No. 276 shows that higher nitrogen harvest index. In legumes reproductive and vegetative growth compete for nutrients during more than half of the life-cycle (**Egli** and **Leggett, 1973**). Secondly, especially in groundnut more than 90 per cent of N_2 fixation/accumulation occurred during fruit formation and maturation (**Hardy** et al., **1971**). About 25 per cent of the nitrogen of each mature plant was

supplied by fixation. This suggests that a large proportion of the assimilated N in RS-113 and No.276 is utilized immediately rather than first being incorporated into leaf or stem protein, in turn saving lot of energy for the plant. Thus genotypes Mani Blanco and US-1 differ from RS-113 and No.276 in having lower nitrogen harvest index.

There are two enzyme systems, nitrogenase and nitrate reductase which are involved in nitrogen fixation and organic nitrogen uptake respectively by plants. Efficiency of both the enzymes are very essential for groundnut, as both the enzymes contribute significant amount of nitrogen to plants nitrogen reservoir. Nitrogenase, the enzyme responsible for atmospheric nitrogen fixation, showed a consistent difference between two groups of genotypes. Nitrogenase activity of No.276 and RS-113 at early (60th day) and later stages (100th day) were generally higher to that of Mani Blanco and US-1 for all treatments. However, in all the treatments, genotypes did not differ much in their dry weight accumulation. Hence, the higher nitrogenase activity is not brought about by genotypic growth differences. This is in contrary to reports of **Connolly** et al., **(1969)**. Differential nitrogenase activity in groundnut is also reported by **Nambiar** and **Dart (1983)**. The nitrogenase activity was highest for the genotypes under Rhizobium treatment than with rest of the three treatments. This confirms the earlier findings that inorganic N depresses nitrogenase activity (**Koermendy** and **Eaglesham, 1984**). The usefulness of higher nitrogenase activity in No.276 and RS-113, lies in the enhanced nitrogen supply to plants and developing pods during these periods. N metabolism at this period significantly affect the productivity of crops suggesting that the quantity and quality of grain production may be influenced by manipulating these elements. Study of activity of

second enzyme, nitrate reductase, revealed that genotype, No.276 has got higher nitrate reductase activity both at 60th and 80th day compared to rest of the genotypes studied under all treatment conditions. More than that, No.276 has got higher nitrogenous activity also. The lower absorption of organic nitrogen is characteristic of nodulated plants (**Wych** and **Rains, 1978**). However, higher nitrogenase and nitrate reductase activity of No.276 keeps it in an advantageous situations as far as its nitrogen nutrition is concerned. The genotype Mani Blanco showed lower nitrogenase activity and higher nitrate reductase activity. Since legume plants are susceptible to inorganic nitrogen, accumulation of NO_2 might be responsible for lower nodule activity as suggested by the **Becana** et al., (1985). It has been suggested that the efficiency of nitrate utilization in legumes could be improved by nodule nitrate reductase being prominent during early stages of vegetative development, when nitrogen fixation was not completely established (**Randall** et al., **1978**), and during pod filling stage, to alleviate nitrogen starvation (**Pate** and **Dart, 1961**). It seems that in genotype No.276 these characters might have been operating to sustain higher yields across nitrogen regimes.

From this pot culture experiment some of the questions which were asked could not be answered. Like for instance, relative contribution of NO_3 -N and N_2-N on legumes nitrogen nutrition. This is due to lack of a perfect controlled environment. In this investigation, there was nodule formation even in the control and organic nitrogen condition, though insignificant. Secondly from the available data it is not possible to outline conclusively, the reason for nodule suppression with inorganic N application.

Significant findings of this experiment help to outline how a genotype can be a high yielder under both nitrogen poor and rich soil conditions. There are genotypes which have got the inherent capacity to put higher dry matter production, higher carbon and nitrogen translocation to developing fruits.

Though much effort was gone into this experiment to get a comprehensive idea about differential responses of genotypes to varied soil nitrogen conditions, the results obtained were not encouraging. Unlike field experiment data, all the four genotypes were having an equal biomass production throughout growth period. Plants were raised in pot culture in a sterlized perlite-sand mixture. They were adequately nourished with nutrient solution. Then, the lack of growth differences exhibited by the genotypes might be due to the use of unsuitable growth media or inappropriate combination of components of growth media. Hence, any conclusion drawn by this experiment subjects itself to above said limitation.

Only two points were highlighted by the whole experiment. Genotype expression for nitrogen fixation/utilization was greatly influenced by Rhizobium and nitrogen conditions. This is evident by the significant variations observed among environments. By thesmselves genotyps did not show any differences. Then, the poor and superior performance of genotypes under N_0 and N_2 is not solely due to their intrinsic superior/inferior genetic make up for growth. It amounts to say that nitrogen fixation/uptake is not limited by plant growth.

Secondly genotypes can be distinguished based on their enzyme activity and assimilate translocation. The poor performing genotypes Mani Blanco and US-1 showed lower nitrogenase activity and lower nitrogen and carbohydrate accumulation in pods than RS-113 and No.276

both at N_0 and N_2 nitrogen levels. However, genotypes did not differ much among themselves regarding uptake of soil nitrogen (NRA activity). Hence, poor yield of Mani Blanco and RS-113 at N_0 and N_2 soil nitrogen might have brought about by lack of adequate nitrogen fixation and limited supply of carbohydrate for nitrogenase activity. On the contrary, RS-113 and No.276 maintained higher nitrogenase activity both under N_0 and N_2 soil nitrogen conditions. There was higher rate of carbohydrate movement to nitrogenase activity. Thus, high yield or poor yield of genotype is limited mainly by amount of nitrogen fixed under N_0 and N_2 soil nitrogen conditions. Applied nitrogen decreases yield performance purely by inhibiting nitrogenase activity and affecting assimilate transport to developing sink.

Heterosis and heterobeltiosis observed in F_1 progenies of selected parents

Hybridization and stabilization of new lines by self-pollination during selection is of course a regular means whereby plant breeders construct new genotypes with desired combination of properties. At the outset, then, one must have sufficient genetic variation in the relevant characters. Genetic collection of peanuts in the current investigation exhibited sufficient variation for biological nitrogen fixation related characters at different stages of plant growth. Further, variations in multiple characters were used in selecting plants (parents) of low, medium and high performance for the economic yield. Efficiency of such selection method in choosing parents for hybridization can be judged by the extent of transgressive segregation realized from crosses.

Towards this understanding, heterotic effects were studied for different morphological/physiological characters among F_1 progenies of crosses Mani Blanco x US-1, Mani Blanco x RS-113, Mani Blanco x No.276, US-1 x RS-113, US-1 x No.276 and RS-113 x No.276.

Heterosis and heterobeltosis are presented in Table 77. None of the cross combinations showed any consistent heterosis or heterobeltosis, for root length, shoot length, leaf length and breadth. This shows that all the F_1 plants are of compact type. Even for NR activity there was no heterosis. Such results are also observed by **Mishra** et al., **(1980)**. They could not obtain any heterosis when high NR parent was crossed with either low or medium parent.

However, when F_1 progenies were tested for their yield and biomass, there was some significant heterotic effect. We can classify the four genotypes into three categories: Mani Blanco in low performing category, US-1 and RS-113 in medium category and No.276 in high performing category. The cross between Mani Blanco x US-1 (low x medium) exhibited significant heterosis and heterobeltosis effect in shoot dry weight, root dry weight, leaf dry weight, total dry weight, leaf area and final pod yield both in N_0 and N_2 soil nitrogen conditions. Similar heterosis and heterobeltosis were also noticed for the progenies of RS-113 x No.276 (medium x high) except for root dry weight. This indicates that higher heterosis is realized only when parents do not diverge too much for their characters. Crosses from the categories medium x medium (US-1 x RS-113) or Low x High (Mani Blanco x No.276) did not show any significant heterosis for the biomass and economic yield. This is contrary to reports of **Langham (1961)**, who

advocated in high low method of crop improvement, where extremely divergent crosses should yield higher heterotic combination. In the present context only parents of intermediate divergence showed high F_1 heterosis. Such reports are also observed by **Prasad** and **Arunachalam (1983)**. Transgression of F_1 heterosis does not always occur when divergent lines are crossed (**Cr** **s, 1966;** **Arunachalam** et al. **1984a**) opined that it is not logical to advocate the use of extremely divergent parents to obtain heterotic combination. The observation of **Timothy (1963)** that heterosis could not be a measure of genetic divergence might explain absence of heterotic effect in extremely divergent cross of Mani Blanco x No.276. Explanation for such outcome rests on mutual cancellation of components of heterosis. Thus one would see while heterotic crosses would, in general, entail parental diversity, crosses between genetically diverse parents need not necessarily result in heterosis. According to the observations of **Sukanya** - (personal communication), who is carrying these material for their performance in F_2 and subsequent generations - the crosses Mani Blanco x US-1 and RS-113 x No.276, which gave highest heterosis for yield and biomass characters also gave higher F_2 means confirming the validity of F_1 heterosis. These higher F_2 means of crosses Mani Blanco x US-1 and RS-113 x No. 276, indicates that these improvements might have been brought about by additive x additive gene actions.

The F_1 progenies of cross Mani Blanco x US-1 showed heterosis for biomass characters and yield only at rich (N_2 levels) soil nitrogen condition showing essentiality of organic fertilizers for higher productivity. There was another cross between US-1 x No.276, which showed high heterotic estimates for yield at poor (N_0 level) soil nitrogen

condition. However, these F_1 progenies showed higher heterotic effect for leaf dry weight, total dry weight and leaf area at N_2 level of nitrogen. There is no immediate explanation forthcoming for such expressions. According to **Cregan** and **Berkum (1984)**, such expressions are quite possible to occur. In the short term experiments unanticipated physiological difficulties may arise as a result of combining traits from divergent genetic backgrounds, and therefore physiological/biochemical selection is unlikely to produce immediate increase in crop productivity. Secondly, whole study was based on 97 groundnut genotypes, which may not be indicative of the variation available within a species of groundnut itself.

All these experiments enivsage that considerable variability exists in quantitative physiological characters and fundamental physiological processes in groundnut genotypes across soil nitrogen status. In this investigation an effort was made to identify groundnut genotypes for optimum response to low and high soil nitrogen input conditions. Such efforts should be worth rewarding if it were operated at the appropriate environments, as symbiotic process is sensitive to slight changes in the environmental conditions.The present investigation also throws some insight into the usefulness of selection method based on multiple characters over one or few characters. It is quite a common approach in breeding efforts to select plants either only for final economic yield or for one or two characters which show correlated response for nitrogen fixation. This approach may mislead the breeder more often than expected. To quote some of the instances observed in these experiments, it has been observed that higher dry weights and leaf area enhanced yield under field conditions of some

genotypes over others. When plants with poor and higher dry matter were tested in the pot culture experiments, they did not differ much in their dry matter production. But they are differing in their carbohydrate and nitrogen partitioning to economic parts and in their enzyme activities. Secondly, it is advocated that NR activity could be used as a selection criterion. However, in this case, poor yielder Mani Blanco showed higher NR activity which is on par with high yielding genotypes RS-113 and No.276. Thus, genotypes that have high NR, do not necessarily give more dry matter or reduced nitrogen as observed by **Sinha** and **Nicholas (1981)**. It was suggested that NR activity in combination with high leaf area potential could provide better opportunity to harness high nitrogen harvest index. Problem is equally true with nodule number. Though increased nodule number seems to increase N_2 fixation, this need not always be the case. **Nutman (1959)** observed that nodule number was not an indication of amount of active tissue. Yet another situation is higher nitrogenase activity as an indication of higher N_2 fixation in turn affecting yield enhancement. However, one can not dwell completely on nitrogenase activity as a selection criterion to achieve higher productivity. It is shown that nitrogenase activity per se and also relative to nitrate assimilation requires lot of energy (**Bergersen, 1971**). Consequently nitrogen fixation could be limited by want of photosynthate supply (**Sinha, 1973; Hardy** and **Havelka, 1975**). Therefore, while improving nodulation capacity, it must be kept in mind that increased nitrogen fixation could be realized only when provision for increased photosynthetic rate is made as in the genotypes RS-113 and No. 276.

Therefore, unless one knows in detail, an effect of a particular trait on yield, the measurement of only one physiological or

biochemical trait is probably not a reliable estimate of the harvestable end product because of confounding effects or physiological and biochemical compensation among the characters. This can be augmented, as revealed by the present investigation, by an approach which envisaged estimation of harvestable end products with many related physiological and biochemical processes which preceded plant maturity. Incidentlly, plant breeding programme of this nature resulted in genetically enhanced plant productivity. Finally, such an approach permitted the identification of parents with exceptional levels of specific parameters to be followed by hybridization and continued selection to combine, these traits into one unique genotype as in the case of F_1 genotypes of Mani Blanco x US-1 and RS-113 x No.276.

The entire investigation highlights the following points with respect to nitrogen fixation at varied nitrogen levels to enhance economic yield:

1. Selection for symbiotic and yielding ability of a legume genotype should be carried across the environment in which it is intended to grow.

2. It is more rewarding, if selection is carried on multiple characters related to yield than on one or few characters, to avoid physiological/biochemical/genetical compensation.

3. Higher heterosis and transgressive segregants can be realized in crosses of medium divergence to that of extreme divergent crosses.

4. The expression of seed yield is the product of components which individually may or may not display heterosis (**Boyce, 1948**). From these statements, it would mean that heterosis for seed yield should be reflected in individual components of yield. Heterosis for biomass and leaf area gave transgressive segregants for the yield.

SUMMARY

VI. SUMMARY

Legumes are unique among the crop plants having the capacity to fix atmospheric nitrogen. However, depending on the legume species, rhizobial strain, these plants require soil nitrogen varying from 25-60 per cent to realize higher economic yield. But higher soil nitrate status, generally hinders symbiotic function on one side, and many a times plant species are not responsive to inorganic N.

Present investigation was carried out with a legume species groundnut (Arachis hypogea L.) with following objectives.

1. To find out extent of genetic variability present in the groundnut germplasm for low and high nitrogen input conditions.
2. Selection of poor and better performing genotypes under low and high soil nitrogen input conditions.
3. To elucidate physiological and biochemical basis for such variation.
4. Identification of best cross combinations among crosses of selected parents to combine effective symbiotic nitrogen fixing and related traits to evolve transgressive segregants.

Towards these objectives, 97 groundnut genotypes of diverse origin were evaluated during 1984 summer season in poor and high soil nitrate conditions for their yielding ability in a split-plot design. In the experiment, three nitrogen levels (N_0, N_1 and N_2) were taken as whole plot treatment and genotypes were treated as sub-plot treatment. Observations were scored on shoot dry weight, leaf dry weight and leaf area at 60th day and final pod yield at harvest. Genotypes did not show any significant differences for nitrogen levels. However, there was significant difference among genotypes for leaf area and final pod

yield at sub-plot level. Association analysis revealed significant association among shoot dry weight, leaf dry weight and leaf area. But with final pod yield only leaf area showed significant association at highest soil nitrogen level (N_2).

This was an initial evaluation of genotypes. A system of classification was formulated to select diverse genotypes from among 97 groundnut genotypes for next season. The system was based on mean of 97 groundnut genotypes for a particular character and the critical difference (C.D.) value. This system enabled to assess the worth of a genotype when many characters were considered. In this system, genotypic performance was classified as superior performance (H), medium high performance (M_1), medium low performance (M_2) and very poor performance (L).

These performances viz., H, M_1, M_2 and L were assigned a score of 4, 3, 2, and 1 respectively. Later, total scores obtained on inidividual genotype were arranged in ascending order to know the relative position of 97 genotypes for their overall performance for the observed characters. To maintain enough diversity for next selection cycle, genotypes were randomly selected right from very poor performance till the highest performance from the scoring chart.

Second cycle of selection with 50 selected groundnut genotypes was a duplication of the previous one. However, here more number of characters were observed at 60th, 80th and 100th day at nil soil nitrogen condition (N_0) and applied nitrogen condition (N_2). Whole experiment was laid out in split-plot design taking two nitrogen levels (N_0 and N_2) as main treatments and 50 groundnut genotypes as sub-plot treatments.

Nitrogen levels (main-plot treatments) did not show any significant difference between them which was also observed in the first season experiment. This might be due to confounding effect brought about by increasing and decreasing response of genotypes to applied nitrogen. Toxic level of soil nitrogen also might have played a role in such type of response.

From this experiment, genotypes which were showing differential response to nitrogen were selected as parents. These differential responses were classified as: (i) genotypes showing poor response both under nil nitrogen (N_0) and abundant soil nitrogen (N_2) condition (LL types), genotypes showing poor response at N_0 and good performance at N_2 (LH types), genotypes showing good performance at N_0 and poor response at N_2 (HL types) and lastly good performance of genotypes both under N_0 and N_2 conditions (HH types).

While selecting genotypes for previously mentioned classes, performance of a genotype was assessed taking into consideration many traits over 60th, 80th and 100th day of growth period. Assessment was made considering mean performance of the genotype and C.D. values of a character. Most of the characters included for multiple trait selection viz., shoot dry weight, leaf area, total dry weight, pod dry weight and nodule number were significantly differing among genotypes at 60th and 100th day observations.

In the third phase of the experiment selected four genotypes - Mani Blanco (poor performance at N_0 and N_2), US-1 (poor performance at N_0 and good performance at N_2), RS-113 (good performance at N_0 and poor performance at N_2) and No.276 (good performance both at N_0 and N_2), were grown in pot culture condition. All these genotypes were

subjected to following four environmental conditions - control, Rhizobium, applied nitrogen and simultaneous application of fertilizer nitrogen and Rhizobium Observations were recorded throughout the growth period (60th, 80th and 100th day) on biomass yield, ^{14}C translocation pattern, nitrate reductase and nitrogenase activity.

Genotypes did not show much differnce for biomass production throughout growth period. There was also not much difference in the activity of nitrate reductase. However, genotypes No.276 (HH type) and RS-113 (HL type) exhibited higher nitrogenase activity and, ^{14}C and nitrogen translocation to economic part compared to Mani Blanco (LL type) and US-1 (LH type). Though genotypes did not show any significant difference among themselves, they do differ significantly across environments. Much inference could not be drawn from this experiment owing to failure in getting genotypic differences under pot culture.

Four selected genotypes (Mani Blanco, US-1, RS-113 and No.276) were crossed among themselves to assess the worth of selection of parental genotypes based on many traits at a time. And secondly, to identify the parental combination which gives higher heterotic effect. Observations were recorded on biomass characters, morphological characters and on nitrate reductase activity.

None of the cross combinations showed any significant positive heterotic effect for morphological characters studied and for nitrate reductase activity. However, F_1's of Mani Blanco x US-1 and RS-113 and No.276 showed significant heterotic effect for biomass characters and pod yield both at N_0 and N_2 soil nitrogen conditions as shown below:

	Mani Blanco x US-1 (per cent heterosis)		RS-113 x No. 276 (per cent heterosis)	
	N_0	N_2	N_0	N_2
1. Shoot dry weight	99.52	60.14	23.05	50.98
2. Root dry weight	109.88	171.74	-3.40	-1.31
3. Leaf dry weight	58.81	68.60	63.84	80.27
4. Total dry weight	96.51	76.72	37.18	78.91
5. Leaf area	37.85	100.93	63.84	80.27
6. Final pod yield	109.83	153.62	88.31	55.88

The F_1's of Mani Blanco x US-1 showed significant heterotic effect only at N_2 soil nitrogen condition for all biomass characters.

It was noticed that parents with medium divergence viz., Mani Blanco and US-1 (both of poor performance type) and RS-113 and No.276 (both of good performance type), exhibited higher heterotic effects in F_1. Secondly, parents selected based on the performance of many characters resulted in higher heterotic expression for these characters, at least in some of these crosses. These crosses gave lines of higher mean performance in the F_2 generation also.

The entire investigation revealed following information:

1) Groundnut genotypes exhibit significant variation for shoot dry weight, leaf area, nodule number and pod dry weight along different soil nitrogen condition. Highly variable characters also have got a good correlation with economic yield.
2) Then, simultaneous improvement of yield and yield related characters might be an answer to select a genotype for stable performance. Hence, multiple trait selection appears more reliable than selection based only on one or two characters.

3) Nitrogen fixation process is highly sensitive to change in environmental conditions, viz., soil with and without Rhizobia, and with and without fertilizer nitrogen. This was observed in the pot culture experiment using groundnut genotypes Mani Blanco, US-1, RS-113 and No.276. Hence, it is advisable to exercise selection in an appropriate environment to get desirable type. Here groundnut genotype No.276 and RS-113 are suitable both for nil and applied nitrogen conditions. While genotype US-1 can perform better only under applied nitrogen condition.

4) In the pot culture experiment genotypes Mani Blanco, US-1, RS-113 and No. 276 did not show any morphological differences. However genotypes No.276 and RS-113 had higher nitrogenase activities and better translocation capacity from source to sink. Hence, selection methods based on combined morphological and physiological characters may yield stable genotype of predictable performance.

5) Parents with medium divergence like Mani Blanco x US-1 and RS-113 x No.276 exhibited heterotic effect for yield and yield attributing characters and higher mean progency performance in F_2 generation.

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Original not seen.

APPENDIX

APPENDIX - I

List of the groundnut genotypes used in the experiment

Sl. No.	ICG No.	Identity	Origin	Botanical type
1.	3455	RS-60	India	Spanish
2.	3773	No. 243	India	Sp
3.	3769	Natal Common	S. Africa	Sp
4.	3752	Russian International-2	USSR	Sp
5.	3402	Mani Blanco	India	Sp
6.	3387	KG-61-99	India	Sp
7.	3379	JH-313	India	Sp
8.	3440	R-4	India	Sp
9.	Non-nodulating	NC.17 x PI 259747	India	Sp
10.	3383	K-71	-	Sp
11.	3568	28-8-2	India	Sp
12.		TMV-2	India	Sp
13.	1860	A-17-1700	India	Val.
14.	1933	EC-161297	Argentina	Val.
15.	3783	EC-20957	China	Sp
16.	3785	EC-21128	Zaire	Sp
17.	2157	U2-12-6	Sudan	Val.
18.	3372	JH-133	India	Sp
19.	3607	Jatuti	India	Sp
20.	3729	No. 53	India	Sp
21.	1290	Ah-7986	Argentina	Val
22.	1290	RB-1	India	Sp
23.	1318	G-0173	India	Sp
24.	3714	Ah-811	Argentina	Sp
25.	3464	S-277	India	Sp
26.	3606	Exotic-7-3	India	Sp
27.	3437	Pollachi-1	India	Sp
28.	3489	Tej Amra Local	India	Sp
29.	1392	U2-1-25	Sudan	Val
30.	1824	EC-21032	Zaire	Val
31.	3738	EC-21081	India	Sp
32.	3422	NG-337	India	Sp

Appendix - I (Contd.)

Sl. No.	ICG No.	Identity	Origin	Botanical type
33.	3721	Ah-39	China	Sp
34.	3370	JH-107	India	Sp
35.	3092	Ah-1716	India	Val
36.	3491	TG-3	India	Sp
37.	3500	TMV-7	India	Sp
38.	3382	K-35	India	Sp
39.	3408	Manfredi-118	Argentina	Sp
40.	3504	US-1	USA	Sp
41.	3148	Almel No.1	India	Val
42.	3771	RS-113	India	Sp
43.	3478	Spanhoma	USA	Sp
44.	3772	No. 276	India	Sp
45.	3387	KG-61-99	India	Sp
46.	3475	Spanish-5	India	Sp
47.	1966	EC-24447	Vemezie;a	Val
48.	1384	U-2-1-13	Tanzania	Val
49.	3716	EC-16674	China	Sp
50.	3462	S-196	India	Sp
51.	1783	EC-1753	Kenya	Val
52.	3740	EC-21088	Zaire	Sp
53.	3479	Starr	USA	Sp
54.	3477	Spanish-191-1	India	Sp
55.	3399	Local Claire	Mauritius	Sp
56.	3469	Sir of Durgapur	India	Sp
57.	3466	Short-1	India	Sp
58.	3760.	Limidi-4	India	Sp
59.	3390	Khandesh	Niger	Sp
60.	3395	Limidi-4	India	Sp
61.	3448	Roiet No.3	India	Sp
62.	3742	EC-21119	Tanzania	Sp
63.	1149	A-15	-	Val
64.	1370	U-1-2-3	Argentina	Sp
65.	3114	Ah-7116	S. Africa	Val

Appendix - I (Contd.)

Sl. No.	ICG No.	Identity	Origin	Botanical type
66*.	3611	EC-106985	USA	Sp
67*.	3463	S-206	India	Sp
68*.	3788	EC-21073	Uganda	Sp
69*.	3458	RS-181	-	Sp
70.	3471	Small Pod	India	Sp
71.	3739	EC-21093	Nigeria	Sp
72.	3397	Local Alarge	Brazil	Sp
73.	3598	Dohad No.1	India	Sp
74*.	3396	Limidi-5	India	Sp
75.	3763	Khandesh	Niger	Sp
76*.	3736	Taluka Harur Local	India	Sp
77*.	3364	J-11	India	Sp
78*.	3757	EC-21164	Brazil	Sp
79.	3781	EC-16675	China	Sp
80.	1379	U-2-1-8	Zaire	Val
81.	3425	No. 53	-	Sp
82.	3452	RS-12	-	Sp
83.	3765	Mani Blanco	Argentina	Sp
84.	3758	EC-21105	-	Sp
85*.	424	NCAC-2742	Argentina	Val
86.	3404	Manfredi-84	Argentina	Sp
87.	3786	EC-21080	Zaire	Sp
88*.	3743	EC-21107	-	Sp
89.	3143	Ah-24439	-	Val
90.	3380	JH-357	India	Sp
91.	1893	S-40-DR	India	Val
92.	3767	Limidi-5-3	India	Sp
93.	3465	Sakaria	-	Sp
94*.	3381	K-3	-	Sp
95.	3516	US-16B	USA	Sp
96.	3516	US-16B	USA	Sp
97*.	1394	U-2-1-28	Senegal	Val

* = Selected for next selection cycles.

Sp = Spanish

Val = Valencia

APPENDIX - II - Bray's Solution (Bray, 1960)

Chemical	Quantity needed/litre
1. Naphthalene	60 g
2. PPO (2,5-Diphenyl oxazole)	4 g
3. Dimethyle popop (1,4-bis-2-4-methyl-5-phanyloxazoly)	0.2 g
4. Methanol	100 ml
5. Ethylene glycole	20 ml
6. 1,4,Dioxine - Using this chemical volume is made upto one litre.	

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