# EXPRESSION OF GARDEN PEA (*Pisum sativum* L. SUB. SP. HORTENSE ASCH. AND GRAEBN.) GENOTYPES IN RESPONSE TO *RHIZOBIUM* INOCULATION

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# CERTIFICATE

This is to certify that the thesis entitled "Expression of Garden pea (*Pisum sativum* L. sub. sp. *hortense* Asch. Graebn.) genotypes in response to *Rhizobium* inoculation" submitted by Miss Mary Neelima Kerketta in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN HORTICULTURE,** Post Graduate School, Indian Agricultural Research Institute, New Delhi embodies the result of ***bona fide*** research carried out under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma. I further certify that such help or information, as has been availed of in this thesis, is duly acknowledged.

4th Feb, 1992

(R.R. Sharma)
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(Mary Neelima Kerketta)

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# INTRODUCTION

Indian agriculture has reached an important juncture in its evolution, with still greater scope for improving both production and productivity. Farming is too serious a business to be left to the farmers alone, hence, a need to lend a helping hand warrants from the other supporting sectors also. To accord an overriding priority to agriculture, is essentially required to be the feature of the emerging agricultural technology in India. Thus, significant multipronged actions are needed to improve and strengthen the infrastructures essential for sustained agricultural growth to fully exploit the individual biological potential of the crop species.

Besides a thrust in production improvement in cereals & pulses, the growing awareness of the farming community has taken a new tilt by taking initiative for reaping full benefits from the ever growing demand for vegetables. Vegetables being of short duration, input mobilizing and output generating , the low risk taking, and comparatively more remunerative, attracted the attention of economically handicapped but progressive sections of the farming community. This has demanded the utilization of vast scope and the growing competitiveness for the production improvement in innovations and technology advancements. The vegetable production has thus become a lucid industry to benefit an optimum blend of quality and quantity from the vast so far untapped yield reservoir.

The family *Leguminoseae* occupies an important status in the plant kingdom, comprising a large and cosmopolitan group of about 600 genera and 1300 species (Delwiche, 1978). Inspite of diversity in plant habit many legumes, particularly those of sub-family *Papilionoideae*, have great economic and agricultural potential as source of food, and are second only to cereals (Cobley and Steele, 1976). Pea (*Pisum sativum*) is one of the important food legumes and ranks 3rd or 4th in production among the grain legumes (Famington, 1974) and consumed either as a fresh succulant vegetable or as dried seed.

The Garden Pea (*Pisum sativum* L. *sub sp. hortense* Asch. and Graebn.), one of the most popular winter vegetables , was known to human civilization from time immemorial probably because of its high nutritional values. Its uses are many but most importantly taken as a high protein food. It also contains balanced amino acid along the carbohydrates, vitamins and minerals. The nutritive analysis indicates the presence of protein 7.2 per cent, vitamin 'A' 600-3,300 I.U., thiamine 350-800 μg, riboflavin 50-250 μg, ascorbic acid 15-30 mg/100 g, calcium 20, phosphorus 139, iron 1.5, sodium 7.8 and chlorine 20 mg/100 g, respectively . As a vegetable, it is now being recognized as the most important constituent of a balanced diet, supplementing vitamins, minerals and crude fibres. According to dieticians an adult individual requires 284 g of Vegetables (green leafy vegetables 114 g, root vegetables 85 g and other vegetables 85 g) per day for maintaining proper health. In India, the per capita consumption of vegetables per day including starchy and root vegetables is only 85 g (FAO production year book, 1971). The corresponding figures for Italy, USSR, Japan, USA, UK, Canada and Australia are 595,564,523,496,449,428 and 346 g, respectively. So here lies tremendous need as well as scope to explore and strive for high production of vegetables. Garden pea belongs to the family *Leguminoseae* which plays a significant and decisive role, in the economic build up of soil environment by providing an additional supplement of the atmospheric nitrogen. No doubt, without them, the soils would present a gloomy picture of bankruptcy in the nitrogen wealth of the soil. The remark "Pulses have been the life blood of the agriculture of our country" evidently indicates their status and role in the agricultural economy of the country (Arnon, 1953). In India, about 6 million tonnes of nitrogen is removed annually from soil, whereas approximately 5.30 million tonnes is added through various agencies, of which, only 60% (3.2 million tonnes) is available for plant growth, the rest being lost through leaching and denitrification. So, the Indian soil system has all the time a negative nitrogen balance (Rangaswami 1975). Thus, the potentialities of chemical fertilizers for increased crop production has been the subject matter of investigation by many workers. Though attempts have been made to reveal the possible relationship between fertilizing nutrients and crop yield, yet many facts like its practicability and availability pose a question mark for its use and subsequent continuation. In light of this, the major shift that took place in the legume cultivation is the inclusion of artificial induction of bacterial inoculum into the soil micro community by the process of seed treatment. This proved much cheaper and affordable than the chemical fertilizers.

The discoveries of Hellreigel and Wilfarth ended the period of controversy about the existence of biological nitrogen fixation. Since then, the agronomic application of the inoculation to the leguminous crops gave definite evidence for the improved production. In discussing the possible future role of Biological Nitrogen Fixtion (BNF) in solving agricultural productivity, both basic and applied research needed to be examined. No important agricultural improvement has yet emerged from the impressive advances achieved, in basic BNF research, over the last 30 years. If anything, the gap between fundamental understanding of BNF and the farmer is growing. So, it has become an indispensable present day requirement to link the basic and the applied research efforts.

The characteristic feature of leguminous crops is their capability to establish symbiosis with the bacterium *Rhizobium*, which in conjunction with the host fixes atmospheric nitrogen. This biological contrivance has obvious implications in the nitrogen economy. Besides, being a source of fixed nitrogen in an ecosystem, it also helps in conserving the available industrially manufactured nitrogen which may be diverted for other non leguminous crops.

The limitations to the reliance on the natural symbiosis have prompted the use of artificial inoculation of selected strains of *Rhizobium*. This ensures the assured nodulation of the host for maximum nitrogen fixation. However, the success or failure of a particular introduced rhizobial strain depends not only on the ability of the strain to infect and survive but also on the properties of the ecosystem with specific effects, including various methods of the artificial inoculation of the bacterium. Thus, failure and success of expression of the introduced strain is the sum total of the interaction behaviour of all these factors. In the present study, an attempt has been made to study the nodulation pattern of the 30 garden pea (*Pisum sativum* L. *sub sp. hortense* Asch. and Graebn.) cultivars at three different growth stages, viz., pre flowering, flowering and post flowering stages. This nodulation pattern was further understood in terms of the yield expressions of the individual genotype, varying significantly with the inoculation procedure. Three inoculation methods viz., the conventionally inoculated, the pelleted without the inclusion of any bacterial inoculum and the joint application of inoculant and pelletant along with the control, were undertaken for the study. A set of six characters were selected to make out a clear picture of the expression behaviour of an individual cultivar in terms of yield.

Yield is a complex character derived from various biological, edaphic and ecological factors, working together and simultaneously with a complementary and competitive behavioural nature. The present studies were so designed to make use of the morphological frame work of an individual genotype which helped to assess its correlation with yield. Keeping this in view, it might be useful to consider information on the morphological characters that might have a direct or indirect bearing on yield. Thus a sum of 15 yield attributing characters were taken for the study to work out their associative behaviour bearing direct or indirect effects on yield.

In the present investigation, the stable high yield is one of the objectives, since, the control on optimum growing condition is very limited. With the availability of sophisticated techniques for measuring stability and its components (Eberhart and Russell, 1966 and Perkins and Jinks, 1968), it is possible to identify genotypes those have stability for high yields and to partition the gxe interaction into additive and non additive portions. Stability is an important factor to be ensured in an improved variety, which would not only help to stabilize production from location to location and season to season but also simplify immensely the task of pure seed production with high responsiveness to inputs. The present investigation includes the 30 garden pea genotypes to be tested for yield stability after understanding the importance of this diverse mechanism.

In light of the above mentioned background, the present studies were undertaken to obtain sufficient information (I) on the inoculation methods most reliable for yield enhancement, (II) on the pattern of nodulation, (III) on the plant characters those attributed towards yield through pairing or individual direct effects, (IV) on the identification of most responsive genotype and (V) on the stability of the responsive genotype.

# REVIEW OF LITERATURE

Agricultural economy depends more extensively on the quantum of biological nitrogen fixed through symbiotic association created between the bacterium *Rhizobium* and the leguminous plants which are endowed with the unique capability of trapping gaseous nitrogen. The relationship was first suggested by Hellriegel and Willfrath (1886).

It was observed that neither the plant nor the *Rhizobium* can fix nitrogen when grown separately, but, with interaction between the two, this property was acquired. This triggered a considerable interest in the plant-microb symbiosis which culminated in the isolation and identification of symbionts as *Rhizobium* by Beijerinck (1888). Energy crisis and soaring prices of fertilizers holds more significance for rhizobial inoculation, enhanced biological nitrogen fixation by the ability of the rhizobial strain to adapt to prevailing soil conditions, its population, efficiency and its persistence into the subsequent growing seasons.

Considering the importance of legume-*Rhizobium* symbiosis, a study was made to know the beneficial effects of inoculation by artificial means with pure and efficient culture of *Rhizobium*, on different growth parameters including nodulation pattern in garden peas. The literature pertaining to the interaction between the bacterial culture and the legume host and its influence on yield contributing characters was thoroughly reviewed and presented as follows.

## A: ROLE OF *RHIZOBIUM* IN AGRICULTURE:

The importance of legume in agriculture was ascertained long before the discovery of *Rhizobium* and its symbiotic association with the host plant. The Greek and the Roman writers, notably Virgil, Varro and Columella described in great detail the use of leguminous plants in green manuring in ancient agriculture. The scientific informations regarding biological nitrogen fixation started to accumulate with the beginning of modern agricultural science in the nineteenth century. Boussingult, the French Agronomist was the first to observe that the unmanured land considerably gains in nitrogen, when leguminous crop like clover is grown on it. But many scientists of that era could not accept the idea of Boussingult that legumes are capable of fixing atmospheric nitrogen. Lawes *et al*.

(1942) made an attempt to investigate into the matter of Rothamsted but they were so careful in handling the soil that they destroyed the organism, fixing the nitrogen symbiotically and thus failed to become the discoverer of the symbiotic nitrogen fixation process.

Our knowledge of natural relationship between rhizobia and leguminous plant has had a broad development. Early investigations placed emphasis on the isolation and on the biochemical characteristics and other properties of rhizobia as effective and ineffective agents. In contrast, the host plant was more or less regulated to the role of recipient of the microsymbiont or at best a reflector of the reactions that took place. As the knowledge enlarged, emphasis has gradually shifted towards the plant as the potentially dominant participant in the symbiotic complex. Two broad categories of the association invite continued researches. One of these relates to the importance of symbiotic nitrogen fixation in agriculture, the other points to new Vistas in Methodology. Towards the end of nineteenth century, the idea of symbiotic nature of bacteria and the host, was elucidated. Later on Hellriegel and Willfrath (1934) of Germany demonstrated that leguminous plants are capable of fixing atmospheric nitrogen.

## B: CLASSIFICATION OF NODULE BACTERIA:

The causative organism in the nodule fixing atmospheric nitrogen was first isolated by Beijerinck in 1888, who named it *Bacillusis redicicola*. Later on the root nodule organism was placed in a separate genus *Rhizobium* .

Allen and Allen (1958) reported considerable specificity between *Rhizobium* and legume, leading to the formation of the "Cross inoculation groups". The phenomena is expressed more specifically in the genetic relationships which must exist between plant and bacterium. *Rhizobium* functions in two ways, first as its ability to form nodules and secondly as to enhance the growth of legumes. This effect attributed to plant, is known as host specificity. Burton (1967) reported that each *Rhizobium* strain is specific and can infect only the member plants of the same cross inoculation groups. It is imperative that the correct inoculum is used for different crops as per the seven recommended groups as given by Fred et al. (1932) as follows:

| | |
|---|---|
| Alfalfa | *Rhizobium meliloti* |
| Clover | *R. trifolii* |
| Peas | *R. leguminosarum* |
| Beans | *R. phaseoli* |
| Lupine | *R. lupini* |
| Soybean | *R. japonicum* |
| Cowpea and Miscellaneous group | |

The ineffective bacterial strain are those which enter root tissue and bring about nodule formation, and effective strains are those which are able to induce nitrogen fixation and enhance plant growth (Allen and Allen, 1958). Many workers considered genetic character for ineffectiveness or effectiveness and observed that there were host plant genes which prevented the formation of effective nodules and there were genes in the bacterium which were essential for effective or ineffective nodule formation and which could be lost by nutrition or bacteriophage action. Burton (1952) found *Rhizobium* plant association as effective, moderately effective and ineffective on the basis of total nitrogen of the plant studied. Mill, (1981) noted that symbiosis of pea cultivar 'Rondo' inoculated with different strains of *R. leguminosarum* showed marked differences in N-fixing characters. N-fixation was highest with strain 'PRE' which produced a low nodular mass with a high nitrogenase activity. With this strain red nodules were located mainly on the primary roots, but lateral root nodules were steadily produced. Pea plants inoculated with strain 'S 313' produced large amounts of pink, whitish nodular mass on the primary root but virtually no nodule on the lateral roots, whereas with strain 'S 310a', the primary (red) root-nodules were replaced by large amounts of red lateral root-nodules. Pea plants inoculated with the ineffective strain 'P8' produced small white nodules predominantly on the lateral roots. All strains produced equal nodule numbers on the primary roots whereas number on lateral roots were inversely correlated to nodule weight on the primary roots. It was calculated that nodule formation is connected with nitrogenase activity,low activity being compensated for by the production of large nodules (S 313) or by the formation of many new nodules (S 310 a).

These results indicated that for successful *Rhizobium* inoculation it was of prime importance to isolate an efficient strain of *Rhizobium* specific towards a particular variety of host plant. The relative nitrogen fixing abilities of the *Rhizobium* strains can be directly compared with the dry weights without nitrogen analysis as it had been shown by Erdman and Means (1952) that a direct correlation existed between Effect of pH in *Rhizobium* establishment in soil:

## (C): INFLUENCE OF ENVIRONMENT ON RHIZOBIA:

### (1) Effect of pH on *Rhizobium* establishment in soil:

Soil reaction influences the growth and survival of rhizobia and also nitrogen uptake by the host. Mostly nodule formation takes place within narrower range of hydrogen ion concentration.

The soil reaction at its extremes frequently reduces nodule formation by reduction of colonization of soil and the legume rhizosphere by rhizobia. *Rhizobia* flourish well at slight acidic (6.5 pH) and neutral soil reaction.

It was known much earlier that slow growing rhizobia, which produce alkali on yeast manitol agar, were more likely to be adapted to acid soils than the fast growing, acid producing rhizobia (Morris, 1965). The lowest pH range was given by Fred *et al.* (1932) and Graham and Parker (1964) for the rhizobial growth as 4.0 to 6.0. Slow growing R. *japonicum*, R. *lupini* and the cowpea type rhizobia were less sensitive than fast growing strains such as *R. meliloti*. Date (1969) found that some strains isolated from *Stylosanthes* sp. growing in acid soil (pH 4.5) grew best on agar at pH 4.5 and two strains out of fifty were obligate in their requirement for low pH conditions for growth. This led the question of the ecological role of acid or alkali production of rhizobia. It was assumed that alkali production also occurred in the field and was sufficient to alter the micro environments in favour of survival of these strains under acid conditions. High acid soils often have low levels of phosphorus, calcium and molybdenum and high concentrations of aluminium and manganese. Rerka Sen (1977) has demonstrated that ability of some strains of Rhizobia to survive high aluminium concentrations at low pH values. Calcium can ameliorate aluminium toxicity in *Rhizobium*-legume symbiosis Andrew, 1976). But the interaction effect of calcium and aluminium on *Rhizobium* were also seen by Key Ser and Munhus (1979).

Acidity (pH 5.2) was also found to be preferential in favoring one strain to another. Distribution of some strains of rhizobia e.g. *R. japonicum* 135, was determined primarily by pH, occurring only in soils of pH 7.5 (Damirgi *et al.* 1967; Ham *et al* . 1971). It was also found that different phases of nodulation were acid sensitive steps (Lie, 1969). Low pH altered the competitive ability of paired strains of R. *meliloti* on *Medicago truncatula.*

Bhardwaj (1975) studied the survival and symbiotic characteristics of *Rhizobium* in saline-alkaline soils. Survival, growth and symbiotic performance of rhizobia isolated from normal saline-sodic and mildly acidic soils were studied. Rhizobia of four out of nine legumes studied for nodulation were found to be present in a highly saline-sodic soil. Majority of the strains of these bacteria did not survive in the original saline-sodic soil of pH 10.5 but as the pH was amended to lower than 10.0, all the strains survived, Virtually no difference were noticed in the survival and symbiotic characteristic nature of exotic strains of *Rhizobium leguminosarum* and *R. trifoli* in the saline-sodic soil.

Salt tolerance varied between legumes and might be classified as highly sensitive, moderately sensitive and less sensitive. Their sensitivity categories reflect 50% growth reduction at electrical conductivities of about 12,8 and 4 m·mhos/cm, respectively. Since rhizobia tolerate much higher salt concentrations than the agricultural plants do, selection for tolerance would be useful only to eliminate the odd sensitive strain (Richard, 1954; Lauter *et al.* 1981).

Kumar and Garg (1980) studied the effect of saline-alkaline conditions on nodulation in pea (*Pisum sativum* L.) and found that the variety Bonneville had a complete failure of nodulation at pH 10. It was concluded that alkalinity reduced the number and weight of the nodules with the delayed appearance of leghaemoglobin in the nodules and facilitated earlier and enhanced senescence of the nodules.

Kumar and Garg (1981) also studied the effect of shift to saline-alkaline conditions on nodulation, nitrogen fixation and growth in pea (*Pisum sativum* L.) in a said culture experiment, well nodulated pea plants were shifted to saline-alkaline conditions. Production of new nodules continued upto 35 days after shifting at a pH of 10, whereas nodulation failed if a pH of 10 existed from sowing. Increased pH (from 7 through 9 to 10) and salinity levels progressively reduced the production of nodules and growth of nodules. It also reduced production of pink pigment and enhanced greening. Nitrogen and dry matter of the plant were also found to be decreased. Siddiqui *et al.* (1985) found similar effects of salinity/ alkalinity on pea but also observed that desalinization (45 days after sowing) increased the production and growth of nodules. The production and growth of nodules during the first 25 days after desalinization was faster in the desalinized than in the control plants.

Siddiqui *et al.* (1986) further studied the salinization and desalinization effect on nodulation and nitrogen fixation in pea and gram (*Cicer arietinum* L.) and found that nitrogenase activity was more adversely affected by salt treatments than nodule fresh weight. The plant dry matter under salinity, salinization and desalinization was most closely related to the total nitrogen of the first fully expanded leaf.

## (2) Effect of Seed Coat Exudates on Survival of Rhizobia:

For the applied bacterial cells, seed coat is the immediate vicinity. Seeds of legumes as well as non legumes produce diffusible substances active against nodule bacteria by producing toxicity and thus hampering the inoculation. (Lobb, 1958; Thompson, 1960; Bowne, 1961; Thompson, 1961 Masterson, 1965).

Thornton (1929) obtained less number of nodules when the inoculated seeds were stored, the loss was greatest between 1 to 7 days of storage. This loss in viability might be due to the possibility of existence of some toxic elements on the seed surface.

Dadarwal (1968) studied the toxic effects of seed diffusates of pea, Bengal gram and green gram (*Phaseolus aureus*) on their respective *Rhizobium*. The toxicity was found to vary with the host, seed permeability and finally on the size of the bacterial population seeded on the host medium.

## (3) Temperature Effect:

Little attention has been paid to the effect of temperature after the earlier work of Jones and Tisdale (1921). The optimum temperature for the effectiveness of *Rhizobium* varied with the climate of the host plant (Gukova, 1945). He found that the nodule bacteria were more susceptible to a rise than to a fall below the optimum soil temperature. The optimum temperature for pea nodule bacteria was found to be $20^0$ C. It was found that temperature for the growth of *Pisum sativum* and for its nodule bacteria was the same. Nutman (1956) found that $24^0$ C was the optimum temperature for the root nodules of pea, soybean, red clover and alfalfa. Mes (1959) found that a rise in the soil temperature from 18,19 or $21^0$ C to 25 or $27^0$ C generally decreased the activity of nodule bacteria of *Vicia sativum, Lupins lutens* and *Pisum sativum.*

## (4) Moisture Effect

Moisture content of the soil play a vital role on the survival and efficiency of *Rhizobium*. Coltrel *et al.* (1900) observed that excessive drying due to open air caused decrease in survival rate , though a few may survive for a longer period due to hygroscopic water present around soil particles. Sen and Sen (1956) reported that out of nine cultivated soils containing *Rhizobium japonicum*, the organism survived in two, after storage in air dry condition for over 19 years. The longevity of the organism with an unaltered characteristic might be due to the presence of organic substances and for trace elements in the soil solution which protected the *Rhizobium* against desiccation. Lochhead and Thexton (1947) suggested that the minimum moisture content of the peat carrier should be 25 to 30 percent, however, moisture content less than 30 percent and more than 60 percent was reported to be harmful for the survival of rhizobia (Roughly and Vincent, 1967).

Taneja *et al.* (1980) found a decrease in growth as well as inmalate dehydrogenase activity in rhizobia-and *Azotobacter* cells due to water stress upto -2 to -4 bars. The decrease was related to the decrease in total protein of cells. Goyal *et al.* (1984) reported that water stress also affected adversely the optimum point, temperature and thermostability of the enzyme phosphatase.

Rhizobia is an aerobic organism. Hence proper aeration is essential for its successful growth and functioning. In nodule the *Rhizobium* resides in reduced oxygen tension but its reproduction in soil and survival were greatly increased by supplying free air (Fred, Baldwin and Mccoy, 1932). Mahan (1977) studied the respiration and energy requirement for nitrogen fixation in nodulated pea roots. *Pisum sativum* L. CV Tropper plants were inoculated and grown in a controlled environment on N free nutrient solution and application of N after 4 weeks as

$NH_4NO_3$, $KNO_3$ or $NH_4Cl$ were done. Rates of $C_2H_2$ reduction, root and nodule respiration, and leaf photosynthesis were determined a week later. The increase in respiration per unit of $C_2H_2$ reduction was not affected by either the form of N added or the light condition during growth, although the basal respiration rate with no $C_2H_2$ reduction increased with incidence level. The mean regression coefficient from plots of respiration versus $C_2H_2$ reduction was 0.23 + 0.04 (pZ .01) mg of $CO_2$ ($\mu$ Mol of $C_2H_2$ reduced)$^{-1}$ which was very similar to the values for the coefficient of respiration associated with nitrogenase activity estimated by subtracting growth and maintenance respiration. Since the rate of N accumulation in N free nutrient conditions was proportional to the rate of $C_2H_2$ reduction, it appears that the method gives a true estimate of the energy requirement for N fixation which for these conditions was equivalent to 17 grams of carbohydrate consumed per gram of N fixed.

## D: SEAT OF NITROGEN FIXATION:

The earlier doubts regarding the actual seat of nitrogen fixation in the leguminons plants had lately been expelled by Burris and Eppling. By $N^{15}$ and spectrometric determination they have proved beyond question that nitrogen fixation occurs exclusively in the root nodules of legumes.

Nodules may be of two kinds (1) effective nodules, that fix nitrogen, normally adequate for the plants need, (ii) ineffective nodules that fix little or no nitrogen (Thornton, 1952). The effective nodules are large, few in number and occur near the main root, whereas the ineffective ones are small, numerous and scattered on the entire root system (Hetz *et al.* 1927; Fred *et al.* 1932 and Thornton, 1949 and 1952). Effective nodules are red or pink in colour while ineffective ones are pale and white (Virtanen, 1947).

Kroulik and Gainey (1942) found a significant negative correlation between the number of nodules formed and the quantities of nitrogen fixed by a large number of strains. But Fedoror and Kozlor (1954) found that nitrogen fixation was proportional to the volume of nodules. Masefield (1955) obtained positive correlations between nodule weight and plant weight.

Khurana *etal.* (1978) studied nodulation in cluster bean, taking 32 genotypes under field condition, and the extent of variation in nodule number, nodule dry weight, nitrogen content and their correlation with seed yield. They found a direct correlation between nodule dry weight and nitrogen content. All other correlations were non significant. Rai and Singh (1979), studying chick pea found that there was no significant correlation between seed yield and the number of nodules or dry weight of nodules but yield was significantly correlated with leghaemoglobin content of nodules. Gupta *et al.* (1982) also found no correlation between number of nodules per plant or average weight of nodules per plant with nitrogenase activity in mung bean and gram. However, Nandwal and Bharti (1982), observed a negative correlation (r =-0.38) between dry weight and N-fixing efficiency of nodules in peas. Shanmugam *et al.* (1984) studying black gram and gram with respect to root nodule number, nodule dry weight and nitrogenase activity at three developmental stages, suggested that genotypes with high nitrogen fixing capacity even at the later stage (Pod developing) of growth could be selected. However, Rao *et al.* (1986) suggested that nodulation and nitrogen fixation did not appear to be correlated with seed yield in Guar and Moth.

## E: NECESSITY OF INOCULATION:

The necessity for regularly inoculating legume seed with culture of *Rhizobium* are two; first, the *Rhizobium* even if present in the soil may not be sufficient in number, secondly, although the legume may be inoculated by the soil *Rhizobium* in the absence of added inoculum, the soil strain may be inefficient (Black, 1957). Actually the success of the inoculation depends entirely on the effectiveness of the strain used for inoculation . A particular species of *Rhizobium* may contain a large number of strains, some of which are effective and some ineffective. Srivastava *et al.* (1980), regarding competition studies with *R. leguminosarum* reported that low frequency of nodulation by inoculants emphasized the necessity for developing *Rhizobium* strain with superior competitive ability against the native rhizobia.

## F: RESPONSE TO INOCULATION:

Nodulation is significantly improved following inoculation with appropriate strain of nodule bacteria. Arrazola *et al.* (1950) found that the root nodule of inoculated plants were similar to but better developed than those of uninoculated ones . Bhargava *et al.* (1974) studying response of soyabean to inoculation found that there was better nodulation and higher bacteroid and leghaemoglobin content in the nodules in case of inoculated plants, however, application of fertilizer nitrogen adversely affected the nodulation.

The nodulation pattern and yield with native and introduced rhizobia were examined by Dadarwal and Sen (1974), in different genotypes of bengal gram, pea, soybean and green gram. It was found that under similar soil and environmental conditions with similar doses of inoculum, the number of nodules produced and the efficiency of an inoculating strain varied with the genotype of the host species. Both nodulation and response to yield were found to be quantitive characters. The time of flowering and maturity of the host were not related with the efficiency.

Pahwa and Patil (1983) studied response of some pasture legumes to cowpea *Rhizobium* inoculation and noted significant increase in plant height, nodulation, fresh weight and dry weight. Twenty one lentil cultivars were tested for nodulation and grain yield with respect to native rhizobia. A significant variation in the nodulation pattern of different cultivars was noted. Marked influence of native strains was observed with local cultivars. Khurana *et al.* (1984) made an attempt to determine the relationship between seed yield component and nodulation trait of soybean. The study revealed the presence of highly significant difference between varieties, bacterial cultures and variety x culture interaction. Dry weight of nodules per plant compared to number of nodules per plant was found to be more closely related to seed yield and may be used as a selection criterion for improvement in seed yield in soybean. Sahoo *et al.* (1984) also reported increased number of nodules, plant height, green fodder yield and dry matter yield over uninoculated control of cowpea. The different varieties behaved differently to inoculation with the same strain of *Rhizobium*. Mane and Shinde (1986) studying nodulation and yield as influenced by *Rhizobium* . Seed inoculation in grain, reported a significant increase in the nodule dry weight in all the chick pea varieties tested and also found a significant increased grain yield.

## G: PATTERN OF NODULATION:

Attachment of *Rhizobium* to the legume root surface is an area of intensive research since it is thought that binding is a critical step in recognition between the macro and the microsymbionts. It is possible that specificity in attachment involves lectin, a protein, found in plant seeds and roots that can bind to specific carbohydrate moieties. Lictins may act as signals to *Rhizobium*, triggering nonreversible binding of rhizobia with fibrils and then root hair curling and infection thread formation.

Mal and Yadav (1972) studying shoot, root and nodule characters, on four plants selected at random for two varieties of guar, at five stages of growth viz., 30,40,50,60 and 70 days after sowing, found that maximum nodulation was at pre flowering stage. Top roots produced comparatively lesser but larger nodules than the root branches. The nodules began to degenerate after the onset of flowering. The root shoot ratio progressively decreased as the plant advanced in age but the leaf weight and nodulation progressively increased upto certain age of the plant after which they decreased.

During the growth of pea plants in nitrogen free media, a marked condition exists between the accumulation of labeled photosynthates in the nodules and the rate of nitrogen fixation, as measured by acetylene reduction (Lawrie and Wheeler, 1973). Nitrogenase activity, the total fresh weight of active nodules and the accumulation of radioactive photosynthates were all at a maximum just prior to flowering, when there was a rapid decline in both nitrogenase activity and accumulation of photosynthates in the nodules. This was due to the fact that nutritional demands of the reproductive processes might starved the nodules of assimilates necessary to support optimum levels of nitrogenase activity. Similar conclusions were drawn for some other species , e.g. *Vicia sativa* root nodules were most-active in fixation just prior to flowering and that removal of the flower buds resulted in continued nodule development on secondary roots. Roponen and Virtanen (1968) observed a delay in nodule sequence in *Pisum sativum* on removal of the apical flower bud, resulting in the production of abnormally large, active nodules.

Ann C Lawrie and Wheelar (1974) found that during the period from flowering to fruiting, nitrogenase activity and accumulation of $^{14}C$ -photosynthates in the nodules declined by 60% whereas the photosynthesis of the plant doubled. The acetylene reduction reached a maximum in vegetative plants of 3 weeks old and then declined rapidly with the onset of flowering and subsequent fruit development.

Pate (1958) studied the Synchronization of host and symbiotic development in the field pea, *Pisum arvense* L. and found that nodule initiation was complete at the 7 leaf stage of plant development. Peak values in total nodule numbers and nodule/ plant weight ratio occurred at this stage. Later, the regular decline in nodule numbers was offset by large increase in the size and fixation efficiency of remaining nodules.

Well defined pigment changes occurred in nodule populations. Numbers of young (white) nodule developed during primary root expansion in the 1-3 leaf stages. Haemoglobin formation was rapid in all nodules. The first developed nodules on primary roots were pigmented (red) first before cotyledon nitrogen resource were exhausted. Maximum total red nodules were obtained in the 6-8 leaf stages. The subsequent active ( red ) life of nodules varied from 8-80 days. Senescent (green) nodules accumulated on roots following extensive haemoglobin destruction in the nodule of maturing plants. Average nodule fresh weight increased some 30-50 fold during plant growth. Comparisons of the average sizes of green and red nodule population samples revealed a progressive elimination of smaller nodules throughout plant development. Nodule nitrogen and haemoglobin concentrations increased together to peak values in mid vegetative stages. Approximately 30 per cent of the nitrogen in the red nodule remained as nodules turned green in early senility. Nitrogen returns from this source were estimated at less than 3% of the fixation benefit from healthy (red) nodule activity. High nodule plant nitrogen transfer rates were recorded from red nodules from the 5-leaf stage until plant flowering.

It was concluded that besides consideration of the growing legumes as a symbiotic association, attention must be given to the welfare of the associated rhizobia and the factors affecting the establishment and function of the nitrogen fixing nodules. The factors include environmental factors (Soil temperature, Soil nitrogen and supplementation with fertilizer nitrogen, moisture, oxygen concentration and fertilizer treatment) and growth phases (particularly the establishment phase and flowering), which have significant influence on nodule initiation and development, nodule function and nodule sequence.

Shantha Kumari and Sinha (1974) suggested that nitrate reductase activity in cowpea and mung bean leaves was very high during profuse flowering stage when nodules started degenerating after 8th and 9th week of sowing. The utilization of nodular carbohydrate by the bacteria in the symbiotic association, at different stages of plant growth as studied by Singh *et al.* (1978) indicated that sucrose, glucose and fructose were the only water soluble carbohydrates present in nodules at all stages of plant growth. Khurana and Vyas (1977) studying respiratory and enzymatic activity of different dehydrogenase of bacteroid from pea as a function of plant age found that the respiratory activity of bacteroids from pea changed in a definite pattern with the age of the plant. There was a decline in the respiratory activity of bacteroid in 30day old plants with glucose, pyruvate, xylose, arabionose and α-Ketoglutarate as substrates. The maximum respiratory activity with all the substrate was observed with 44 day old plant and the value was maximum with succinate and lowest with glucose. The activity continued to decline after 44 days till 68 days. The enzyme activities increased till the plants were of 44 to 51 days age. Thereafter, the enzyme activity declined till the senescence of nodules.

Khurana and Vyas (1978) studied the biosynthesis of macromolecules in bacteriods from pea and reported that macromolecule biosynthetic ability of pea bacteriods at different plant age by radioactive incorporation revealed that DNA and protein synthesis was high in bacteroid isolated from nodules of 23-30 days old plant. Decline in the rate of synthesis was observed from 30-37 days, which remained constant upto 72 days. Further, Sinha (1978) reported that nodulation keeps pace with plant growth until flowering in cowpea, Mung bean and Bengal gram. The photosynthesis rate was higher in these crops in the seedling and preflowering stages. With the early pod development, both the nitrogen content of leaves and the rate of photosynthesis fall. Kabi and Bhaduri (1978) reported that number of nodules in tap root was maximum in colchicine induced polyploids of *Phaseolus aureus*. During the preflowering stage, total number of nodules increased in the host but it was reversed during flowering stage. Dudeja and Khandelwal (1980) reported that before the commencement of flowering, high level of glutamine synthetase activity was found in nodule cytoplasm fraction of chickpea after which the enzyme activity declined with the age of plants. Das (1982) reported maximum haemoglobin content and nitrogenase activity in root nodules of *Vigna radiata* at 30 days after sowing. Garg *et al.* (1982) also reported the maximum nitrogenase activity in cowpea (*Vigna unguiculata*) between 2 and 4 weeks after sowing.

## H:Inoculation Methods:

Various improved techniques had been devised and adopted from time to time, however the method of inoculation and handling of inoculum during seed inoculation also determines the effectiveness of rhizobia.

Simon (1907) was the first to report the use of soil as suitable carrier for *Rhizobium* and steam sterilized soil was better medium for the growth of rhizobia and he further reported that the use of nutrients like alfalfa meal, hay or sucrose incorporated in the soil culture increased the population of *Rhizobium*. Johnson (1965) found better survival of R. *meliloti* in air dried soil to which 0.5 percent manitol and some $CaCo_3$ was added. Later on the addition of liquid cultures to soil or on seed surface were experimented. Shimshi *et al.* (1967) reported that deep placement of bacterial suspension at soil depth where drying of soil was less, resulted in poorer nodulation in groundnut. Burton and Curley (1965) observed that the nodulation in *Glycine max* was highly effective when the broth culture was applied within 7 days of sowing and that no significant increase in yield was obtained with 14 and 21 days stored broth inoculation. Then,the survival of *Rhizobium* in peat was found to be greater which was due to the presence of more organic matter and high moisture absorption capacity. The electron microscope study of rhizobia in broth and peat showed that the bacteria maintained their structure similarity in lag phase and that the fibrillar matrix was found to protect the rhizobia from desiccation.

## I :SEED PELLETING:

Seed pelleting has been used as a technique for several years in agriculture (Brockwell, 1963). Pelleting includes all the ingredients which influence the survival of *Rhizobium*, like use of adhesive (Gum arabic) for sticking the culture on the seed surface, coating material ($CaCO_3$, $CaSO_4$, Gypsum) and carrier (Peat) for mixing the inoculum. The efficiency is said to be increased by pelleting. The efficiency includes survival of the inoculum, the colonization of the seedling rhizosphere by the inoculants, promptness and extent of nodulation and the nitrogen fixed by the nodulated plants. This technique was evaluated in diverse situations ; Burton (1956), Lobb (1958), Hasting and Drake (1960), Brockwell (1962), Brockwell and Whalley (1962), Goss and Shipton (1965), Murguai and Date (1965), Moorison (1966), Jones *et al.* (1967), Radcliffe *et al.* (1967), Iswaran *et al.* (1969), Cnhonkar *et al.* (1971), Jain (1972), Bhatnagar *et al.* (1981) and Jarhri *et al.* (1981)}.

Pelleting involved the wrapping of seeds, after inoculation, in a coating of Calcium (Carbonate, sulphate, dolomite) stuck with 45% Gum arabic or 5% cellofas (Methyl ethyl cellulose) or 5% pure methyl cellulose. This provides protection from the adverse pH of the soils and sufficient calcium. It was also found that small amount of the lime induced good nodulation. Lime pelleting also improved nodulation and growth during establishment and drilling reduced nodulation slightly as compared with broadcasting (Jones and Thomas, 1966; Jones *et al.* 1967; Morrison, 1966).

Norris (1967) was of the view that lime pelleting should be used intelligently and for a specific purpose, not as an act of faith. If used in the later fashion, it could result on occasions in actual harm, with less nodulation and a lower germination in return for the cost and trouble of performing the operation.

Iswaran *et al.* (1970) studied the effect of pelleting pea seeds (*Pisum sativum* L.) with phosphorus compounds on its yield and found that pelleted and inoculated seeds gave better results than unpelleted inoculated seeds. Iswaran *et al.* (1969) also studied the pelleting effect on nodulation and growth of Pea and found a significant increase in nodulation and growth over control. While studying the method of improvement of pelleting, found that the pelletant should be half the quantity of small seeded legumes and equal to the quantity of large seeded legumes. Iswaran *et al.* (1972) reported Gum arebic as the best adhesive for uniform coating. He also found the pelleted and inoculated seeds gave better nodulation than unpelleted inoculated seeds. Date (1968) had also reported Gum arabic to be the best adhesive material for survival of *Rhizobium* and firmness of pellet. It was reported that the pelleting materials Calcium carbonate, Calcium sulphate and rock phosphate showed significant increase in grain yield and nitrogen contents due to inoculation and pelleting over ordinary inoculated and uninoculated control in *Phaseolus aureus*.

Pijnenborg and Lie (1990) examined the effect of lime pelleting on the nodulation of lucerne (*Medicago sativa* L.) in an acid soil. A comparative study was carried out in the field, in pots and in rhizotrons. The nodulation was studied in soil (pH 5.2) with seed either inoculated with *Rhizobium meliloti* (R) or inoculated and pelleted with lime (RP). For comparision experiments were done in the field and in two types of Micro-cosmos, pots and rhizotrons. In the field experiments, lime pelleting improved the establishment of seedlings and augmented the nitrogen yield of the first harvest. These positive responses in plant growth were the consequences of a better nodulation on the upper 10 mm of the seedling top root. the number of seedlings carrying crown nodulation increased from 18% to 56% (RP) at 26 days after sowing. In both pots and rhizotrons, lime pelleting also increased crown nodulation; in pots from 32% (R) to 60% (RP), and in rhizotrons from 5% (R) to 90% (RP.) Rhizotrons, made of plastic petridishes allowed for continuously following early root developments and nodule formation. Crown nodulation could be measured after 14 days. Based on these experiments it was concluded ( 1) that crown nodulation was an adequate parameter to quantify the benefit of lime pelleting and (ii) that rhizotrons because of the more pronounced effects and shorter incubation time, were more suitable to study nodulation response in soil caused by the addition of Rhizobia and lime (Lie, 1969).

## J: INCREASED LOAD OF INOCULUM AND RHIZOBIAL SURVIVAL:

Inoculants contain rhizobial strains selected for their superior nitrogen fixing ability. Inoculation failure may result from subminimal levels of inoculants application (Vincent, 1958a; Date 1969). The potential value of these strains often was unmalized because the present nodules recovered from the added strain is low. Erdman (1961) stored *Rhizobium* treated seeds of vernal alfalfa, Kenl and Red clover up to 21 weeks at $5^0$ C and $25^0$ C. The count per seed remained fairly high even after 21 weeks at $5^0$ C but the number of bacteria decreased rapidly when stored at $25^0$C. It was found that 100 cells per seed was the lower limit to give satisfactory inoculation. It was also concluded that in exceptionally dry conditions following aerial sowing, the inoculum and seed coating material remained on seed of *Trifolium incarnatum* L. Johonson *et al.* (1965) recovered an average of only 5% of the nodules from the inoculation strain applied at the standard rate. Caldwill and Vest (1970) found that only 5 to 10% of the nodules were derived from inoculum introduced into the soil. A substantial range in recover,0 to 17%, is relatively low recovery value if one expects to obtain some benefit from inoculation. It may, therefore, be concluded that the naturalized population was more successful than inoculum strains in competing for the limited number of host root nodule sites. It is imperative that rhizobiologists utilize more competitive and efficient rhizobia strains or devise a technique whereby currently efficient strains are assured greater opportunity to nodulate. Approximately 500,000 Rhizobia per soybean seed is the currently recommended inoculation rate. High inoculation rates could be utilized to increase the probability of nodulation with the desired strain in soils with high naturalized population (Wade *et al.* 1972; Weaver and Frederick, 1972).

Survival was related to the size of inoculation for the first two weeks. Recovery was above the same in all treatments in the final two weeks. Population of more than $3 \times 10^4$ rhizobia /seed should give excellent nodulation. However, Burton and Curley (1965) showed that a minimum $2 \times 10^5$ rhizobia/seed was needed for good nodulation in soybean. *Dolichos lablab* required higher levels of inoculum than *Vigna sinensis*. The effect of inoculum level was also noted in adverse soil condlitions with higher number giving better nodulation (Rice, 1975). An inoculation rate of fifty times the recommended level gave rise to the successful establishment of lucerne in a semi arid region (Musgrave, 1976).

Date and Cornish (1968) pointed out a fundamental difference in survival characteristics between temperate and tropical rhizobia. The tropical organism was better to withstand the dry conditions and lost viability at slower rate than the temperate organisms. It was also found that host species had considerable influence on survival.

It was reported that higher the soil temperature at sowing depth, lower was the nodulation percentage and number of nodules per plant and it was also observed that increase in nodulation and dry weight per plant when lime and rock phosphate were used as pelleting materials. Pelleting had protective influence against 10 pH and also suppressed the effect of the toxic substances present in soil.

# J: CORRELATION AND PATH COEFFICIENT ANALYSIS FOR YIELD ATTRIBUTING CHARACTERS

Besides the interaction studies between host (*Pisum sativum* L.) and the bacterial culture (*Rhizobium leguminosarum*), a thorough study was made to know the response of individual varieties taken for the study. To sort out the varietal differences, 15 plant characters were taken for observation from germination till the plant senescence. This was in view of the earlier reports which suggest that individual genotypic responses do play role in the interaction when inoculated with a particular culture because any particular strain varied in its efficiency When used for inoculation of different varieties of the same host. Dadarwal *et al.* (1978) carried out a detailed study on varietal differences with regard to *Rhizobium* compatibility and efficiency of nitrogen fixation in chick pea and found that nodulation depends to a great extent on the host genotype. Khurana *et al.* (1984) studying the response pattern of soybean (*Glycine max* ) genotypes reported the presence of highly significant differences between varieties, bacterial cultures and variety x culture interaction.

The 15 plant characters studied were node number at which first flower appeared, days to first flower appearance, days to first green pod harvest, number of flowers per peduncle, internode length, number of primary branches, pod length, number of grains per pod, pod width, pod breadth, grain weight of 10 pods, shelling percentage, number of pods per Kg weight, average yield per plant and plant height. The literature pertaining are as follows:

Saini *et al.* (1976) found significant varietal differences for node at which first flower appeared when studying 30 pea varieties. Regarding the first flower appearance, Choudhury and Singh (1970), after evaluating 13 pea varieties found great variability for this trait with high heritabiity associated with a large expected genetic advance. Narsinghani *et al.* (1978) made a study of 65 diverse varieties of pea and found seed yield to be positively correlated with number of days to first flower appeared. Saini *et al.* (1976) studying thirty pea varieties found low heritability for first picking. Path analysis showed that days to maturity had direct effects on yield coupled with many other characters (Narsinghani *et al.* 1978). They further observed a positive correlation between days to maturity and yield. For number of flowers, Saini *et al.* (1976) found that variability (Phenotypic as well as genotypic) was minimum for number of pods per axil as compared to the other characters. Lonming (1985) observed grain yield to be highly and positively correlated with internode length. Kumar *et al.* (1965) found number of branches to be correlated with yield per plant. Singh *et al.* (1973) on the basis of path coefficient analysis suggested the existence of strong direct effect of secondary branch number on yield. Narsinghani *et al.* (1978) found positive correlation between number of branches and yield but observed a negative direct effect of number of branches on yield while studying path analysis in peas. Singh *et al.* (1978) found a significant and positive association of branch number with pod number and secondary branches in chickpea while path analysis revealed a positive direct effect on seed yield of primary branches. Kumar *et al.* (1965) found a positive correlation between fruit length and number of seeds and weight of the green pods of peas. Singh and Pratap (1968) reported the same result in peas. Teotia *et al.* (1983) reported a positive association between yield and pod length at both genotypic and phenotypic level. They also found number of seeds per pod to be positively and significantly correlated with pod length at phenotypic level. Pod width was reported by Trehan *et al.* (1969) to be highly correlated with yield. They also observed that the yield per plant was significantly correlated with number of seeds per pod. it was also found that in peas the number of seeds per pod and number of pods per node were negatively correlated. Teotia *et al.* (1983) reported that incase of garden pea, the yield was positively associated with number of seeds per pod at both genotypic and phenotypic level. They also observed that the number of seeds per pod had positive and significant correlation with length of pod at phenotypic level. It was also observed that seed yield in pea was strongly and positively correlated with pods per plant and seeds per pod. Kumar *et al.* (1965) found that weight of green seeds was positively correlated with the length of pods and weight of green pods in pea. Trehan *et al.* (1969) and Kohli (1971) also reported the same results as were reported by Kumar *et al.* (1965). However, a negative correlation was observed by Malik and Hafeez (1977) between 1000 seed weight and seed yield per plant in peas. Narsinghani *et al.* (1978) studying correlation in pea reported that yield components except 1000 seed weight were positively correlated with each other and while studying path analysis they found that 1000 seed weight had a direct effect on yield. A strong and negative correlation between yield and 1000 seed weight in pea was also found . Trehan *et al.* (1969) studied genetic variability for shelling percentage in 30 varieties of peas and found comparatively high heritability values alongwith high genetic advance. Saini *et al.* (1976) found a high heritability in broad sense for shelling percentage while evaluating thirty pea varieties . They also observed significant varietal differences for number of pods per Kilogram of sample. Malik and Hafeez (1977) suggested in case of peas that yield per plant was correlated with mean number of pods per plant (r = 0.976) and mean number of seeds per plant was correlated with mean number of 10 pods per plant (r = 0.993). Singh and Joshi (1982) studied path coefficient in pigeonpea and reported that maximum direct effect on yield was shown by pods per plant. Teotia *et al.*(1983) reported that in peas, correlation was positive between yield and number of pods per plant both at genotypic and phenotypic levels. Singh and Pratap (1968) reported that yield per plant in peas were associated strongly with the weight of green pods per plant, length of pods and number of pods per plant. Tikka and Assawa (1977) studying yield found it to be positively correlated with number of pods per peduncle, pod length and seed size. It was also reported seed yield per plant in peas to be strongly and positively correlated with pods per plant while a negative correlation was observed between seeds per pod and 1000 seed weight. Regarding plant height, Kumar *et al.* (1965) suggested that height in pea does not contribute towards an increase in yield . However, Kohli (1971) reported a high positive correlation between plant height and yield of *Pisum sativum.* Narsinghani *et al.* (1978) found that height had the direct effect on yield, on the basis of path analysis.

## K: ANALYSIS OF STABILITY OF YIELD IN DIFFERENT ENVIRONMENTS

An important aspect of crop production in general and vegetables in particular, is the stability of their yield performance over varied agro-climatic conditions. Yield stability of crop plants, probably a complex genetic trait, is ensured by the inherent ability of the genotype to perform well and be able to face fluctuating growing conditions. Stability is the measure of adaptability. Adaptation is the property of a genotype that permits its survival under selection while adaptability is the property of a genotype or a population of genotypes which permit subsequent alteration of the norms of adaptation in response to changed selection pressure (Simmonds, 1962).

Plaisted and Paterson (1959) described a procedure to characterise the stability of performance of several varieties. A combined anova over all environments was fitted and an estimate (mean of$^{-2}VC)^2$ obtained for each variety. The variety with smallest mean value of $^{-2}VC^2$ was considered as most stable. The technique, however, becomes most cumbersome with increase in number of varieties calling for $\frac{n(n-1)}{2}$ analysis.

Finlay and Wilkinson (1963) introduced the regression method which allowed a dynamic interpretation of the varietal adaptation to natural environments which could provide a basis for formulation of broad biological concepts. In this method the two parameters taken to express the varietal performance are the overall mean measured over a suitable sample of environments and the regression and environmental potentiality measured by the performance of large number of genotypes.

An improvement over Finlay and Wilkinson (1963) was made by Eberhart and Russell (1966) by adding another stability parameter, namely the deviations from regression. Breese (1969) discussed the utility of this technique in predicting relative performance of populations and hybrids over years, seasons and locations to detect differences in stability. He showed that a major part of genotype x environment interaction could be explained by differences between linear response as estimated by regression.

For parameters in a biometrical genetical model the approach is based on fitting of models which specify the contribution of genetic, environmental and genotype x environmental interactions to generation means and variances. This approach allows for contribution of additive, dominance and epistatic gene action to the genetic and interaction components in a pair of inbred lines and generations derived from the cross between them. (Bucio Alavis and Hill, 1966). This analysis allows prediction across environments as well as across generations. The conclusion drawn from this approach is that the magnitude of genotype x environment interaction is a linear function of environmental effect and this is valid for the interaction of the environment with the additive and dominance effects (Bueio Alavis, 1966, Bueio Alavis and Hills, 1966).

Perkins and Jinks (1968) have presented evidence that prediction of the slope parameters can be made both across environments and across generations. Their conclusion was that while a significant proportion of g x e component of variation was a linear function of environmental component, there was still a significant amount of g x e which remained unaccounted for by the linear regression. They examined the non-linear component by grouping varieties into homogenous groups on the basis of correlation between deviations from linear regression and reported a significant and marked reduction in the residual component of the interaction as a result of grouping the varieties.

Bucio Alavis *et al.* (1969)further extended this covering F2 and back cross generation of an initial cross between the two involved lines. It was later extended to a complete set of diallel crosses and to a triple cross data (Perkins, 1970; Perkins and Jinks, 1971)

Singh (1973) showed that the joint regression analysis can be carried out without calculation of genotypic values. Similarly grouping of populations on the basis of correlations between the residual deviations from the linear regression between pairs of populations can also be carried out using original values in place of genotypic values (Singh and Rao 1972).

The most important aspect of measuring stability concerns the determination of the potential of the environment. However, the interpretation of a set of data depends little on whether independent or dependent values are used for the index in calculating the regression slopes (Perkins and Jinks, 1973 ).

Genotype x environment (g x e) interaction has been studied extensively for yield and yield components by many earlier workers. Mehra (1974) studied g x e interaction with 46 genotypes of green gram at three locations over nine environments. It was found that most of the variation could be attributed to the differences between the linear slope of regression. Individual regression analysis revealed that a large proportion of genotypes had predictable behaviour in respect of yield component.

Singh (1976) studied the adaptability of 20 elite varieties and reported that there was no difference in response of varieties to environmental stimuli for yield. However, the linear component of g x e interaction was significant for seed size. Ramanujam (1979) and Mehra (1974) had also reported similar results for seed size.

Mehra and Ramanujam (1979) studied the stability parameters of yield and its components and the nature of association between them to understand yielding behaviour of population across environments. A major portion of g x e interaction was linear and thus predictable.

Bahl *et al.* (1980) tested a set of eight Bengal gram cultivars at a number of locations. Stability parameters were worked out for yield. Cultivars BDN-g was found to possess general adaptability. Govil (1981) evaluated one hundred thirty five genotypes of chickpea for their adaptability under six environments in different years. Individual regression analysis revealed that major portion of genotype x environment interaction was linear and thus predictable. Shah et al. (1983) evaluated 14 promising chickpea genotypes for yield at nine environments. Significant linear g x e interaction was observed. Regression coefficient ranged from 0.64 to 1.90 indicating very different environmental responses of genotypes.

Lin *et al.* (1986) reported that a genotype may be considered to be stable (i) if its among environment variance is small (ii) if its response to environments is parallel to the mean response of all genotypes in the trial or (iii) if the residual mean square from a regression model on the environmental index is small. They further suggested that the parametric approach to stability has the advantage of computational simplicity.

# MATERIALS AND METHODS

## A: MATERIALS:

### 1. SEED:

Disease free viable seeds of garden pea (*Pisum sativum* L. sub sp. hortense Asch. and Graebn) representing well established indigenous and exotic cultivars/selection lines obtained from various sources were used in this study. The cultivars and their sources are listed below in Table 1.

**Table 1: Names and Sources of the varieties**

**EARLY GROUP**

| S.No. | Variety | Source |
|---|---|---|
| 1. | Arkel | England (U.K) |
| 2. | Meteor | England (U.K.) |
| 3. | Early Badger | U.S.A. |
| 4. | Little Marvel | England (U.K.) |
| 5. | Hara Bona | Punjab Agricultural University, Ludhiana (Punjab) |
| 6. | J.P. 829 | Jawaharlal Nehru Krishi Viswa Vidyalaya, Jabalpur (M.P.) |
| 7. | Jawahar Matar-4 | Jawaharlal Nehru Krishi Viswa Vidyalaya, Jabalpur (M.P.) |
| 8. | VP-78O2 | Vivekanand Parvatiya Krishi Anusandhanshala Almora (U.P.) |
| 9. | VP-7839 | Vivekanand Parvatiya Krishi Anusandhanshala Almora (U.P.) |
| 10. | VP -8005 | Vivekanand Parvatiya Krishi Anusandhanshala Almora (U.P.) |

**MID GROUP**

| | | |
|---|---|---|
| 11. | Bonneville | U.S.A. |
| 12. | Lincoln | England (U.K.) |
| 13. | Vipasa | I.A.R.I. Regional Station Katrain Kullu Valley, H.P. |
| 14. | VL-3 | Vivekanand Parvatiya Krishi Anusandhanshala, Almora, (U.P.) |
| 15. | Jawahar Matar -1 | Jawaharlal Nehru KrishiViswa Vidyalaya,Jabalpur,(M.P.) |
| 16. | KS-123 | Chandra Shekhar AzadUniversity of Agriculture and Technology, Vegetable Research Station,Kalianpur Kanpur |
| 17. | IP-3 | G.B. Pant University of Agriculture & Technology, Pantnagar (U.P.) |
| 18. | VL-2 | Vivekanad Par~~y~~vatiya Krishi Anusandhanshala,Almora (UP). |
| 19. | Pb-88 | Punjab Agricultural University, Ludhiana, (Punjab) |
| 20. | Sel-222 | Received through NBPGR and maintained at I.A.R.I., New Delhi. |

**LATE GROUP:**

| | | |
|---|---|---|
| 21. | Early Perfection | U.S.A. |
| 22. | Selection-17 | U.P. |
| 23. | Kala Nagni | Local variety of Himachal Pradesh. |
| 24. | JP 501 | Jawaharlal Nehru Krishi Viswa Vidyalaya Jabalpur, (M.P.) |
| 25. | P-388 | Jawaharlal Nehru KrishiViswa Vidyalaya Jabalpur, (M.P.) |
| 26. | P-6587-1 | Jawaharlal Nehru Krishi Viswa Vidyalaya Jabalpur, (M.P.) |
| 27. | P-6588-1 | Jawaharlal Nehru Krishi Viswa Vidyalaya Jabalpur, (M.P.) |
| 28. | UU-2 | Agricultural Research Station, Durgapura, Jaipur (Rajasthan) |

| | | |
|---|---|---|
| 29. | UU-3 | Agricultural Research Station, Durgapura, Jaipur, (Rajasthan) |
| 30 | ACC-65 | I.A.R.I, New Delhi |

## 2. Inoculant:

Charcoal-Soil (3:1) carrier based inoculant of *Rhizobium-leguminosarum* (P-3-88) was obtained from Division of Microbiology, Indian Agricultural Research Institute, New Delhi-110012 for inoculation of pea seeds. The inoculant had a fibre of 31.0 x $10^9$ viable cells of *Rhizobium leguminosarum* (P-3-88) per gram of carrier.

## 3. Adhesive:

Sucrose (commercial grade, B.D.H. Chemical) and a preservative free, non-toxic, light coloured gumarabic powder were used as adhesives.

## 4. Pelletant:

Finely powdered gypsum (Commercial grade Calcium Sulphate, B.D.H. Chemical) was used as a pelleting material.

## 5. Soil:

The soil of the experimental field was alkaline in reaction and had low contents of organic matter, nitrogen and available phosphorus. However, availability of potash was good.

## 6. Fertilizer:

Single super phosphate ($P_2O_5$ 17%) and urea (47% N) obtained from local market were used for soil enrichment.

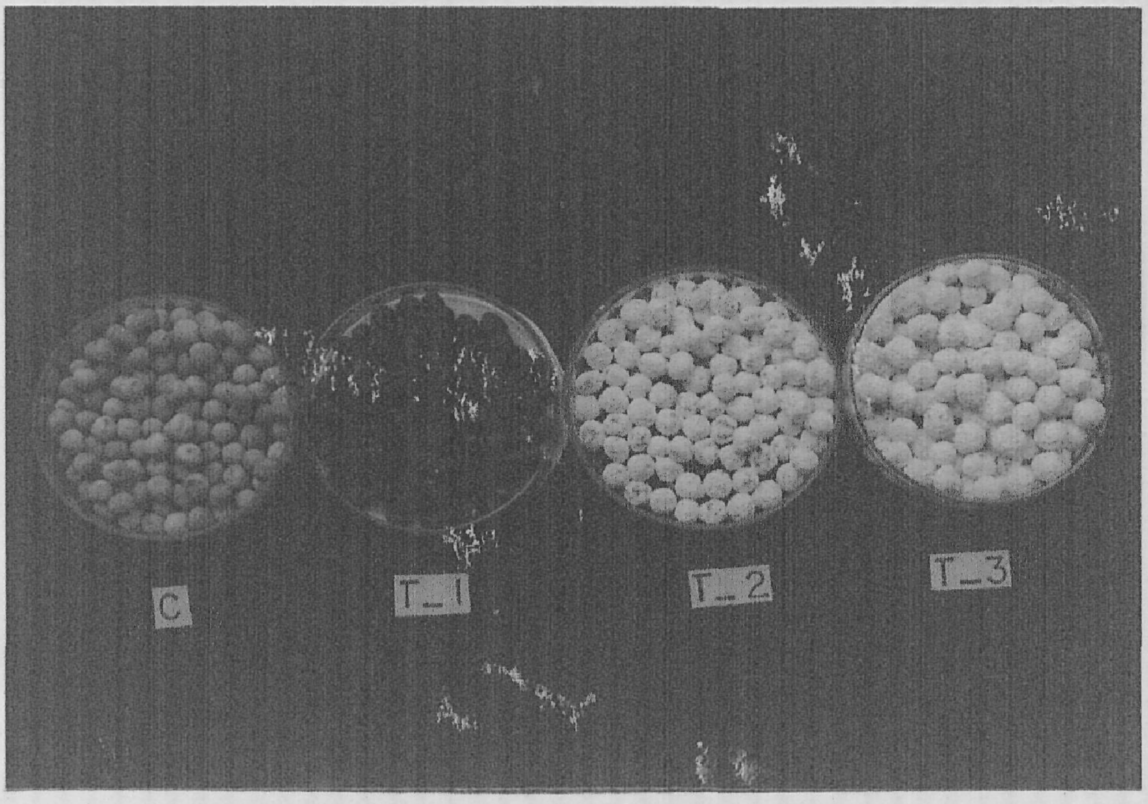
## 7. Weedicide:

A weedicide named Lasso (active ingredient as 1 Kg ai/ha) obtained from local market was used to suppress weeds in the field.

# B. METHODS:

## 1. Preparation of adhesive solution:

Gumarabic and sucrose solutions of 45 and 10% concentrations, respectively were prepared in hot distilled water with constant mixing. The Gumarabic solution being acidic in nature, was neutralized with appropriate quantity of standard 1/10 sodium hydroxide solution. Both the solutions were then steam sterilized in an autoclave at 15 p.s.i. for 30 minutes. On cooling they were stored in a refrigerator




Pl. I Showing differently treated seed lots

C – control

$T_1$ – conventionally inoculated

$T_2$ – Pelleted

$T_3$ – inoculated – pelleted

over night to acquire appropriate tenacity.

### 2. Preparation of Slurry:

100 gms of carrier based inoculant was added to each of 225 ml. of sucrose (10%) and gum arabic (45%) solutions and mixed thoroughly. The inoculant slurry in 45% gumarabic solution increased to 380 ml while that of sucrose solution increased to 315 ml due to swelling of solids. The final quantities of these slurries were used to treat 14 Kg seeds of pea.

### 3. Inoculation of seeds with slurries:

The known quantities of seeds of different cultivars/selection lines were treated with appropriate quantities of these slurries of inoculant at afore mentioned rate.

Where no inoculation was required the seeds were treated with distilled water.

### 4. Pelleting of seeds:

For pelleting gypsum was weighed at the rate of 3.5 Kg for 14 Kg of pea seeds and kept ready on separate sheets of polythene for each lot of inoculated seeds of different cultivars/selection lines. As soon as the seeds of each cultivars were evenly coated with inoculant slurry in 45% gumarabic Solution, it was transferred immediately on the heap of gypsum placed and mixed rapidly by shaking the seeds to and fro by holding it from its corners. Generally 2-3 minutes were required for covering the seeds evenly by this method. For pelleting seeds without rhizobia, the method and all materials used were same excepting that the inoculant was replaced by sterile carrier.

## C. ASSESSMENT:

The influences of different methods of inoculation on various growth parameters of the 30 test cultivars/selection lines of pea was evaluated in a field experiment during the year 1988-89. The experiment was repeated in the year 1989-90 to confirm the results.

## D. DETAILS OF FIELD EXPERIMENT:

### 1. Location:

The experiment with 30 test cultivars (early mid and late maturing group) of pea was carried out at the experimental farm of the Division of Vegetable Crops, Indian Agricultural Research Institute, New Delhi-110012 during the winter season of 1988-89 and 1989-90.

## 2. Physical relief and climate of location:

The geographical spread of Delhi in physical map of India falls on the latitude 28.4$^0$ N and longitude 77.12$^0$ E. The contour reading shows an elevation of 228.6 mts. (750 fts.) above the sea level. The climate is semi-arid, sub-tropical type characterized by hot summers and dry cold winters. During summer, the mean maximum temperature ranged between 26$^0$-42$^0$ C and the minimum between 12.8$^0$-32$^0$ C. In winters, the mean maximum and minimum ranged between 20.2$^0$-27.6$^0$ C and 5.8$^0$-7.7$^0$ C, respectively.

The rainfall occurred during the years of experimentation in 1988,1989 and 1990 was 1012,303.6 and 905.5 mm, respectively through South West and Rains due to Western Disturbances , but sometimes unreliable and uneven showers also occurred during this period.

The data for various meteorological parameters during the crop season are given as follows:

**Table 2:**

**1988-1989**

| | Mean Temperature ($^0$C) | | Rainfall (mm) |
|---|---|---|---|
| Month | Maximum | Minimum | |
| October | 33.1 | 17.7 | 0 |
| November | 28.7 | 11.6 | - |
| December | 23.9 | 7.8 | 1 mm on 20th & 23rd Dec. |
| January | 19.7 | 6.1 | 63.6 |
| February | 23.5 | 7.9 | - |
| March | 28.5 | 13.5 | 27.0 |
| April | 34.8 | 17.4 | - |

**1989- 1990**

| Month | Mean Temperature (0C) Maximum | Minimum | Rainfall (mm) |
|---|---|---|---|
| October | 34.3 | 17.0 | 6.2 |
| November | 28.4 | 11.7 | 9.2 |
| December | 21.0 | 7.5 | 9.6 |
| January | 21.7 | 9.0 | - |
| February | 22.2 | 11.1 | 88.0 |
| March | 26.8 | 13.4 | 3.4 |
| April | 35.8 | 19.1 | 3.3 |

## 3. Cultivation:

The land was thoroughly cleaned and weeds and scrub vegetation were uprooted. The preparatory irrigation was given 20 days before sowing. This was followed by one deep ploughing and a cross ploughing with a mould board plough. The soil was crushed to the right tilth with the help of a disc-harrow.

**Fertilizer application:** A basal dose of fertilizers at the rate of 25 kg N/ha, 70 Kg P/ha and 50 Kg/ha was applied along with FYM at the rate of 20 tonnes/ha. A top dressing of urea was done before the flower initiation.

## 4. Layout:

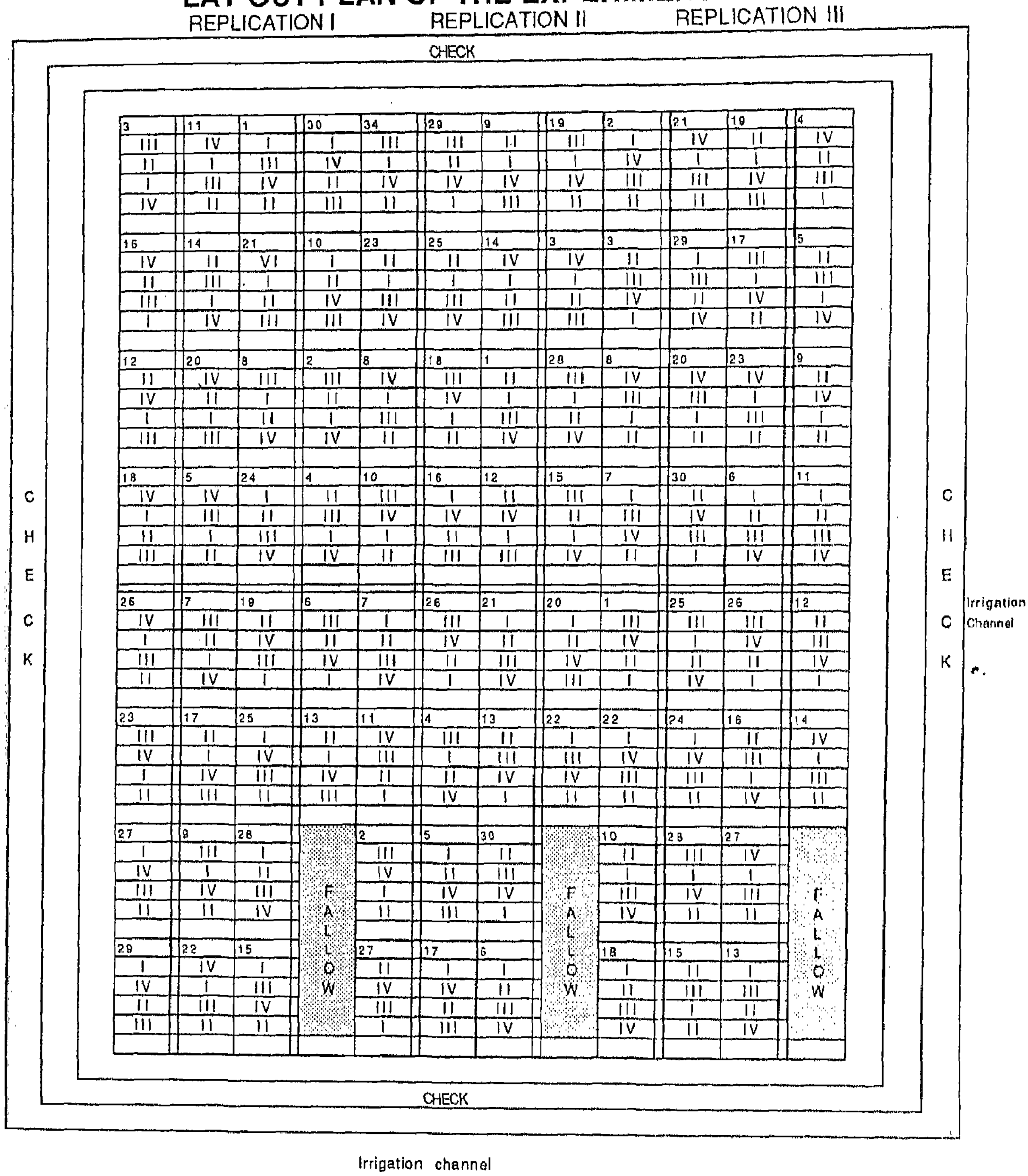
The experiment was laid in a Split Plot Block Design with three replications. The whole field was surrounded by four rows of check varieties to nullify the border effect. The 30 test varieties were randomized to constitute the main block while variously inoculated seeds were randomized for sub plots (two lines of 2 m length for each treatment). A distance of 60 cm was maintained between two lines making a treatment while 120 cm between two treatments. Plant to plant distance was kept 10 cm., Other measurements of main and subplots and the layout plan of the experiment are depicted in Fig. 1.

## 5. Sowing:

The soil was treated with weedicide, lasso at the rate of 1.0 Kg a.i./ha and seeds were sown in furrows made with the help of a hand plough.

The details of various treatments replications wise are given below:

# LAY OUT PLAN OF THE EXPERIMENT




| | | |
|---|---|---|
| Total Area | 1400 SQ. M | (L-56M x B-25M) |
| Total area of Main plot | 14 SQ. M. | (L-7 M x B-2M) |
| Total area of Sub Plots | 3.6 SQ. M. | (L-1.75M x B-2M) |
| Treatment | Four with two M length | |
| TI | Control | |
| TII | Inoculated | |
| TII | Pelleted | |
| TIV | Inoculated+ Pelleted | |

**Table 3: Lay out plan' of Varieties as main plots.**

| Plot No. | Replication I | Replication II | Replication III |
|---|---|---|---|
| 1 | 3 | 24 | 2 |
| 2. | 16 | 23 | 3 |
| 3. | 12 | 8 | 8 |
| 4. | 18 | 10 | 7 |
| 5. | 26 | 7 | 1 |
| 6. | 23 | 11 | 22 |
| 7. | 27 | 2 | 10 |
| 8. | 29 | 27 | 18 |
| 9. | 11 | 29 | 21 |
| 10. | 14 | 25 | 29 |
| 11. | 20 | 18 | 20 |
| 12. | 5 | 16 | 30 |
| 13. | 7 | 26 | 25 |
| 14. | 17 | 4 | 24 |
| 15. | 9 | 5 | 28 |
| 16. | 22 | 17 | 15 |
| 17. | 1 | 9 | 19 |
| 18. | 21 | 14 | 17 |
| 19. | 8 | 1 | 23 |
| 20. | 24 | 12 | 6 |
| 21. | 19 | 21 | 26 |
| 22. | 25 | 13 | 16 |
| 23. | 28 | 30 | 27 |
| 24. | 15 | 6 | 13 |
| 25. | 30 | 19 | 4 |
| 26. | 10 | 3 | 5 |
| 27. | 2 | 28 | 9 |
| 28. | 4 | 15 | 11 |
| 29. | 6 | 20 | 12 |
| 30. | 13 | 22 | 14 |

**TREATMENTS AS SUB PLOTS**

| Plot No | Sub Plots |
|---|---|
| 1. | Control |
| 2. | Inoculated |
| 3. | Pelleted |
| 4. | Inoculated - Pelleted. |

Replications: 3 (for the main and sub plots ).

Total area of the land: Length 56 m
Breadth 25 m
Total Area = Length x Breadth
= 56 m x 25 m
= 1400 sq m

Total number of main plots: 30 per replication

Total number of sub plots: 120 per replication

Area of the main plot Length 7 m
Breadth 2 m
Area = Length x breadth
= 7 m x 2 m
= 14 Sq m

Area of the sub plot:
Length = 1.75 m
Breadth= 2 m
Area = Length x breadth
1.75 x 2
= 3.5 Sq m

## Parameters Studied:

Observations were recorded on five randomly selected plants for each set of observations in each treatment in all the three replications. Following are the parameters studied.

## Characters related to nodulation pattern:

***1. Number of nodules per plant*** Five sample plants were pulled off from the soil carefully so that the nodules may remain intact with the roots. The roots were washed under running water putting it inside a strainer. Thus the total number of nodules per plant were counted.

2. ***Dry weight of nodules:*** The washed nodules were air dried and put inside butter paper bags with their identity numbers. The bags were then oven dried for 12 hours at $50^0$ C. The weight of these dried nodules were taken in milligrams.

3. ***Fresh Weight of the whole plant:*** The freshly uprooted plants with roots intact were weighed individually in grams.

4. ***Dry weight of the whole plant:*** After taking fresh weight the individual plants were put inside paper bags and were oven dried at $110^0$ C for 24 hours. This left the plants totally deprived of water and then weighed in grams individually.

5. ***PlantHeight:*** The plant height was measured in centimeters after the physiological maturation of randomly selected five plants from each of the treatment per replication. Roots were not taken into consideration while measuring the height.

6. ***Yield:*** Once the maturity is reached and further growth is seized the dry seed yield was taken from ten plants from each treatment from each replication. Then the average seed yield per plants was calculated.

All the above mentioned observations excluding yield were noted down at three different stages of the plant growth viz.,

| Observations | Stage of taking observations |
|---|---|
| 1st observation | Before flowering stage |
| IInd observation | Flowering stage. |
| IIIrd observation | After flowering stage. |

**Characters related to yield contribution:**

1. ***Node number at which first flower appeared:*** On the main stem the nodes were counted from the base till the appearance of first flower.

2. ***Days to first flower appearance:***Days counted from sowing up to the first flower appearance.

3. ***Days to first green pod harvest:*** The duration from sowing till the first harvesting of green pods was noted down.

4. ***Number of flowers per peduncle:*** The flowering pattern whether single or double per node was observed.

5. ***Internode length:*** The internodal length just below the node where the first flower appeared was measured in cm.

*6. Number of primary branches:* The branches coming out from the main stem were counted.

*7. Pod length:* Fully matured green pods were taken for length measurement in cm. 10 pods from each of the five plants were considered to get an average per pod length.

*8. Pod Width:* Vernier Calliper was used to measure the width (side to side distance) of fully matured green pods. 10 pods from each of the five plants were taken randomly to get the average width per pod in cm.

*9. Pod breadth:* The breadth (Suture to Suture distance) was measured with vernier calliper of the mature green pods. Here also 10 pods from each of the 5 plants were considered to get average breadth per pod in cm.

*10. Number of grains per pod:* 10 pods from each of the randomly selected five plants were taken to get the number of green mature seeds per pod.

*11. Grain weight of 10 pods:* The average grain weight from randomly selected 10 mature green pods were taken in gm from each of the five plants.

*12. Shelling percentage:* Estimated as follows:

$$\text{Shelling percentage} = \frac{\text{Wt. of green seeds}}{\text{Wt. of green pods}} \times 100$$

*13. Number of pods per Kg weight.*

*14: Plant Height:* The height from ground upto shoot tip was measured in cm.

*15. Average yield per plant:* The average yield per plant was taken in gm considering 10 plants from each variety/selection line per replication.

Details of the field operation:

## FIRST PLANTING (1988-1989)

| S.No. | Particulars | Date |
|---|---|---|
| 1. | Cleaning of the field | October, 12,1988 |
| 2. | Preparatory irrigation | October 13, 1988 |
| 3. | First ploughing | October 23, 1988 |
| 4. | One deep and one cross ploughing in parts | October 24, 1988 |
| 5. | Clod crushing with disc harrow with pata and experimental lay out | October 25, 1988 |

| | | |
|---|---|---|
| 6. | Fertilizer application (Basal dose) | October 26, 1988 |
| 7. | Sowing | October 26, 1988 |
| 8. | Weedicide spray | October 26, 1988 |
| 9. | 1st weeding | November 27, 1988 |
| 10. | Top dressing of urea | November 30,1988 |
| 11. | 2nd weeding | December 18,1988 |

## SECOND PLANTING (1989-90)

| | | |
|---|---|---|
| 1. | Cleaning of the filed | October 15,1989 |
| 2. | Preparatory irrigation | October 16, 1989 |
| 3. | First ploughing | October 25, 1989 |
| 4. | One deep and one cross ploughing | October 26, 1989 |
| 5. | Clod crushing with disc harrow and experimental layout | October 27,1989 |
| 6. | Fertilizer application: Basal Dose | October 28, 1989 |
| 7. | Sowing | October 28, 1989 |
| 8. | Weedicide spray | October 28, 1989 |
| 9. | 1st weeding | November 30, 1989 |
| 10. | Top dressing of urea | December 2,1989 |
| 11. | 2nd weeding | December 21, 1989 |

***Irrigation:*** The irrigation were provided excluding the pre sowing irrigation.

***1st irrigation:*** Provided just before the flowering stage.

***IInd irrigation:*** Provided at pod filling stage.

***Harvesting:*** The harvesting was done thrice depending on the three maturity groups.

| | | |
|---|---|---|
| Early maturing group | : | Harvesting started 55-60 days after sowing |
| Mid maturing group | : | Harvesting started 90-95 days after sowing |
| Late maturing group | : | Harvesting started 100-105 days after sowing. |

In each maturing group some plants were kept as such without the green pod harvest to get the average yield per plant.

Experimental layout plan:

## STATISTICAL ANALYSIS

So as to accommodate two sets of factors in a single experimental unit, the split plot design was taken as the experimental layout model. A randomized block design for the first set of treatments (requiring larger plot size and called main plot treatments as given in table 3) was obtained by allotting the main plot treatments at random to the whole plots of a block and then randomizing the second set of treatments (requiring smaller plot size and called the sub plot treatments) within each whole plot. This enabled to test for the main effects of the sub plot treatments and the interaction of the whole plot treatments and the sub plot treatments more efficiently than the main effects of the main plot treatments.

Suppose fresh set of factor A has p levels and the second factor 'B' has q levels, which were applied to the plots of a block after subdividing each plot into q sub plots. Thus there were p whole plots in a replicate and q sub plots in a whole plot. The model used is:

$$y_{ij}k = \mu + b_i + t_j + e_{ij} + \gamma_k + \delta_{ij} + n_{ij}k$$

Where $y_{ij}k$ = is the value of observation in the kth sub plot, jth main plot and ith replication.

(i = 1,2,.....,r; j = 1,2...., p ; K= 1,2...., q).

$\mu$ = General mean

$b_i$ = is the effect of ith replication

$t_j$ = is the effect due to jth level of A.

$y_k$ = is the effect due to kth level of B.

$y_{ii}h$ = is the interaction between jth level of A and kth level of B, with

$$\Sigma_i t_j = \Sigma_k \gamma k = \Sigma_j \delta jk = \Sigma_k \delta jk = 0$$

The random components $e_{ij}$ and $n_{ij}k$ and independently normally distributed with means zero and respective variances $\sigma^2 e$ and $\sigma^2 w$.

The analysis was done in two steps. In the first step analysis of RBD with P- treatments in y replications

MAIN PLOT X REPLICATION

| REPLICATION | MAIN PLOT TEREATMENTS 1 | 2 | J | P | Total |
|---|---|---|---|---|---|
| 1 | $y_{ii}$ | $y_{12}$ | $y_{1j}$ | $y_{1p}$ | $y_1$ |
| 2. | $y_{21}$ | $y_{22}$ | $y_{2j}$ | $y_{2p}$ | $y_2$ |
| 3. | ... | ... | ... | ... | ... |
| i | $y_{i1}$ | $y_{i2}$ | $y_{ij}$ | $y_{ip}$ | $y_i$ |
| -- | .... | .... | .... | .... | .... |
| y | $yr_1$ | $yr_2$ | $yr_j$ | $yr_p$ | yr |
| Total | $y_1$ | $y_2$ | $y_j$ | $y_p$ | r...=GT |

$$\text{Correction factor GF} = \frac{y_2}{rpq}$$

$$\text{Total ss for table (Main plot x replication)} = \frac{\Sigma_i \Sigma_j y^2}{q} - CF \qquad ....(1)$$

$$\text{Replication s.s, SSR} = \frac{\Sigma_i y^2 i}{pq} - CF \qquad ......(2)$$

$$\text{whole plot treatments SS, } SS_A = \frac{\Sigma_i y^2 j}{rq} - C.F. \qquad ....(3)$$

whole plot eror, SS (E1) = Total SS for table (Main plot X replication)
- Replication SS - Whole plot treatment - SS

Now the second step: MAIN PLOT X SUB PLOT

| Sub plot | 1 | Main plots 2 | j | p | Total |
|---|---|---|---|---|---|
| 1. | $y_{11}$ | $y_{21}$ | $y_{ji}$ | $yp_1$ | $y_1$ |
| 2. | $y_{12}$ | $y_{22}$ | $y_{j2}$ | $yp_2$ | $y_2$ |
| K | $y_{1k}$ | $y_{2k}$ | $y_{jk}$ | $y_{pk}$ | $y_k$ |
| q | $y_{1q}$ | $y_{2q}$ | $y_{jq}$ | $y_{pq}$ | y..q |
| Total | $y_1$ | $y_2$ | $y_j$ | $y_p$ | y = G.T. |

Total S.S. for table (Main plot x Sub plot = $\dfrac{\Sigma_j \Sigma_K y^2 jk}{y}$ - C.F .......(5)

SS due to sub plots, SSB = $\dfrac{\Sigma_K y^2 ....K}{rp}$ - C.F .....(6)

SS due to interaction AB, $SS_{AB}$ = Total SS for table (Main plot x Sub plot)- Whole plot treatment SS - SS due to sub plots

Total SS for (i,j,k) table = $\Sigma_i \Sigma_j \Sigma_k y^2_{ijk}$ - C..F ......(8)

Subplot error ($E_{11}$) = (8)- {(2)+(3)+(4)+(6)+(7)}

The hypothesis to be tested are :

$H_{01} = t_1 = t_2 = .....t_p = 0$

$H_{02} = y_1 = y_2 = ..... y_q = 0$

$H_{03} = \delta_{11} = \delta_{12} = ....\delta_{pq} = 0$

Layout experiment:

| Source | D.F. | S.S | M.S. | F |
|---|---|---|---|---|
| Replication | (y-1) | $SS_R$ | $S^2_R$ | $S^2_R/S^2_{E1}$ |
| Whole plot treatments(A) | (p-1) | $SS_A$ | $S^2_A$ | $S^2_A/S^2_{E1}$ |
| Whole plot error (E1) | (y-1)(p-1) | $SS_{E1}$ | $S^2_{E1}$ | |
| Sub plot treatment (B) | (q-1) | $SS_B$ | $S^2_B$ | $S^2_B/S^2_{E11}$ |
| Interaction (AB) | (p-1)(q-1) | $SS_{AB}$ | $S^2_{AB}$ | $S^2_{AB}/S^2_{E1}$ |
| Subplot Error (E11) | p(q-1)(r-1) | $SS_{E11}$ | $S^2_{E11}$ | |
| Total | pqr-1 | | | |

1. Test for $H_{01}$ is provided by F= $S^2_A/S^2_{E1}$, which follows on F-distribution with (P-1), (r-1)(p-1) d.f.
2. The test for $H_{02}$ is provided by F= $S_B{}^2/S^2_{E11}$, which has an F distribution with (q-1) and p (q-1) (r-1) d.f.
3. The test for $H_{03}$ is provided by F = $S^2_{AB}/S^2_{E11}$ which also follows an F-distribution with (p-1)(q-1),p(q-1)(y-1)d.f.

$H_{aj}$ (i = 1,2,3) is rejected at the level and if$F_{cal} > F_\alpha$; $n_1,n_2$ where n1 and $n_2$ correspond to degrees of freedom of mean squares in the numeration and denominator respectively.

## Standard Error and Critical differences :

1. Estimation of Standard Error of Difference between two main plot treatment means was

$$SEd = \sqrt{\frac{2S^2E_1}{rq}}$$

2. Estimation of Standard Error of difference between two sub-plot treatment means was

$$SEd = \sqrt{\frac{2S^2E_{11}}{rp}}$$

3. Estimation standard error of difference between two main plot treatment means at same or different levels of sub plot treatment was

$$SEd = \sqrt{\frac{2(q-1)S^2E_{11} + S^2E_1}{rq}}$$

4. Estimation of Standard Error of difference between two sub plot treatment means at the same level of main plot treatment was

$$SEd = \sqrt{\frac{2S^2E_{11}}{r}}$$

Critical difference (C.D.) = $SE_d$ x $t\alpha$; error d.f.

In case of (3) the above formula for calculating C.D. can not be used because the ratio of the treatment difference to its standard error does not follow the t-distribution. For practical purpose, an approximation to exact test involved calculation of 5 per cent level of \`t' by the following formula:-

$$\tau = \frac{(q-1)S^2_{E11}\, t_\beta + S^2_{E1}\, t_\alpha}{(q-1)S^2_{E11} + S^2_{E1}}$$

Where $t_\alpha$ and $t_\alpha$ are t-values at error (E1) and error (E11) d.f.

C.D. for (3) = SEd x t (as obtained above).

## Estimation of Correlation:

Correlation Co-efficients were calculated for both sets of plant and nodule characters adopting the following formula:

$$r_{xy} = \frac{\text{Cov. xy}}{\sqrt{\text{Var. x . Var. y}}}$$

Where, Cov. xy = Covariance of characters x and y.

Var x = Variance of character x

Var y = Variance of character y

To test the significance of correlation coefficient at Plenotypic level, the estimated values were compared with the table values (Fisher and Yates, 1967)at (n-2) degree of freedom at 5 and 10 per cent level of probability, where n is the number of pairs of observations on which correlation is based.

## Path coefficient analysis:

The estimates of direct and indirect contribution of various characteristics were calculated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

The following set of simultaneous equations was formed and solved for estimating various direct and indirect effects:

$$r_1y = P_1Y + r_{12}P_2Y + r_{13}P_3Y + ...... + r_1I^PI^Y$$

$$r_2Y = r_{21}P_1Y = P_2Y + r_{23}P_3Y + .... + r_2I^PI^Y$$

-

-

-

$$r_1Y = r_{II}\,P_1Y + r_{12}P_2y + r_{13}P_3Y + ..... + P_1Y$$

Where $r_1Y$ to $r_1Y$ = Coefficients of correlation between casual factors 1 to I and dependent character Y

$r_{12}$ to $r_1Y$ = Coefficients of correlation among casual factors.

$P_1Y$ to $P_1Y$ = Direct effect of characters 1 to I on character Y

The above equations were written in matrix for as:

$$\underset{A}{\begin{vmatrix} r_1y \\ r_2y \\ r3y \\ - \\ - \\ - \\ - \\ r_1y \end{vmatrix}} = \underset{C}{\begin{vmatrix} 1 & r_{12} & r_{13}.....r_{11} \\ r_{21} & 1 & r_{23}.....r_{21} \\ r_{31} & r_{32} & 1 \; ... \; r_{31} \\ & & \\ & & \\ & & \\ & & \\ r_{11} & r_{12} & r_{13}......1 \end{vmatrix}} \quad \underset{B}{\begin{vmatrix} P_1y \\ P_2y \\ P_3y \\ \\ \\ \\ \\ P_1Y \end{vmatrix}}$$

then $B = C^{-1} A$

where, $C^{-1}$ =

$$\begin{vmatrix} C_{11} & C_{12} & C_{13} & C_{11} \\ C_{21} & C_{22} & C_{23} & C_{21} \\ - & & & \\ - & & & \\ C_{11} & C_{12} & C_{13} & C_{11} \end{vmatrix}$$

Then direct effect were calculated as follows:

$P_1y = \quad 1\Sigma C_{11}\, r_iY$

$P_2y = \quad 1\Sigma C_{21}\, r_iy$

$P_1y = \quad 1\Sigma C_{1i}\, r_iy$

Residual effects which measures the contribution of the characters not considered in the casual scheme was obtained as residual effect ($P_{Ry}$) = $1\text{-}R^2$

Where $R^2 = P^2_{iy} + 2 \; 1 = j \; P_{iy} \, P_{jy} \, r_{ij}$

A simple path analysis was done for Nodule related characters whole in yield characters. It is elaborated as genotypic and phenotypic path.

**Statistical procedure for stability analysis following Eberhart and Russel Model 1966:**

Following the methodology of Eberhart and Russell (1966) three parameters of stability were estimated for each variety. The model was:

$Y_{ij} = u_I + b_i I_j + \delta_{ij} + e_{ij}$

where, $Y_{ij}$ = mean yield of ith variety in jth environment

$\mu_I$ = average yield of ith variety over all environments

$b_i$ =regression coefficient that measures the response of the ith variety to varying environments.

$\delta_{ij}$ = is the deviation from regression of the ith variety at jth environment

$I_j$ = environmental index, as the deviation of the mean of all varieties in jth environment from grand mean and

$$\Sigma I_j = 0$$

The first stability parameters is a regression coefficient estimated in the usual manner.

$$b_i = \Sigma Y_{ij} I_j / \Sigma I_j^2$$

The deviations $\delta_{ij}$ = ($Y_{ij}$ - $Y_{ij}$)can be squared and summed to provide an estimate of another stability parameters.

$$\sigma^2 di \text{ estimated as } s^2 d_i = [\Sigma\delta^2 ij/(n-2) - s^2\, e/r)]$$

where, $s^2e/r$ = is the estimate of pooled error.

The deviation from regression for each variety was tested by the formula

$$F = \Sigma_j \delta^2 ij\ /\ (n-2)/\text{pooled error.}$$

These two parameters along with the varietal means have been referred to as the three phenotypic stability parameters by many workers (e.g. Perkins and Jinks, 1968). The analysis of variance as suggested by Eberhart and Russell (1966) is as given under.

ANOVA

| Source | d.f. | S.S. | M.S. |
|---|---|---|---|
| Varieties | (v-1) | $1/n\ \Sigma Y_i^2$ - CF | $MS_1$ |
| Environments | $(n-1)_{v(n-1)}$ | | |
| V x E | (V-1)(n-1) | | |
| Env. (linear) 1 | | $1/v\ \Sigma^n_{j=1}(Y_j I_j)^2/\Sigma I^2_j$ | |
| V x E (linear ) | | $(v-1)\ \Sigma\ (\Sigma Y_{ig} I_g)^2/\Sigma I^2_g$ Env.(l) | $MS_2$ |
| Pooled deviations | | $\Sigma_i \Sigma_j\ \delta^2_{ig}$ | $MS_3$ |
| Total | (nv-1) | $\Sigma\Sigma Y^2_{ij}$ - CF | |

F $MS_1$ /$MS_3$ tests the significance of differences among the variety means; and $F = MS_2/MS_3$ approximately tests the hypothesis that three are no significant genetic differences among varieties for their regression on environmental lines.

Let us now reconsider model (x)

$$Y_{ij} = u_I + b_i I_j = \delta_{ij} + e_{ij} \qquad ....(x)$$

Let u = general mean = $\Sigma_i \Sigma_j Y_{ij}/bv$

Define now $B_i = [\, \Sigma_j Y_{ij} I_j / \Sigma_j I^2_j - 1]$

$= (b_i - 1)$

or $b_i = 1 + B_i$ - substitute ....(X)

$Y_{ij} = u + g_i + I_j + B_i I_j + \delta_{ij} + e_{ij}$

Further, define $g_i$, the value

$g_i = u_I - u$ where, $u = \Sigma u_i / v$

or $u_I = u + g_i$ - Substitute in (x)

$Y_{ij} = u + g_i + I_j + B_i I_j + I_j + \delta_{ij} + e_{ij}$ (B)

In model (B) , gi = deviation of $u_i$ from general mean.

$$\Sigma^n_{i=1} g_i = 0$$

This model (B) is identical to the additive model

$Y_{ij} = u + g_i + I_j + B_i I_j + \delta_{ij}$ for inbred lines developed by Perkins and Jinks (1968 a); except that gi is now defined as the deviation of $u_I$ the value corresponding to ith strain from u the general mean.

As shown by Singh (1973) least square estimates of U, i $+B_i$ & $g_i$ are

$$\mu = \Sigma_i \Sigma_j Y_{ij} / vn$$

$$\hat{g}_i = (\Sigma^n_{j=1} Y_{ij})/n - \hat{\mu}$$

and

$$1 + \beta_i = \Sigma^n_{j=1} Y_{ij} I_j / \Sigma^n_{j=1} I^2_j$$

$=$ $b_i$ of Eberhart and Russell (1966)

The sum of square of each variety is split up as the sum of squares due to linear regression (assuming that the genotypic values corresponding to ith variety mean shows linear response to environmental effect) and sum of squares due to deviation from linearity. The relation for the ith variety is

$$\Sigma^n_{j=1} (Y_{ij} - Y_i/n)^2 = (\Sigma Y_{ij} I_j)^2 / \Sigma^n_{j=1} I^2_j + \Sigma f^2_{ij}$$

$$= (1 + \beta i)^2 \Sigma^n_{j=1} I^2_g + \Sigma^n_{j=1} f^2_{ij}$$

$\Sigma^{n}_{j=1} f^{2}_{if}$ = s.s. due to deviation from linearity

The analysis of variance corresponding to model ( B) will contain the following components analogs to the components of Perkins and Jinks (1968a) although the present analysis is based only on phenotypic values. In fact, as shown by Singh (1973). This analysis leads to the estimates identical to Perkins and Jinks (1968). The ANOVA is given as follows:

ANOVA

| Source | d.f. | S.S. |
|---|---|---|
| Varieties/families | (v-1) | $\Sigma^{v}_{i=1} (YC)^{2}$-CF = SS(V) |
| Environments | (n-1) | v $\Sigma^{n}_{j=1} I^{2}_{g}$ = SS (Env) |
| (Joint Regression) | | |
| Variety x Environment | (v-1)(n-1) | $\Sigma^{v}_{i=1} \Sigma^{n}_{j=1} (Y_{ij} I_{j})^{2}/\Sigma I^{2}_{j}$-SS(Env.)-SS(v) |
| (i) V x E (linear ) | (v-1) | $\{\Sigma^{v}_{i=1} (Y_{ij}I_{j})^{2}/\Sigma I^{2}_{j}\}$ - SS(Env.) |
| (ii) V x E (non linear) | (v-1)(n-2) | $\Sigma^{v}_{i=1}\{[\Sigma^{n}_{j=1} Y^{2}_{ij} - Y^{2}/n] - [\Sigma^{n}_{j=1}(Y_{ij}I_{j})^{2}/\Sigma_{j} I^{2}_{j}]\}$ |

Pooled error: As obtained from individual location analysis.

# EXPERIMENTAL FINDINGS

The objective of the experiment was to elucidate the influence of various treatments on the growth, development and yield expression of different genotypes of garden pea (*Pisum sativum* L.) cultivars. The effect of the treatments on six different plant characters were observed at three growth stages namely, pre-flowering, flowering and post-flowering stages, in two consecutive years (1988-89 to 1989-1990). The results of the experiment are presented below.

## 1. Number of nodules per plant

The observed values for this character revealed significant changes due to treatments over different growth stages and individual varietal responses. The results obtained at different growth stages were as follows:

### 1 a. Pre-flowering stage:

At pre-flowering stage the microbial treatments enhanced the number of nodules per plant significantly (Table 4A & 4B). Analysis of variance revealed that significant differences existed in this regard among the test varieties. In the early group of varieties the means of different treatments ranged from 13.35 to 84.81 nodules per plant in first year and 12.85 to 87.68 nodules/plant in second year (minimum in Early Badger and highest in Hara Bona in both the years). In case of mid and late maturing groups, the nodule number/plant ranged from 11.60 to 57.55 and 21.5 to 47.86, in the first year and 16.03 to 59.38 and 23.38 to 49.06 , respectively in second year respectively. In both the years VL-3 was observed to perform best with regard to the nodule count per plant in mid maturing group while in late maturing group Kala Nagini was the best performer. Minimum nodule numbers/plant were noticed in mid and late maturing group in varieties selection -222 and UU-3 respectively during both the years.

The methods of *Rhizobium* culture application showed significant differences and also interacted differently with different cultivars/selection lines. Observed differences between the cultivars revealed that the treatment combination Inoculated-Pelleted was significantly superior to all other treatments, taking all

# Table No. 4 (A)Mean Nodule Count per plant at pre flowering stage

**Ist Year**

**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 9.13 | 22.73 | 12.00 | 29.47 | 18.33 |
| 2. | Meteor | 19.47 | 31.07 | 23.27 | 60.40 | 33.55 |
| 3. | Early Badger | 9.53 | 10.33 | 9.80 | 23.73 | 13.35 |
| 4. | Little Marvel | 34.47 | 54.00 | 42.67 | 68.67 | 49.95 |
| 5. | Hara Bona | 71.53 | 91.93 | 78.13 | 97.67 | 84.82 |
| 6. | JP-829 | 17.47 | 60.00 | 19.93 | 73.47 | 42.72 |
| 7. | Jawahar Matar-4 | 21.00 | 38.60 | 27.00 | 42.00 | 32.15 |
| 8. | V.P.-7802 | 26.47 | 55.33 | 41.13 | 68.40 | 47.83 |
| 9. | V.P.-7839 | 18.20 | 60.53 | 41.33 | 70.67 | 47.68 |
| 10. | V.P.-8005 | 21.40 | 74.33 | 42.13 | 141.73 | 69.90 |
| 11. | Bonneville | 15.80 | 35.33 | 22.93 | 82.13 | 39.05 |
| 12. | Lincoln | 15.93 | 29.80 | 16.33 | 43.23 | 26.32 |
| 13 | Vipasa | 14.53 | 58.73 | 38.80 | 89.33 | 52.85 |
| 14. | VL-3 | 28.73 | 71.27 | 48.53 | 81.67 | 57.55 |
| 15. | Jawahar Matar-1 | 45.27 | 57.80 | 46.97 | 73.13 | 55.67 |
| 16. | KS-123 | 12.40 | 29.20 | 30.40 | 45.87 | 29.47 |
| 17. | IP-3 | 9.27 | 18.33 | 9.07 | 18.80 | 13.87 |
| 18. | VL-2 | 25.67 | 54.80 | 30.87 | 70.67 | 45.50 |
| 19. | Pb-88 | 16.60 | 24.93 | 15.60 | 60.53 | 29.41 |
| 20. | Sel. 222 | 7.40 | 12.27 | 8.80 | 17.93 | 11.60 |
| 21. | Early perfection | 21.33 | 59.93 | 28.73 | 65.53 | 43.88 |
| 22. | Selection-17 | 24.33 | 32.57 | 30.93 | 67.47 | 38.82 |
| 23. | Kala Nagini | 22.80 | 50.80 | 25.33 | 92.53 | 47.86 |
| 24. | JP-501 | 15.00 | 32.40 | 18.53 | 33.13 | 24.76 |
| 25. | P-388 | 15.47 | 49.47 | 21.13 | 52.87 | 34.73 |
| 26. | P-6587-1 | 13.13 | 28.00 | 18.87 | 35.40 | 23.85 |
| 27. | P-6588-1 | 16.47 | 24.13 | 12.93 | 40.87 | 23.60 |
| 28. | UU-2 | 23.60 | 34.47 | 29.13 | 65.27 | 38.12 |
| 29. | UU-3 | 11.00 | 27.60 | 12.53 | 34.87 | 21.5 |
| 30. | ACC-65 | 18.67 | 42.93 | 26.27 | 69.53 | 39.35 |

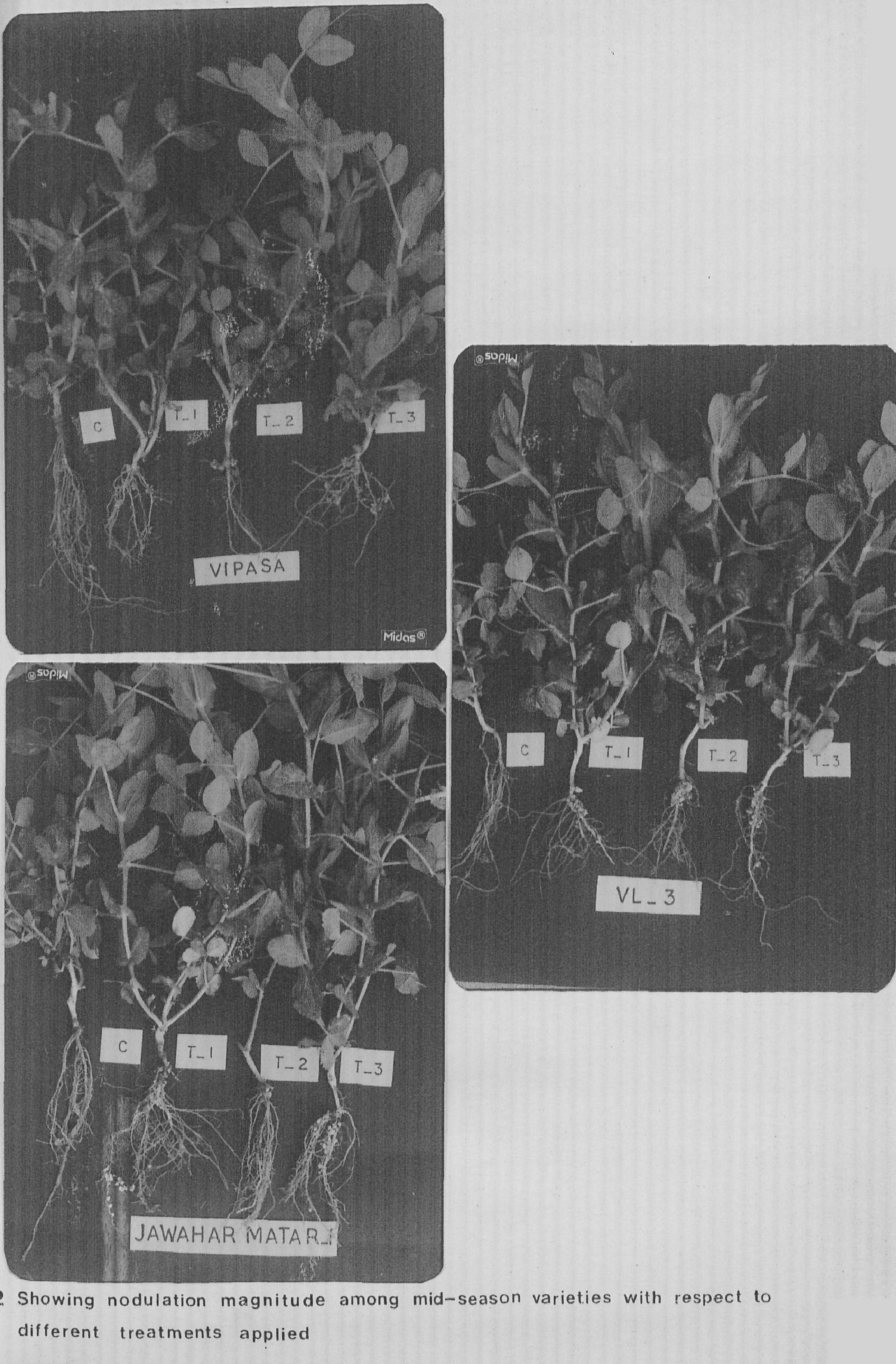
C.D.((P= 0.05) varietal means = 2.642

C.D. (P= 0.05) Treatment means =1.968

**Table No. 4 (B) Mean Nodule Count per plant at pre flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 8.80 | 25.67 | 10.33 | 27.87 | 18.17 |
| 2. | Meteor | 18.60 | 29.40 | 23.60 | 60.60 | 33.05 |
| 3. | Early Badger | 9.73 | 8.53 | 10.20 | 22.93 | 12.85 |
| 4. | Little Marvel | 37.47 | 52.93 | 42.73 | 66.93 | 50.01 |
| 5. | Hara Bona | 76.60 | 106.87 | 74.20 | 98.07 | 87.68 |
| 6. | JP-829 | 17.73 | 58.13 | 20.73 | 76.53 | 43.28 |
| 7. | Jawahar Matar-4 | 22.40 | 42.53 | 17.13 | 43.20 | 31.31 |
| 8. | V.P.-7802 | 28.13 | 53.73 | 44.00 | 70.53 | 49.10 |
| 9. | V.P.-7839 | 18.80 | 60.40 | 38.07 | 72.00 | 47.32 |
| 10. | V.P.-8005 | 23.80 | 75.27 | 43.13 | 56.40 | 49.65 |
| 11. | Bonneville | 14.93 | 36.47 | 23.47 | 82.73 | 39.40 |
| 12. | Lincoln | 16.13 | 22.00 | 16.80 | 46.80 | 25.43 |
| 13. | Vipasa | 15.60 | 57.47 | 36.07 | 84.27 | 41.35 |
| 14. | VL-3 | 32.47 | 68.27 | 52.40 | 84.40 | 59.38 |
| 15. | Jawahar Matar-1 | 46.33 | 60.27 | 49.73 | 67.33 | 55.91 |
| 16. | KS-123 | 13.47 | 29.80 | 23.33 | 43.17 | 28.44 |
| 17. | IP-3 | 9.20 | 20.27 | 9.53 | 19.07 | 16.90 |
| 18. | VL-2 | 26.67 | 56.00 | 27.60 | 72.53 | 36.77 |
| 19. | Pb-88 | 17.80 | 26.27 | 17.13 | 64.60 | 38.88 |
| 20. | Sel. 222 | 7.80 | 13.27 | 95.13 | 20.53 | 16.03 |
| 21. | Early perfection | 23.13 | 63.53 | 28.60 | 70.02 | 46.33 |
| 22. | Selection-17 | 26.07 | 30.40 | 29.80 | 63.13 | 45.63 |
| 23. | Kala Nagini | 23.26 | 52.33 | 28.20 | 92.53 | 49.06 |
| 24. | JP-501 | 12.00 | 35.80 | 20.47 | 34.07 | 26.83 |
| 25. | P-388 | 17.80 | 53.40 | 24.13 | 54.87 | 37.55 |
| 26. | P-6587-1 | 15.13 | 31.07 | 21.53 | 35.20 | 25.73 |
| 27. | P-6588-1 | 17.07 | 26.13 | 16.87 | 43.40 | 26.12 |
| 28. | UU-2 | 24.93 | 34.00 | 27.60 | 64.20 | 37.68 |
| 29. | UU-3 | 13.13 | 27.43 | 12.53 | 39.93 | 23.38 |
| 30. | ACC-65 | 20.60 | 40.13 | 26.53 | 65.13 | 38.10 |

CD (P=0.05) varietal means = 2.242
CD (P=0.05) Treatment means = 2.620




Pl.2 Showing nodulation magnitude among mid-season varieties with respect to different treatments applied

the 30 varieties together, as well as in all the three maturity groups when studied separately. The next best treatment was conventional inoculation that performed much better than pelleted.

The interaction of varieties with rhizobial culture was found to be reasonably significant. Here the caution was taken for interpreting the interaction effects by pointing out the performance superiority of a particular variety, considering its relative increase in performance over control. In all the three maturity groups, the treatment combination inoculated-pelleted was found best which was followed by conventionally inoculated and then pelleted. In case of inoculated trial of early maturing group, the highest relative increase of nodule number per plant was obtained in cultivar VP-8005, in case of pelleted the cultivar VP-7802 performed best but when the two methods were applied jointly, i.e.. inoculated + pelleted, the cultivar JP -829 gave the best result in both the years. In the mid maturing group the highest relative increase of nodule number/plant was observed over control in cultivars Vipasa, VL-3 and Vipasa in inoculated, in pelleted and in inoculated -pelleted treatments, respectively. The second year study also showed the same trend except differing only in the magnitude. In the late maturing group, Early Perfection was found to give highest relative increase under inoculated condition in first year, while in the second year, selection-17 proved better than Early Perfection. In inoculated -pelleted combination, Kala Nagini was found to respond better in both the years.

### 1b. Flowering Stage:

Though significant differences were observed in effect of different treatments at flowering stages, the magnitude of effect was found to be less as compared to pre-flowering stage (Table 5A & 5B). In early maturing group, Hara Bona was found to perform better with highest nodule number per plant (59.83 and 59.71 in two different years, respectively), while in the mid maturing group the variety Jawahar Matar-1 performed better (50.58 and 47.00 in both the years). In the late maturing group, Acc-65 was found to respond best (31.47 and 34.72). A clear distinction was evident among the three maturity groups, i.e. early group showed highest response than those of the mid and late maturity groups.



The different methods of application seemed to follow the same trend when

**Table No. 5 (A) Mean Nodule Count per plant at flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

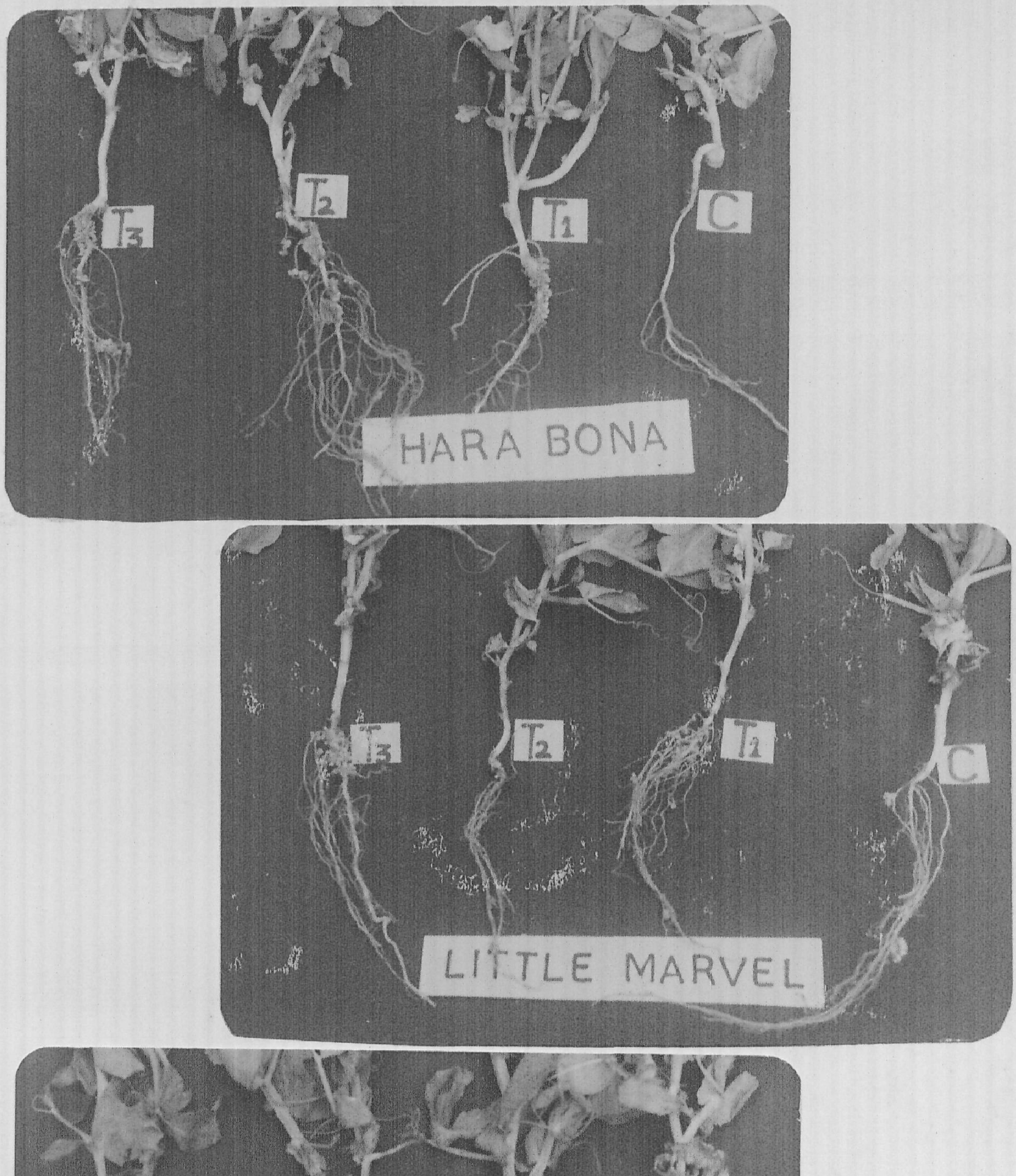
| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 4.87 | 9.00 | 5.80 | 8.33 | 7.00 |
| 2. | Meteor | 12.47 | 21.27 | 17.93 | 27.53 | 19.80 |
| 3. | Early Badger | 6.07 | 8.67 | 7.27 | 9.80 | 7.95 |
| 4. | Little Marvel | 20.93 | 32.87 | 22.33 | 34.93 | 27.76 |
| 5. | Hara Bona | 42.33 | 67.40 | 48.80 | 80.80 | 59.83 |
| 6. | JP-829 | 10.13 | 30.40 | 12.73 | 38.33 | 22.98 |
| 7. | Jawahar Matar-4 | 13.00 | 21.07 | 14.13 | 30.67 | 19.72 |
| 8. | V.P.-7802 | 15.87 | 25.20 | 20.13 | 35.33 | 24.13 |
| 9. | V.P.-7839 | 8.40 | 17.87 | 12.53 | 22.60 | 15.35 |
| 10. | V.P.-8005 | 10.40 | 25.60 | 14.53 | 26.27 | 19.20 |
| 11. | Bonneville | 6.93 | 28.33 | 10.20 | 54.40 | 24.96 |
| 12. | Lincoln | 6.87 | 20.93 | 11.00 | 28.33 | 16.78 |
| 13. | Vipasa | 8.00 | 36.27 | 26.87 | 56.53 | 31.92 |
| 14. | VL-3 | 19.40 | 26.93 | 23.73 | 34.53 | 26.15 |
| 15. | Jawhar Matar-1 | 38.00 | 58.67 | 38.53 | 67.13 | 50.58 |
| 16. | KS-123 | 10.07 | 29.47 | 24.47 | 36.07 | 25.02 |
| 17. | IP-3 | 6.80 | 12.07 | 6.87 | 18.47 | 11.05 |
| 18. | VL-2 | 21.93 | 44.73 | 26.47 | 60.40 | 38.38 |
| 19. | Pb-88 | 12.20 | 17.27 | 12.43 | 26.07 | 16.99 |
| 20. | Sel. 222 | 4.73 | 7.60 | 4.87 | 8.80 | 6.50 |
| 21. | Early perfection | 13.93 | 37.40 | 17.93 | 44.13 | 28.35 |
| 22. | Selection-17 | 14.87 | 19.57 | 17.87 | 33.60 | 21.48 |
| 23. | Kala Nagini | 13.67 | 26.67 | 17.33 | 53.87 | 27.88 |
| 24. | JP-501 | 9.33 | 25.53 | 14.07 | 27.47 | 19.10 |
| 25. | P-388 | 10.07 | 21.93 | 14.40 | 23.07 | 17.37 |
| 26. | P-6587-1 | 6.47 | 9.07 | 7.40 | 12.40 | 8.83 |
| 27. | P-6588-1 | 12.07 | 16.33 | 14.03 | 21.53 | 15.99 |
| 28. | UU-2 | 14.80 | 19.40 | 16.53 | 27.27 | 19.50 |
| 29. | UU-3 | 6.93 | 17.40 | 9.87 | 26.67 | 15.22 |
| 30. | ACC-65 | 12.60 | 29.87 | 20.80 | 62.60 | 31.47 |

C.D.((P= 0.05) varietal means = 2.420
C.D. (P= 0.05) Treatment means =1.662

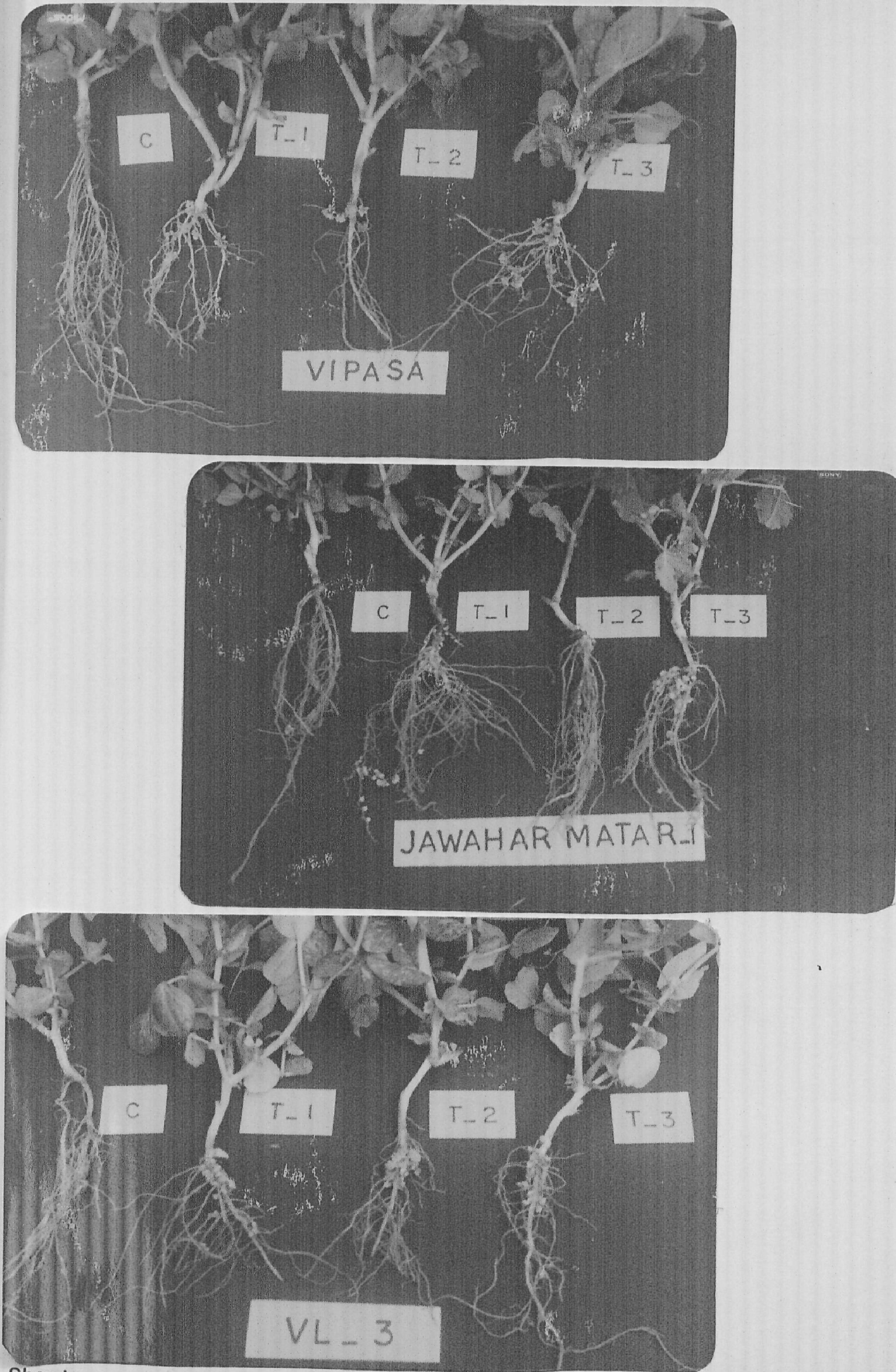
**Table No. 5 (B) Mean Nodule Count per plant at flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.73 | 9.40 | 6.20 | 11.00 | 8.08 |
| 2. | Meteor | 15.43 | 22.33 | 19.20 | 28.27 | 21.31 |
| 3. | Early Badger | 8.73 | 10.87 | 9.60 | 11.87 | 10.27 |
| 4. | Little Marvel | 21.93 | 29.33 | 24.07 | 31.87 | 26.80 |
| 5. | Hara Bona | 44.53 | 66.13 | 50.00 | 78.20 | 59.71 |
| 6. | JP-829 | 14.13 | 29.87 | 18.53 | 38.87 | 25.35 |
| 7. | Jawahar Matar-4 | 12.27 | 25.13 | 21.27 | 29.47 | 22.03 |
| 8. | V.P.-7802 | 13.53 | 22.47 | 21.37 | 34.80 | 23.04 |
| 9. | V.P.-7839 | 7.40 | 18.67 | 13.53 | 25.07 | 16.17 |
| 10. | V.P.-8005 | 10.60 | 24.33 | 13.60 | 28.13 | 19.16 |
| 11. | Bonneville | 7.27 | 27.33 | 9.73 | 52.60 | 24.23 |
| 12. | Lincoln | 7.73 | 23.07 | 13.40 | 29.33 | 18.38 |
| 13. | Vipasa | 8.40 | 40.07 | 29.33 | 56.93 | 33.68 |
| 14. | VL-3 | 21.60 | 27.47 | 25.20 | 38.00 | 28.07 |
| 15. | Jawhar Matar-1 | 37.13 | 47.93 | 42.00 | 60.93 | 47.00 |
| 16. | KS-123 | 10.33 | 28.27 | 25.53 | 38.67 | 25.70 |
| 17. | IP-3 | 7.20 | 12.00 | 7.20 | 18.07 | 11.12 |
| 18. | VL-2 | 22.20 | 46.67 | 25.07 | 63.60 | 39.38 |
| 19. | Pb-88 | 13.60 | 20.67 | 16.20 | 25.40 | 18.97 |
| 20. | Sel. 222 | 4.27 | 8.07 | 5.07 | 10.00 | 6.85 |
| 21. | Early perfection | 14.67 | 37.00 | 20.80 | 38.80 | 27.82 |
| 22. | Selection-17 | 13.73 | 25.08 | 20.13 | 33.53 | 23.30 |
| 23. | Kala Nagini | 14.80 | 29.33 | 17.20 | 55.40 | 29.18 |
| 24. | JP-501 | 10.47 | 25.60 | 15.80 | 29.93 | 20.45 |
| 25. | P-388 | 12.00 | 23.73 | 14.53 | 26.40 | 19.16 |
| 26. | P-6587-1 | 7.27 | 12.73 | 10.87 | 15.53 | 11.60 |
| 27. | P-6588-1 | 13.47 | 18.33 | 14.93 | 22.93 | 20.53 |
| 28. | UU-2 | 18.20 | 24.20 | 22.73 | 27.60 | 23.18 |
| 29. | UU-3 | 8.47 | 17.00 | 12.53 | 26.23 | 16.06 |
| 30. | ACC-65 | 16.47 | 30.13 | 25.50 | 66.80 | 34.72 |

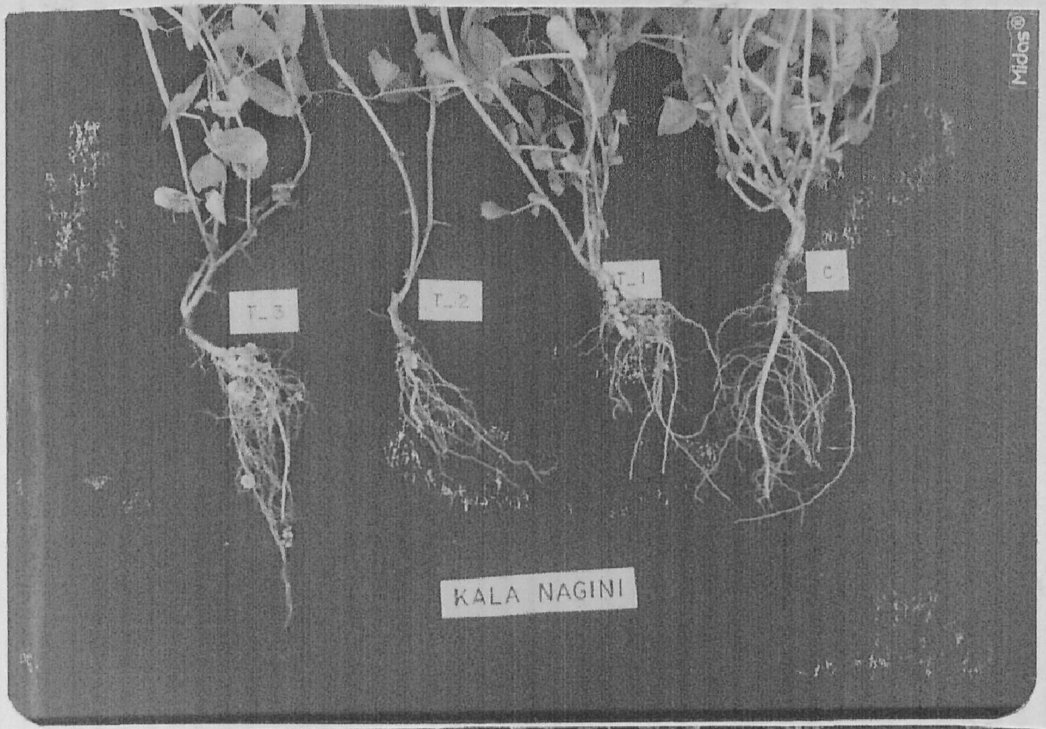
CD (P=0.05) varietal means = 1.486
CD (P=0.05) Treatment means = 2.662

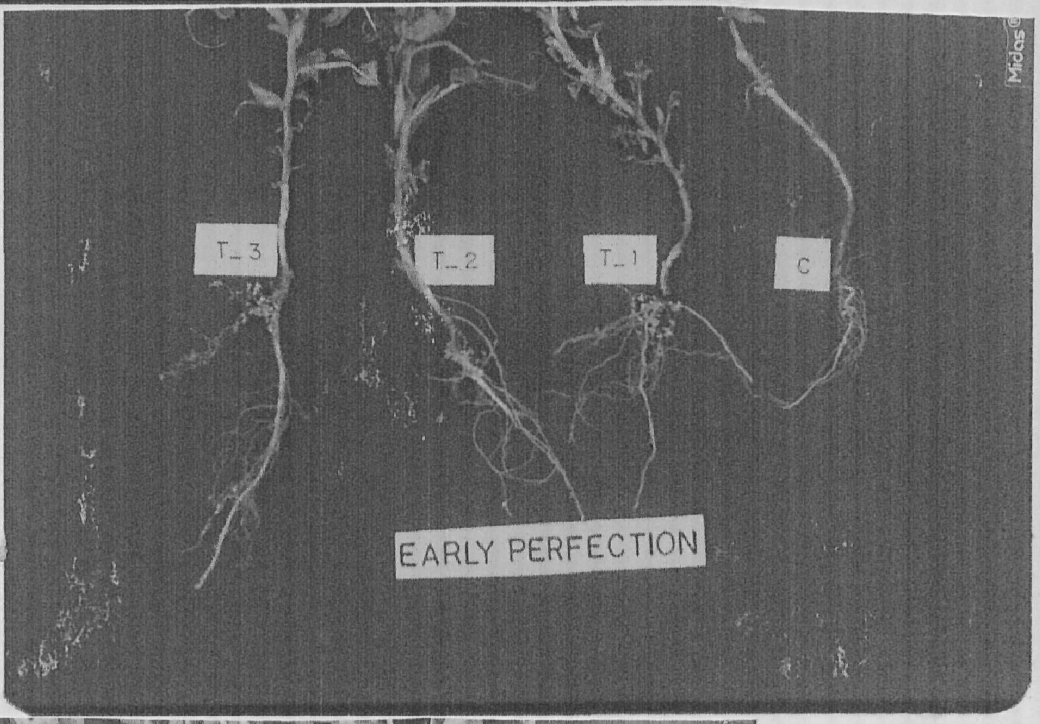


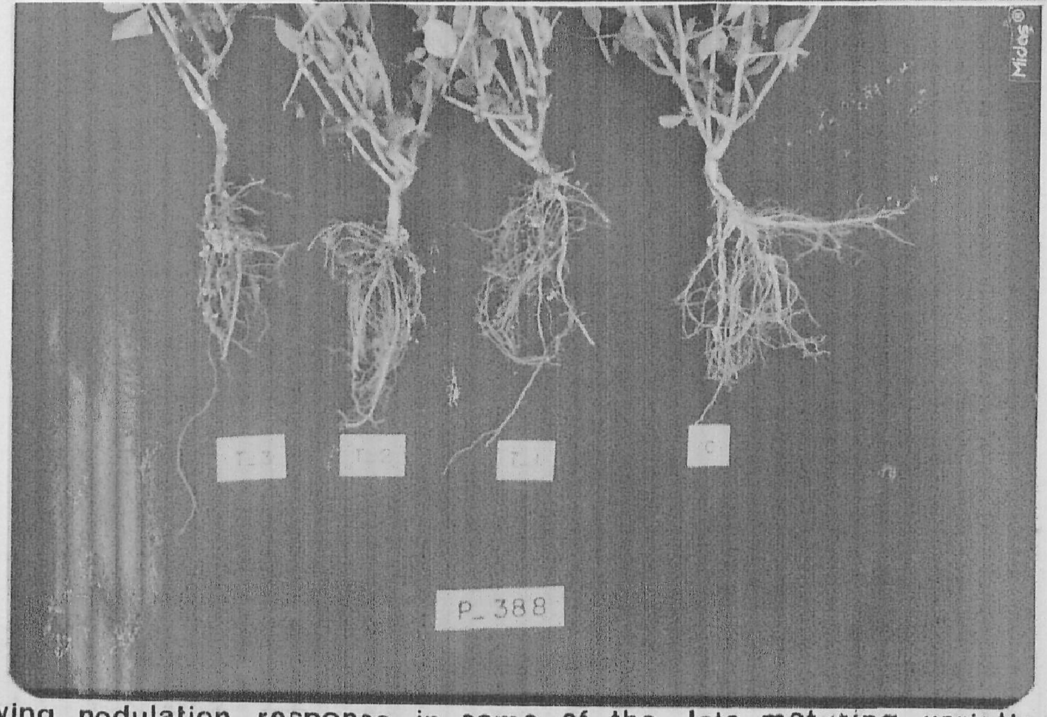

Pl.3 Showing nodulation response in some of the early maturing varieties




Pl.4 Showing nodulation response in soma of the mid-maturing varieties




5 Showing nodulation response in some of the late maturing varieties

compared to pre-flowering stage. Inoculated-pelleted treatment gave the highest response as compared to their separate applications. Inoculated was found to perform better than pelleted.

The interaction of variety x biofertilizer showed that the cultivars Hara Bona and Vipasa established their distinct and significant superiority over all the culture application methods and in their individual responses in early and mid maturing groups in both the years. However, in late maturing group, in both the years, Early Perfection, ACC-65 and Kala Nagini performed best in inoculated, pelleted and inoculated-pelleted conditions respectively.

### 1C Post flowering stage:

The observation recorded on number of nodules per plant at post flowering stage (Table 6A & 6B) proved to be significantly inferior to pre-flowering and flowering stages. The varieties Hara Bona, Jawahar Matar-1 and ACC-65 in early, mid and late maturing groups respectively, were significantly superior in both the years. A remarkable reduction in nodule number at post-flowering stage was observed.

The methods of application of the culture showed the same trend as pre-flowering and flowering stages, except that a reduction, in the magnitude of response of the individual test cultivars.

The interaction effects revealed that the highest relative increase in nodule number per plant was maintained by the cultivar Hara Bona in the early maturing group, in all the treatments over control, in both the years. Inoculated-pelleted gave the highest response, followed by inoculated and then by pelleted when studied separately. The same trend was followed in mid and late maturing groups also. Cultivars Vipasa and sel. 222 were found to perform best in all the treatments over years in mid and late maturing groups respectively.

### 1d Pooled analysis over three growth stages:

The pooled analysis over growth stages revealed that the varietal responses were not consistent in all the three growth stages (Table No. 7A & 7B). In early maturity group the absolute increase was highest in Hara Bona at all the three growth stages. In case of interaction effects, Hara Bona was found to respond best only in the conventionally inoculated method (as was in flowering and post flowering stages). However, VP-7802 responded highest

**Table No. 6 (A) Mean Nodule Count per plant at post flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 3.93 | 7.47 | 4.67 | 8.07 | 6.03 |
| 2. | Meteor | 8.93 | 15.33 | 12.40 | 20.87 | 14.38 |
| 3. | Early Badger | 4.20 | 5.73 | 4.93 | 6.33 | 5.30 |
| 4. | Little Marvel | 15.13 | 24.13 | 17.00 | 26.73 | 20.75 |
| 5. | Hara Bona | 26.33 | 60.40 | 36.60 | 66.20 | 47.38 |
| 6. | JP-829 | 12.33 | 22.87 | 19.40 | 29.40 | 21.00 |
| 7. | Jawahar Matar-4 | 9.67 | 17.20 | 15.53 | 22.40 | 16.20 |
| 8. | V.P.-7802 | 9.53 | 17.27 | 13.53 | 17.60 | 14.48 |
| 9. | V.P.-7839 | 6.47 | 12.47 | 9.73 | 17.87 | 11.63 |
| 10. | V.P.-8005 | 8.27 | 17.93 | 11.73 | 19.33 | 14.31 |
| 11. | Bonneville | 7.60 | 21.07 | 9.20 | 30.13 | 17.00 |
| 12. | Lincoln | 5.73 | 16.20 | 8.80 | 18.47 | 12.30 |
| 13. | Vipasa | 6.53 | 27.40 | 19.73 | 42.40 | 24.01 |
| 14. | VL-3 | 13.80 | 24.40 | 15.13 | 26.93 | 20.06 |
| 15. | Jawhar Matar-1 | 30.67 | 37.00 | 34.40 | 42.80 | 36.22 |
| 16. | KS-123 | 9.47 | 17.13 | 14.73 | 26.87 | 17.05 |
| 17. | IP-3 | 4.87 | 8.67 | 5.67 | 10.47 | 7.42 |
| 18. | VL-2 | 17.60 | 31.13 | 18.13 | 33.33 | 25.05 |
| 19. | Pb-88 | 9.93 | 13.87 | 10.60 | 22.07 | 14.12 |
| 20. | Sel. 222 | 3.80 | 6.67 | 4.33 | 6.93 | 5.43 |
| 21. | Early perfection | 10.93 | 24.13 | 11.93 | 28.67 | 18.91 |
| 22. | Selection-17 | 12.93 | 17.60 | 16.13 | 28.33 | 18.75 |
| 23. | Kala Nagini | 10.33 | 18.67 | 12.00 | 30.53 | 17.88 |
| 24. | JP-501 | 8.67 | 17.00 | 10.60 | 20.27 | 14.13 |
| 25. | P-388 | 9.67 | 15.80 | 10.47 | 18.73 | 13.67 |
| 26. | P-6587-1 | 4.93 | 11.40 | 6.33 | 18.67 | 10.33 |
| 27. | P-6588-1 | 10.40 | 11.20 | 10.60 | 13.87 | 11.51 |
| 28. | UU-2 | 12.33 | 18.00 | 14.73 | 23.07 | 17.03 |
| 29. | UU-3 | 7.00 | 14.67 | 8.80 | 23.20 | 13.42 |
| 30. | ACC-65 | 14.20 | 34.27 | 22.67 | 67.33 | 34.62 |

C.D.((P= 0.05) varietal means = 1.642
C.D. (P= 0.05) Treatment means =1.668

**Table No. 6 (B) Mean Nodule Count per plant at post flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 4.47 | 6.97 | 5.13 | 7.40 | 5.99 |
| 2. | Meteor | 9.13 | 17.53 | 10.53 | 22.47 | 14.91 |
| 3. | Early Badger | 4.20 | 4.60 | 4.47 | 5.80 | 4.77 |
| 4. | Little Marvel | 16.07 | 22.13 | 18.20 | 25.27 | 20.42 |
| 5. | Hara Bona | 25.40 | 59.73 | 36.40 | 64.93 | 46.61 |
| 6. | JP-829 | 12.33 | 21.80 | 19.07 | 32.27 | 21.37 |
| 7. | Jawahar Matar-4 | 9.60 | 15.53 | 12.40 | 25.53 | 15.76 |
| 8. | V.P.-7802 | 9.20 | 17.60 | 13.13 | 19.73 | 14.91 |
| 9. | V.P.-7839 | 7.27 | 12.60 | 10.53 | 19.73 | 12.53 |
| 10. | V.P.-8005 | 7.13 | 15.93 | 12.07 | 20.07 | 13.80 |
| 11. | Bonneville | 8.47 | 19.80 | 17.47 | 26.60 | 18.08 |
| 12. | Lincoln | 5.67 | 15.27 | 9.07 | 16.20 | 11.55 |
| 13. | Vipasa | 6.40 | 25.67 | 16.73 | 42.67 | 22.87 |
| 14. | VL-3 | 15.40 | 24.67 | 16.97 | 29.57 | 21.65 |
| 15. | Jawhar Matar-1 | 30.73 | 40.67 | 38.73 | 43.07 | 38.30 |
| 16. | KS-123 | 8.13 | 16.47 | 17.93 | 24.20 | 16.68 |
| 17. | IP-3 | 5.33 | 8.13 | 6.67 | 8.93 | 7.26 |
| 18. | VL-2 | 18.40 | 33.20 | 19.60 | 38.40 | 27.40 |
| 19. | Pb-88 | 10.13 | 13.27 | 10.60 | 24.47 | 14.62 |
| 20. | Sel. 222 | 3.67 | 6.87 | 5.07 | 8.47 | 6.02 |
| 21. | Early perfection | 13.07 | 24.53 | 14.13 | 26.20 | 19.48 |
| 22. | Selection-17 | 13.20 | 18.20 | 15.47 | 28.13 | 18.75 |
| 23. | Kala Nagini | 11.53 | 20.20 | 13.33 | 33.00 | 19.51 |
| 24. | JP-501 | 8.40 | 17.73 | 11.40 | 21.07 | 14.65 |
| 25. | P-388 | 8.80 | 15.93 | 11.00 | 17.87 | 13.40 |
| 26. | P-6587-1 | 4.87 | 13.40 | 7.13 | 19.40 | 11.20 |
| 27. | P-6588-1 | 10.60 | 14.53 | 11.60 | 18.53 | 13.81 |
| 28. | UU-2 | 13.00 | 19.60 | 16.60 | 21.80 | 17.75 |
| 29. | UU-3 | 7.20 | 14.47 | 9.27 | 23.27 | 13.55 |
| 30. | ACC-65 | 14.07 | 33.80 | 21.27 | 64.67 | 33.45 |

CD (P=0.05) varietal means = 2.632
CD (P=0.05) Treatment means =1.963

**Table No. 7 (A) Mean Nodule Count per plant pooled over growth stages**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.98 | 13.07 | 7.49 | 15.29 | 10.46 |
| 2. | Meteor | 13.62 | 22.56 | 17.87 | 36.27 | 22.58 |
| 3. | Early Badger | 6.60 | 8.24 | 7.12 | 13.29 | 8.81 |
| 4. | Little Marvel | 23.51 | 37.00 | 27.33 | 43.44 | 32.82 |
| 5. | Hara Bona | 46.73 | 73.24 | 54.51 | 81.56 | 64.01 |
| 6. | JP-829 | 14.98 | 37.76 | 18.02 | 47.07 | 29.46 |
| 7. | Jawahar Matar-4 | 14.56 | 25.62 | 15.22 | 31.69 | 21.77 |
| 8. | V.P.-7802 | 17.29 | 32.60 | 24.93 | 40.44 | 28.81 |
| 9. | V.P.-7839 | 11.02 | 30.29 | 21.20 | 37.04 | 24.89 |
| 10. | V.P.-8005 | 13.36 | 39.29 | 22.80 | 68.00 | 35.86 |
| 11. | Bonneville | 7.16 | 25.91 | 9.87 | 46.31 | 22.31 |
| 12. | Lincoln | 6.49 | 19.36 | 10.27 | 25.04 | 15.29 |
| 13. | Vipasa | 7.51 | 33.31 | 24.49 | 51.82 | 29.28 |
| 14. | VL-3 | 17.53 | 26.09 | 20.87 | 32.00 | 24.12 |
| 15. | Jawhar Matar-1 | 35.49 | 44.78 | 37.16 | 59.02 | 44.11 |
| 16. | KS-123 | 9.87 | 22.02 | 21.22 | 33.00 | 21.53 |
| 17. | IP-3 | 6.16 | 10.93 | 6.47 | 15.80 | 39.36 |
| 18. | VL-2 | 20.49 | 40.20 | 23.36 | 51.38 | 33.86 |
| 19. | Pb-88 | 11.44 | 16.47 | 12.96 | 24.73 | 16.40 |
| 20. | Sel. 222 | 4.42 | 7.29 | 4.69 | 8.18 | 6.14 |
| 21. | Early perfection | 12.93 | 32.98 | 15.93 | 35.64 | 24.37 |
| 22. | Selection-17 | 14.22 | 18.91 | 17.29 | 31.84 | 20.56 |
| 23. | Kala Nagini | 12.56 | 24.00 | 14.56 | 46.09 | 24.30 |
| 24. | JP-501 | 9.11 | 22.69 | 12.91 | 25.07 | 17.44 |
| 25. | P-388 | 9.93 | 19.89 | 13.09 | 21.62 | 16.13 |
| 26. | P-6587-1 | 5.96 | 9.84 | 7.04 | 14.82 | 9.41 |
| 27. | P-6588-1 | 11.51 | 14.62 | 12.89 | 18.98 | 14.50 |
| 28. | UU-2 | 13.98 | 17.60 | 15.93 | 25.87 | 18.34 |
| 29. | UU-3 | 6.96 | 16.49 | 8.84 | 25.51 | 14.45 |
| 30. | ACC-65 | 13.13 | 31.33 | 21.42 | 64.18 | 32.51 |

C.D.((P= 0.05) varietal means = 2.448
C.D. (P= 0.05) Treatment means =1.628

**Table No.7 (B) Mean Nodule Count per plant pooled over growth stage**

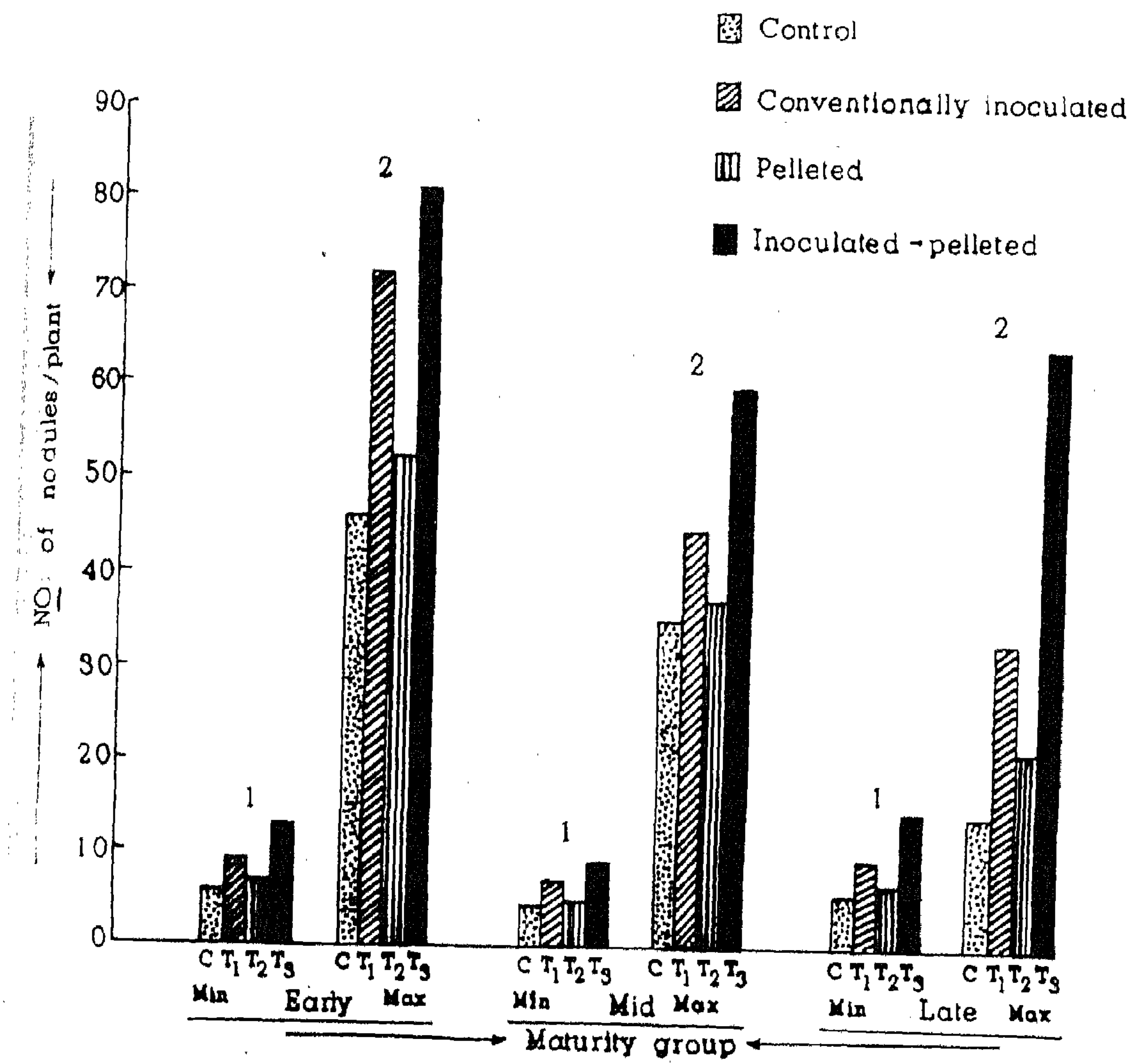
**IInd Year**

**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 6.67 | 14.01 | 7.22 | 15.42 | 10.83 |
| 2. | Meteor | 14.39 | 23.09 | 17.78 | 37.11 | 23.09 |
| 3. | Early Badger | 7.56 | 10.00 | 8.16 | 13.53 | 9.81 |
| 4. | Little Marvel | 25.16 | 34.80 | 28.33 | 41.36 | 32.41 |
| 5. | Hara Bona | 47.18 | 77.58 | 53.53 | 80.40 | 64.64 |
| 6. | JP-829 | 14.73 | 36.60 | 19.44 | 49.22 | 30.00 |
| 7. | Jawahar Matar-4 | 14.76 | 27.73 | 16.93 | 32.73 | 23.04 |
| 8. | V.P.-7802 | 16.96 | 31.27 | 26.17 | 38.36 | 28.19 |
| 9. | V.P.-7839 | 11.16 | 30.56 | 20.71 | 38.93 | 25.35 |
| 10. | V.P.-8005 | 13.84 | 38.51 | 22.93 | 68.20 | 35.87 |
| 11. | Bonneville | 10.22 | 27.87 | 16.89 | 53.98 | 27.24 |
| 12. | Lincoln | 9.84 | 16.78 | 13.09 | 24.11 | 15.95 |
| 13. | Vipasa | 10.13 | 37.73 | 34.04 | 19.29 | 32.80 |
| 14. | VL-3 | 23.16 | 30.13 | 94.52 | 38.66 | 29.12 |
| 15. | Jawhar Matar-1 | 38.07 | 49.62 | 43.49 | 57.11 | 47.07 |
| 16. | KS-123 | 10.64 | 29.84 | 25.60 | 35.34 | 25.35 |
| 17. | IP-3 | 7.24 | 13.47 | 7.80 | 15.36 | 10.97 |
| 18. | VL-2 | 22.42 | 45.29 | 24.09 | 58.18 | 37.49 |
| 19. | Pb-88 | 13.84 | 20.47 | 14.64 | 38.16 | 21.68 |
| 20. | Sel. 222 | 5.24 | 9.40 | 6.56 | 13.00 | 8.55 |
| 21. | Early perfection | 16.96 | 41.69 | 21.18 | 45.02 | 31.21 |
| 22. | Selection-17 | 17.67 | 24.80 | 21.80 | 43.71 | 26.99 |
| 23. | Kala Nagini | 16.51 | 33.96 | 19.58 | 50.31 | 30.09 |
| 24. | JP-501 | 11.96 | 26.38 | 15.89 | 28.36 | 20.65 |
| 25. | P-388 | 12.87 | 31.02 | 16.56 | 33.04 | 23.37 |
| 26. | P-6587-1 | 9.09 | 12.07 | 10.18 | 15.38 | 11.68 |
| 27. | P-6588-1 | 14.04 | 19.67 | 14.47 | 20.29 | 17.12 |
| 28. | UU-2 | 18.71 | 23.93 | 22.31 | 28.98 | 23.48 |
| 29. | UU-3 | 9.60 | 19.80 | 10.11 | 99.81 | 34.83 |
| 30. | ACC-65 | 12.04 | 31.36 | 94.43 | 67.76 | 33.90 |

CD (P=0.05) varietal means =

CD (P=0.05) Treatment means =




1. Varieties showing minimum yield
2. Varieties showing maximum yield

Fig:2 - Effect of inoculation methods on nodule Number (MIN., MAX.)

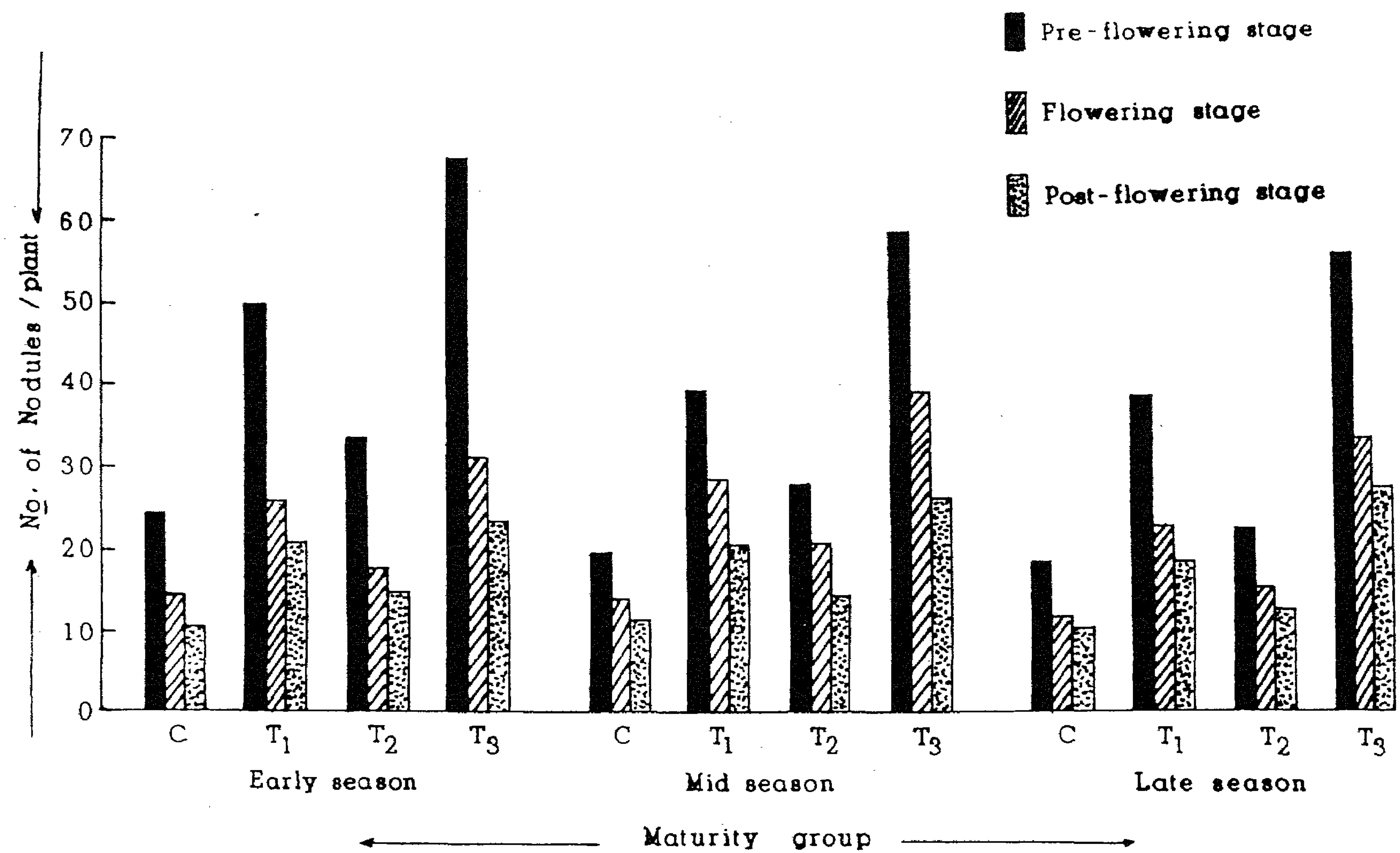



Fig 3 - Effect of inoculation methods on nodule number at different growth stages.

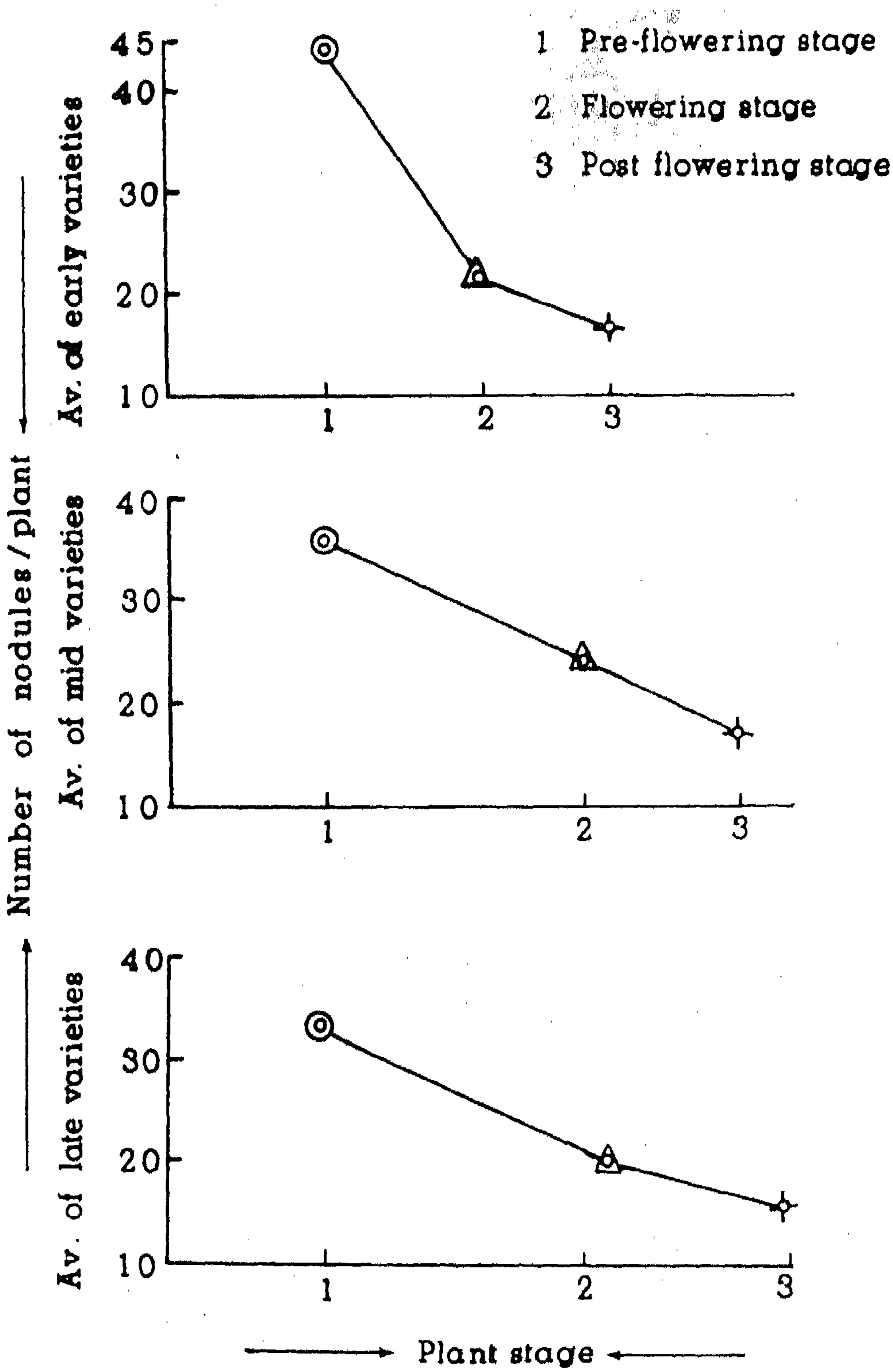
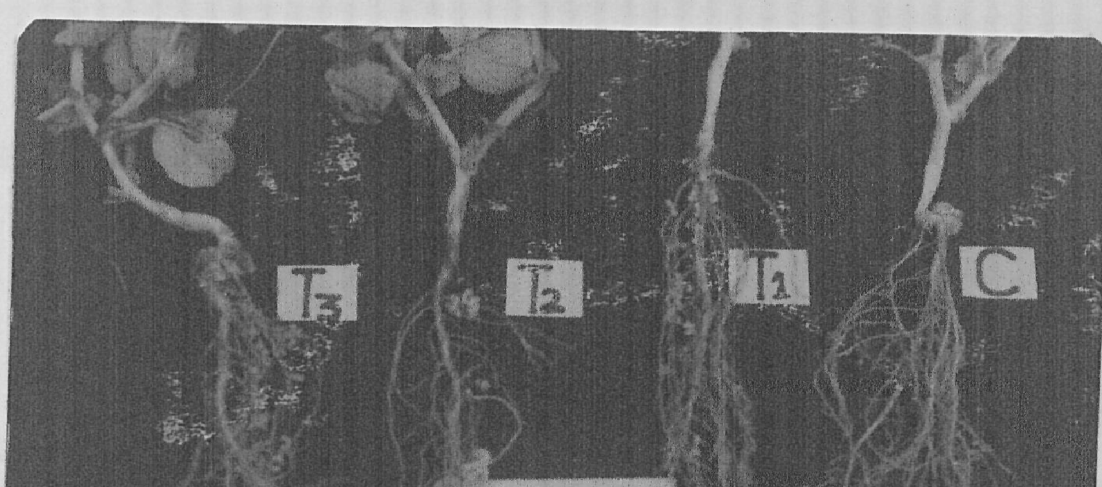



Fig 4 - Variation in nodule number with plant growth stages in early mid and late cultivars.


Pre-flowering stage




Closer view

**Pl.6** Showing nodulation at different plant stages


Flowering stage


Post-flowering stage

Pl.7 Showing nodulation at different plant stages in pelleted (as was in pre flowering stage), and VP-8005 responded best with inoculated -pelleted treatment as was in pre flowering stage).

In the mid maturing group the highest absolute increase was observed in Jawahar Matar -1 (as was at flowering and post-flowering), while the relative increase over control in different treatments indicated Vipasa to respond best.

In late maturing group ACC-65 was found to respond best (as was in flowering and post flowering stages). Inoculated and pelleted when studied separately had similar effects as shown at flowering stage, showing Early Perfection and ACC-65 to respond best, while for the inoculated - pelleted combination, the maximum response was in case of ACC -65 (as was post flowering stage).

Results obtained for number of nodules per plant was also aided by suitable bar diagram for available maximum and minimum responses figures of the three maturity groups in all the treatment effects (fig 2), Maximum response was in inoculated -pelleted combination in the early maturing group followed by late maturing group and mid maturing group. The response was evidently superior in case of mid maturing group.

When all the growth stages were studied together (fig 3) the maximum response was indicated in case of inoculated-pelleted combination at pre flowering stage in early maturing group. A sharp decrease in nodule number was observed as the plant matured and shifted from pre flowering to flowering stage. From flowering to post flowering stage the relative reduction in nodule number was significantly low as compared to early reduction observed from pre flowering to flowering stage. The finding was also supported by the line graph (fig 4).

## 2. Dry weight of nodules per plant (mg)

The observed differences in varieties, treatments and their interactions for dry weight of nodules per plant were found statistically significant. The influence of culture application are summarized over three growth stages as follows:

### 2a Pre flowering stage :

The cultivar Hara Bona (99.35 mg in first year and 98.98 mg in second year)was found to respond maximum in case of early maturing group followed by VP-7839 (90.01 mg) and VP-8005 (87.38 mg). In mid maturing group Jawahar Matar 1 was found to be the best performer in both the years. The varieties next to Jawahar Matar-1 were Vipasa (94.27mg) and VL-2 (81.24 mg) in the first year while in the second year the trend was found reversed. Among late cultivars Early Perfection was found to perform in both the years (78.97 and 62.97 mg) outstanding (Table No. 8A & 8B).

The treatment effects indicated that when the pelletant (Calcium-sulphate) was applied on the conventionally inoculated seeds, it resulted in a significantly higher nodule dry weight per plant over control than inoculated and pelleted effects when examined separately.

Studying the variety and treatment interaction, it was noticed that although the absolute increase was shown by the cultivar Hara Bona, the relative increase over control was observed in different varieties in different treatment groups. For example, the cultivar VP-7839 was found to show maximum relative increase in conventionally inoculated and in Pelleted while variety VP-8005 responded maximum in combination treatment where inoculant and Pelletant were applied together. Similar trends in performance was evident in both the years. In mid maturing group though the absolute increase was shown by Jawahar Matar-1 over treatment means, the maximum relative increase was in Vipasa with conventional inoculation in both the years. When only Pelletant was applied, Vipasa responded maximum in the first year but in the second year Jawahar Matar-1 responded best. In case of inoculated-pelleted combination, the best result was obtained with Bonneville in both the years. In the late maturing group, though the absolute increase was observed in Early Perfection, but the relative performance over control was shown differently in first and second year. The cultivars P-388, Early Perfection and Kala Nagini in first year and cultivars,namely Early Perfection, ACC-65 and again ACC-65 in second year were found to perform best in inoculated, pelleted and inoculated-pelleted combination respectively.

**2b. Flowering stage:**

The observed varietal performance at flowering stage described that the maximum nodule dry weight was found in variety Hara Bona (74.89 mg & 74.14 mg in first and second year respectively) in the early maturing groups, in variety Jawahar Matar-1 (78.03 mg & 97.52 mg in first and second year respectively) in mid maturing group and in variety

**Table No.8(A) Mean Nodule dry weight at pre flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 12.79 | 44.15 | 27.60 | 100.35 | 46.22 |
| 2. | Meteor | 24.29 | 67.93 | 45.51 | 80.15 | 54.47 |
| 3. | Early Badger | 11.62 | 21.61 | 18.25 | 95.85 | 36.83 |
| 4. | Little Marvel | 24.53 | 110.04 | 79.11 | 122.76 | 84.11 |
| 5. | Hara Bona | 44.68 | 123.50 | 93.49 | 135.73 | 99.35 |
| 6. | JP-829 | 21.59 | 88.27 | 39.51 | 138.35 | 71.93 |
| 7. | Jawahar Matar-4 | 22.99 | 57.35 | 40.50 | 121.30 | 60.53 |
| 8. | V.P.-7802 | 22.44 | 65.59 | 36.42 | 130.02 | 63.62 |
| 9. | V.P.-7839 | 22.42 | 119.35 | 83.74 | 134.55 | 90.01 |
| 10. | V.P.-8005 | 23.35 | 111.03 | 59.06 | 156.09 | 87.38 |
| 11. | Bonneville | 17.23 | 70.01 | 43.31 | 140.17 | 67.68 |
| 12. | Lincoln | 21.53 | 126.43 | 33.49 | 122.04 | 80.87 |
| 13. | Vipasa | 20.45 | 128.88 | 88.39 | 139.37 | 94.27 |
| 14. | VL-3 | 25.57 | 97.23 | 63.31 | 129.87 | 78.97 |
| 15. | Jawhar Matar-1 | 31.49 | 124.55 | 92.52 | 138.30 | 46.71 |
| 16. | KS-123 | 14.47 | 74.79 | 43.11 | 135.92 | 67.07 |
| 17. | IP-3 | 13.09 | 41.54 | 20.04 | 64.64 | 34.83 |
| 18. | VL-2 | 18.81 | 106.79 | 62.00 | 137.35 | 81.24 |
| 19. | Pb-88 | 13.50 | 54.60 | 36.50 | 122.57 | 56.79 |
| 20. | Sel. 222 | 8.41 | 28.53 | 15.42 | 49.47 | 25.46 |
| 21. | Early perfection | 24.39 | 98.81 | 60.71 | 131.99 | 78.97 |
| 22. | Selection-17 | 22.73 | 62.16 | 37.14 | 118.37 | 60.10 |
| 23. | Kala Nagini | 23.71 | 102.53 | 50.26 | 138.37 | 78.72 |
| 24. | JP-501 | 15.93 | 75.67 | 38.03 | 103.22 | 58.22 |
| 25. | P-388 | 18.57 | 100.55 | 41.12 | 131.15 | 72.85 |
| 26. | P-6587-1 | 18.27 | 62.96 | 37.08 | 102.15 | 55.61 |
| 27. | P-6588-1 | 18.14 | 51.39 | 27.54 | 85.66 | 45.68 |
| 28. | UU-2 | 22.19 | 86.43 | 52.61 | 124.63 | 71.46 |
| 29. | UU-3 | 15.47 | 59.82 | 24.70 | 88.69 | 47.17 |
| 30. | ACC-65 | 20.25 | 92.75 | 50.14 | 127.30 | 72.61 |

C.D.((P= 0.05) varietal means = 3.766
C.D. (P= 0.05) Treatment means =2.712

**Table No. 8 (B) Mean Nodule Dry Weight at pre flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 12.51 | 44.01 | 28.77 | 100.51 | 46.45 |
| 2. | Meteor | 27.20 | 66.58 | 46.32 | 78.97 | 54.75 |
| 3. | Early Badger | 12.54 | 22.12 | 17.67 | 95.44 | 36.94 |
| 4. | Little Marvel | 22.37 | 109.65 | 78.67 | 125.39 | 84.02 |
| 5. | Hara Bona | 43.97 | 123.48 | 92.12 | 136.37 | 93.98 |
| 6. | JP-829 | 22.17 | 89.08 | 40.11 | 136.39 | 71.94 |
| 7. | Jawahar Matar-4 | 23.65 | 56.39 | 42.65 | 123.23 | 61.48 |
| 8. | V.P.-7802 | 24.36 | 66.47 | 36.07 | 128.67 | 63.89 |
| 9. | V.P.-7839 | 22.16 | 121.07 | 83.87 | 136.41 | 90.88 |
| 10. | V.P.-8005 | 21.99 | 109.27 | 57.83 | 155.45 | 86.13 |
| 11. | Bonneville | 12.57 | 54.78 | 33.59 | 120.29 | 55.31 |
| 12. | Lincoln | 12.05 | 62.81 | 23.01 | 84.17 | 45.51 |
| 13. | Vipasa | 10.73 | 87.34 | 53.67 | 116.41 | 67.04 |
| 14. | VL-3 | 17.43 | 65.08 | 46.34 | 108.11 | 59.24 |
| 15. | Jawhar Matar-1 | 27.67 | 94.20 | 76.53 | 108.40 | 76.70 |
| 16. | KS-123 | 10.84 | 62.64 | 39.63 | 86.13 | 49.81 |
| 17. | IP-3 | 10.05 | 29.67 | 17.07 | 42.05 | 24.71 |
| 18. | VL-2 | 17.45 | 95.06 | 48.73 | 118.79 | 70.01 |
| 19. | Pb-88 | 9.47 | 41.91 | 28.31 | 69.73 | 37.35 |
| 20. | Sel. 222 | 6.37 | 18.78 | 10.73 | 30.07 | 16.49 |
| 21. | Early perfection | 15.31 | 90.45 | 37.76 | 108.37 | 62.97 |
| 22. | Selection-17 | 16.30 | 45.84 | 29.27 | 93.45 | 46.21 |
| 23. | Kala Nagini | 18.77 | 67.31 | 35.49 | 116.17 | 59.43 |
| 24. | JP-501 | 13.01 | 61.96 | 22.19 | 86.73 | 45.97 |
| 25. | P-388 | 12.59 | 55.00 | 27.01 | 66.06 | 40.16 |
| 26. | P-6587-1 | 7.63 | 32.23 | 17.25 | 43.35 | 25.12 |
| 27. | P-6588-1 | 11.17 | 41.24 | 23.53 | 54.84 | 32.69 |
| 28. | UU-2 | 15.52 | 52.17 | 35.32 | 85.48 | 47.12 |
| 29. | UU-3 | 10.38 | 43.79 | 15.99 | 67.97 | 34.53 |
| 30. | ACC-65 | 12.44 | 71.01 | 37.51 | 114.91 | 58.97 |

CD (P=0.05) varietal means = 3.016
CD (P=0.05) Treatment means =3.136

Early Perfection (64.99 mg and 81.09 mg) late maturing group in both the years (Table 9A & 9B).

The treatment effects revealed that the conventionally inoculated and the pelleted results remained statistically inferior than when both were applied in combination in both the years.

The interaction revealed that the results relating relative increase were at par with the absolute result depicting same variety Hara Bona in the early maturing group to respond best in both the years. In mid maturity group, though the absolute result found to be the same in both the years with Jawahar Matar-1 responding maximum. However, the relative performance over control varied differently with respect to individual variety and treatment combinations. In the first year result, the cultivars VL-2, Jawahar Matar-1 and Vipasa were found to respond most when inoculated, pelleted and also when inoculation supplemented with pelletants, while in the second year the cultivars Vipasa, in conventionally inoculated and pelleted effect but Bonnevilla in combination effect were found to respond best in respect of nodule weights per plant. The late maturing group showed entirely a different picture i.e. Early Perfection was found with highest value in inoculated and inoculated-pelleted combination while, in case of pelleted , the cultivar ACC-65 was found best. In the second year study, P-388 was found to respond best in inoculated and combination effects while in pelleted effect UU-2 was found best. Thus the interaction effects found in the mid and late maturing groups did not respond similarly in both the years unlike the early group.

## 2C Post flowering stage:

The varietal performance recorded were found to have the same result in both the years in all the three maturity groups. In early group, the cultivar Hara Bona (67.85 mg & 66.81 mg in first and second year respectively), Jawahar Matar-1 in the mid group, (64.42 mg and 63.77 mg in first and second year respectively) and ACC-65 (51.25 mg and 50.92 mg in first and second year respectively ) in the late group were found to perform the maximum (Table 10A & 10B). A consistent decrease in nodule dry weight was found from early maturing group to late maturing group.

The treatment effect was found to follow the same trend as was observed

**Table No. 9 (A) Mean Nodule dry weight at flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 6.89 | 23.27 | 13.15 | 29.16 | 18.12 |
| 2. | Meteor | 13.47 | 52.65 | 27.56 | 68.79 | 40.62 |
| 3. | Early Badger | 6.09 | 19.42 | 12.35 | 29.53 | 16.85 |
| 4. | Little Marvel | 20.91 | 68.25 | 39.48 | 97.17 | 56.45 |
| 5. | Hara Bona | 29.01 | 101.20 | 59.88 | 109.49 | 74.89 |
| 6. | JP-829 | 17.34 | 64.57 | 28.56 | 91.83 | 50.57 |
| 7. | Jawahar Matar-4 | 12.49 | 43.59 | 31.63 | 84.47 | 43.04 |
| 8. | V.P.-7802 | 14.59 | 41.27 | 23.21 | 56.72 | 33.95 |
| 9. | V.P.-7839 | 11.42 | 31.37 | 22.64 | 58.61 | 31.01 |
| 10. | V.P.-8005 | 11.44 | 52.39 | 28.39 | 69.81 | 40.51 |
| 11. | Bonneville | 13.43 | 55.03 | 32.36 | 121.33 | 55.54 |
| 12. | Lincoln | 11.19 | 66.22 | 22.28 | 83.51 | 45.30 |
| 13. | Vipasa | 9.33 | 86.44 | 56.17 | 117.84 | 67.44 |
| 14. | VL-3 | 16.53 | 63.79 | 46.76 | 106.19 | 58.32 |
| 15. | Jawhar Matar-1 | 28.67 | 94.66 | 76.58 | 112.20 | 78.03 |
| 16. | KS-123 | 11.22 | 63.77 | 39.56 | 87.07 | 56.40 |
| 17. | IP-3 | 9.43 | 29.38 | 15.22 | 41.55 | 23.89 |
| 18. | VL-2 | 17.11 | 94.06 | 47.25 | 119.21 | 69.41 |
| 19. | Pb-88 | 10.30 | 41.90 | 27.63 | 69.42 | 37.31 |
| 20. | Sel. 222 | 5.73 | 19.91 | 11.51 | 26.75 | 15.97 |
| 21. | Early perfection | 13.63 | 89.99 | 25.68 | 130.68 | 64.99 |
| 22. | Selection-17 | 20.38 | 46.85 | 29.14 | 88.68 | 46.26 |
| 23. | Kala Nagini | 18.09 | 67.21 | 34.25 | 115.99 | 58.88 |
| 24. | JP-501 | 11.37 | 60.32 | 23.49 | 84.79 | 44.99 |
| 25. | P-388 | 12.49 | 54.20 | 25.55 | 65.80 | 39.51 |
| 26. | P-6587-1 | 9.57 | 32.83 | 14.33 | 41.18 | 24.48 |
| 27. | P-6588-1 | 12.00 | 40.33 | 24.49 | 53.99 | 32.70 |
| 28. | UU-2 | 13.51 | 54.95 | 36.47 | 86.43 | 47.34 |
| 29. | UU-3 | 9.40 | 43.16 | 17.13 | 66.39 | 34.02 |
| 30. | ACC-65 | 13.04 | 69.65 | 36.43 | 113.79 | 58.23 |

C.D.((P= 0.05) varietal means = 3.256
C.D. (P= 0.05) Treatment means =2.546

**Table No. 9 (B) Mean Nodule Dry Weight at flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 7.33 | 24.96 | 13.27 | 28.90 | 18.61 |
| 2. | Meteor | 15.39 | 50.59 | 29.46 | 68.99 | 41.11 |
| 3. | Early Badger | 6.62 | 21.04 | 14.16 | 29.39 | 17.80 |
| 4. | Little Marvel | 19.21 | 69.09 | 40.64 | 96.27 | 56.30 |
| 5. | Hara Bona | 28.12 | 99.71 | 60.40 | 108.34 | 74.14 |
| 6. | JP-829 | 17.45 | 62.13 | 28.80 | 92.60 | 50.24 |
| 7. | Jawahar Matar-4 | 14.45 | 43.60 | 32.91 | 84.91 | 43.97 |
| 8. | V.P.-7802 | 16.10 | 39.12 | 25.34 | 57.27 | 34.46 |
| 9. | V.P.-7839 | 12.93 | 34.81 | 22.17 | 58.39 | 32.07 |
| 10. | V.P.-8005 | 12.91 | 51.11 | 30.12 | 68.01 | 40.54 |
| 11. | Bonneville | 16.28 | 69.67 | 42.61 | 142.59 | 67.79 |
| 12. | Lincoln | 20.10 | 126.46 | 35.25 | 141.85 | 80.91 |
| 13. | Vipasa | 20.20 | 132.10 | 90.10 | 130.15 | 95.14 |
| 14. | VL-3 | 27.41 | 79.43 | 65.51 | 131.63 | 80.99 |
| 15. | Jawhar Matar-1 | 33.67 | 125.95 | 92.29 | 138.17 | 97.52 |
| 16. | KS-123 | 13.54 | 75.71 | 44.00 | 137.02 | 67.52 |
| 17. | IP-3 | 13.54 | 42.44 | 25.51 | 65.65 | 36.78 |
| 18. | VL-2 | 21.68 | 105.37 | 65.49 | 135.40 | 81.98 |
| 19. | Pb-88 | 15.08 | 55.75 | 37.95 | 126.56 | 58.83 |
| 20. | Sel. 222 | 9.59 | 31.11 | 17.77 | 49.52 | 27.00 |
| 21. | Early perfection | 27.46 | 104.02 | 60.71 | 132.18 | 31.09 |
| 22. | Selection-17 | 23.56 | 64.50 | 37.44 | 116.11 | 60.40 |
| 23. | Kala Nagini | 27.40 | 104.70 | 51.19 | 137.45 | 80.18 |
| 24. | JP-501 | 14.03 | 76.30 | 38.15 | 99.57 | 57.01 |
| 25. | P-388 | 18.33 | 101.67 | 40.73 | 128.73 | 72.36 |
| 26. | P-6587-1 | 18.55 | 66.05 | 39.12 | 102.63 | 56.59 |
| 27. | P-6588-1 | 17.67 | 56.07 | 26.50 | 89.38 | 47.40 |
| 28. | UU-2 | 20.06 | 82.67 | 56.25 | 125.19 | 71.29 |
| 29. | UU-3 | 17.45 | 60.55 | 15.43 | 87.51 | 47.73 |
| 30. | ACC-65 | 19.43 | 92.50 | 52.50 | 128.12 | 73.14 |

CD (P=0.05) varietal means = 3.044
CD (P=0.05) Treatment means = 3.041

**Tabel No. 10 (A)Mean Nodule dry weight at post flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.25 | 14.67 | 9.48 | 19.60 | 12.25 |
| 2. | Meteor | 10.26 | 42.93 | 20.11 | 61.46 | 33.69 |
| 3. | Early Badger | 5.19 | 10.21 | 6.81 | 22.09 | 11.07 |
| 4. | Little Marvel | 17.37 | 49.50 | 36.00 | 63.08 | 41.49 |
| 5. | Hara Bona | 24.86 | 88.63 | 53.83 | 104.09 | 67.85 |
| 6. | JP-829 | 13.63 | 49.43 | 23.09 | 69.65 | 38.95 |
| 7. | Jawahar Matar-4 | 13.49 | 38.73 | 23.35 | 63.29 | 34.71 |
| 8. | V.P.-7802 | 10.52 | 32.80 | 20.05 | 51.82 | 28.80 |
| 9. | V.P.-7839 | 9.45 | 28.31 | 17.31 | 48.51 | 25.89 |
| 10. | V.P.-8005 | 7.51 | 40.07 | 19.01 | 53.19 | 29.94 |
| 11. | Bonneville | 9.47 | 35.66 | 25.46 | 78.99 | 37.39 |
| 12. | Lincoln | 8.73 | 38.23 | 18.59 | 42.67 | 27.05 |
| 13. | Vipasa | 7.70 | 57.44 | 31.51 | 74.50 | 42.79 |
| 14. | VL-3 | 13.37 | 55.52 | 32.60 | 78.85 | 45.08 |
| 15. | Jawhar Matar-1 | 26.31 | 75.29 | 61.00 | 95.09 | 64.42 |
| 16. | KS-123 | 9.12 | 44.04 | 33.17 | 68.69 | 38.75 |
| 17. | IP-3 | 6.50 | 22.35 | 11.30 | 32.94 | 18.27 |
| 18. | VL-2 | 13.64 | 71.14 | 33.91 | 92.19 | 52.72 |
| 19. | Pb-88 | 9.44 | 32.13 | 21.00 | 61.21 | 30.94 |
| 20. | Sel. 222 | 3.97 | 73.92 | 8.63 | 21.71 | 12.06 |
| 21. | Early perfection | 10.51 | 52.77 | 28.57 | 79.01 | 42.71 |
| 22. | Selection-17 | 13.55 | 41.36 | 22.95 | 71.16 | 37.25 |
| 23. | Kala Nagini | 12.83 | 47.78 | 30.20 | 91.58 | 45.60 |
| 24. | JP-501 | 9.98 | 42.11 | 21.13 | 58.56 | 32.94 |
| 25. | P-388 | 10.36 | 36.23 | 20.75 | 50.64 | 29.49 |
| 26. | P-6587-1 | 6.35 | 31.48 | 12.45 | 35.65 | 21.48 |
| 27. | P-6588-1 | 11.01 | 31.25 | 21.79 | 47.90 | 27.99 |
| 28. | UU-2 | 10.56 | 45.20 | 25.52 | 55.67 | 34.24 |
| 29. | UU-3 | 8.36 | 33.25 | 13.01 | 57.53 | 28.04 |
| 30. | ACC-65 | 10.94 | 63.95 | 34.37 | 96.26 | 51.25 |

C.D.((P= 0.05) varietal means = 2.918
C.D. (P= 0.05) Treatment means =2.728

**Table No. 10 (B) Mean Nodule Dry Weight at post flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.80 | 16.51 | 10.39 | 20.43 | 13.28 |
| 2. | Meteor | 11.13 | 40.87 | 21.54 | 62.13 | 33.92 |
| 3. | Early Badger | 5.61 | 11.11 | 7.47 | 24.10 | 12.07 |
| 4. | Little Marvel | 17.40 | 51.57 | 35.01 | 62.53 | 41.63 |
| 5. | Hara Bona | 23.07 | 90.16 | 52.27 | 101.76 | 66.81 |
| 6. | JP-829 | 14.48 | 49.81 | 25.03 | 70.15 | 39.87 |
| 7. | Jawahar Matar-4 | 13.18 | 37.73 | 24.44 | 66.65 | 35.50 |
| 8. | V.P.-7802 | 10.24 | 32.79 | 20.21 | 48.80 | 28.01 |
| 9. | V.P.-7839 | 9.51 | 28.39 | 16.67 | 49.45 | 26.00 |
| 10. | V.P.-8005 | 8.31 | 38.43 | 18.18 | 52.75 | 29.42 |
| 11. | Bonneville | 9.37 | 35.57 | 27.34 | 82.51 | 38.70 |
| 12. | Lincoln | 9.77 | 42.08 | 19.83 | 44.52 | 29.05 |
| 13. | Vipasa | 7.69 | 58.67 | 29.34 | 74.73 | 42.61 |
| 14. | VL-3 | 13.39 | 54.12 | 34.71 | 79.38 | 45.40 |
| 15. | Jawhar Matar-1 | 26.38 | 75.20 | 58.98 | 94.52 | 63.77 |
| 16. | KS-123 | 9.46 | 44.66 | 33.27 | 70.84 | 39.56 |
| 17. | IP-3 | 7.25 | 21.39 | 11.67 | 32.15 | 18.11 |
| 18. | VL-2 | 13.54 | 70.73 | 33.59 | 92.93 | 52.70 |
| 19. | Pb-88 | 9.11 | 31.43 | 20.79 | 60.80 | 30.53 |
| 20. | Sel. 222 | 3.91 | 12.99 | 8.99 | 21.47 | 11.84 |
| 21. | Early perfection | 11.13 | 54.95 | 29.43 | 80.03 | 43.88 |
| 22. | Selection-17 | 12.87 | 40.07 | 23.63 | 70.10 | 36.67 |
| 23. | Kala Nagini | 13.44 | 47.13 | 30.03 | 87.91 | 44.63 |
| 24. | JP-501 | 9.48 | 40.77 | 20.58 | 58.76 | 32.40 |
| 25. | P-388 | 10.79 | 36.05 | 20.53 | 51.17 | 29.63 |
| 26. | P-6587-1 | 6.03 | 30.40 | 11.45 | 35.43 | 20.83 |
| 27. | P-6588-1 | 10.95 | 32.33 | 20.87 | 47.73 | 27.97 |
| 28. | UU-2 | 10.58 | 44.12 | 24.15 | 54.99 | 33.46 |
| 29. | UU-3 | 8.32 | 32.65 | 12.97 | 57.11 | 27.76 |
| 30. | ACC-65 | 11.09 | 62.87 | 33.13 | 96.59 | 50.92 |

CD (P=0.05) varietal means = 2.828
CD (P=0.05) Treatment means = 2.528

in pre-flowering and flowering stages showing inoculant in combination with pelletant to give the best result.

The interaction results depicted reasonable facts to select out cultivars in early and late maturing groups as the best responders in both early and late maturity groups: Hara Bona and ACC-65 were the cultivars in early and late groups respectively. Both the cultivars showed inoculated- pelleted effect to give distinct increase over control followed by conventionally inoculated and then by pelleted effect. However, the mid maturing group behaved differently, although the pattern of change was same in both the years. In case of conventionally inoculated and inoculation in combination with Pelletant, the same cultivar VL-2 was found to respond best in both the years, while when Pelletant alone was applied without culture application, Jawahar Matar-1 was found to respond best in both the years study.

## 2d Pooled Analysis over three growth stages:

The periodic observations taken at different stages of growth when pooled together indicated that the treatment influence on dry weight of nodule per plant was quite significant (Table 11A & 11B). Pooled analysis sorted out the cultivar Hara Bona as the best responder in the early maturing group( which was also the findings of flowering and post flowering stages). The interaction study revealed that the treatment combination (Inoculated - pelleted) responded best (116.44 mg) followed by conventionally inoculated (104.44 mg) and then pelleted (69.06 mg) respectively, in the first year, while the values for second year results followed same trend with little differences. In the mid maturing group both the absolute as well as relative values were found to follow the same trend in both the years. Jawahar Matar-1 was found to have the maximum absolute value (as was in all the three periodic results). However, among relative responses, the inoculated and the inoculated (cultivar-Vipasa) in combination with Pelletant (Cultivar-Bonneville) responded similar to the pre flowering stage. In the late maturity group the maximum absolute value was obtained in the variety Early Perfection (as was in pre flowering and flowering stages) but the maximum relative increase over control in conventionally inocuated was observed in Early Perfection (as was in flowering stage). In case of pelleted and inoculated -pelleted combination, the cultivar

**Table No. 11(A) Mean Nodule dry weight pooled over growth stages**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

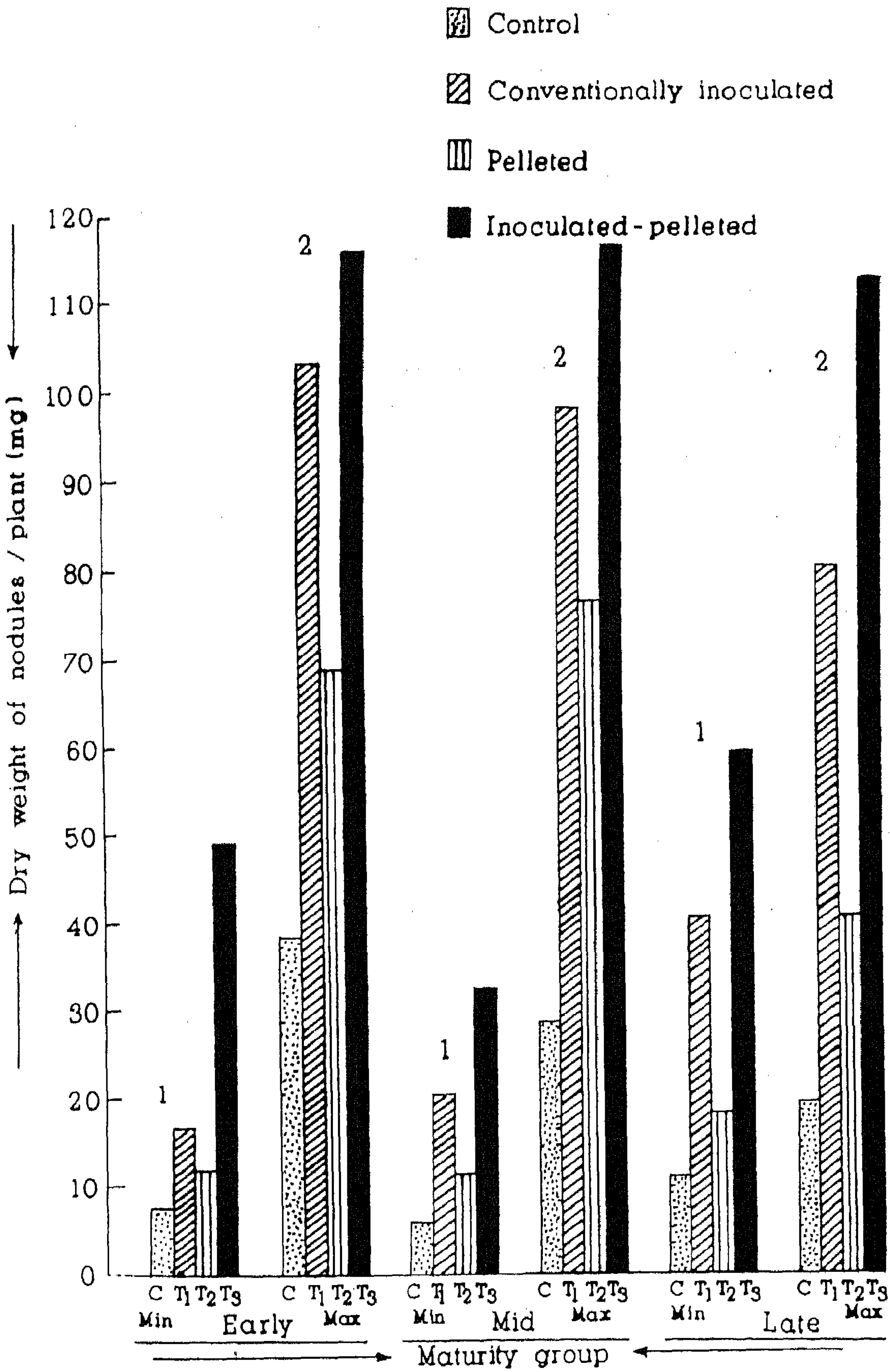
| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 8.31 | 27.36 | 16.74 | 49.70 | 25.53 |
| 2. | Meteor | 16.01 | 54.50 | 31.06 | 70.14 | 42.93 |
| 3. | Early Badger | 7.63 | 17.08 | 12.47 | 49.16 | 21.58 |
| 4. | Little Marvel | 20.94 | 75.93 | 51.53 | 94.34 | 60.68 |
| 5. | Hara Bona | 32.85 | 104.44 | 69.06 | 116.44 | 80.70 |
| 6. | JP-829 | 17.52 | 87.42 | 30.39 | 99.94 | 53.82 |
| 7. | Jawahar Matar-4 | 16.32 | 46.56 | 31.83 | 89.69 | 46.10 |
| 8. | V.P.-7802 | 15.85 | 46.55 | 26.56 | 79.52 | 42.12 |
| 9. | V.P.-7839 | 14.43 | 59.68 | 41.23 | 80.56 | 48.97 |
| 10. | V.P.-8005 | 14.10 | 67.83 | 35.49 | 93.03 | 52.61 |
| 11. | Bonneville | 13.38 | 53.57 | 33.71 | 113.50 | 53.54 |
| 12. | Lincoln | 13.82 | 76.96 | 24.79 | 89.41 | 33.50 |
| 13. | Vipasa | 12.49 | 90.92 | 58.69 | 110.57 | 68.17 |
| 14. | VL-3 | 18.49 | 72.18 | 47.56 | 104.97 | 50.79 |
| 15. | Jawhar Matar-1 | 28.82 | 98.17 | 76.70 | 115.20 | 79.72 |
| 16. | KS-123 | 11.60 | 60.87 | 38.62 | 97.23 | 52.08 |
| 17. | IP-3 | 9.67 | 31.09 | 15.52 | 46.38 | 25.66 |
| 18. | VL-2 | 16.52 | 90.66 | 47.72 | 116.25 | 67.79 |
| 19. | Pb-88 | 11.08 | 42.88 | 28.38 | 84.40 | 41.68 |
| 20. | Sel. 222 | 6.04 | 20.79 | 11.86 | 32.64 | 17.83 |
| 21. | Early perfection | 16.17 | 80.52 | 40.99 | 105.90 | 60.90 |
| 22. | Selection-17 | 19.55 | 50.13 | 29.74 | 92.74 | 48.04 |
| 23. | Kala Nagini | 18.21 | 72.51 | 38.24 | 115.32 | 61.07 |
| 24. | JP-501 | 12.93 | 59.37 | 27.55 | 82.19 | 45.51 |
| 25. | P-388 | 13.81 | 63.66 | 29.14 | 82.53 | 47.28 |
| 26. | P-6587-1 | 11.40 | 42.42 | 21.96 | 59.66 | 33.86 |
| 27. | P-6588-1 | 13.72 | 40.99 | 24.61 | 62.52 | 35.46 |
| 28. | UU-2 | 15.42 | 62.20 | 38.20 | 88.91 | 51.18 |
| 29. | UU-3 | 11.08 | 45.41 | 18.28 | 70.87 | 36.41 |
| 30. | ACC-65 | 14.74 | 75.29 | 40.31 | 112.53 | 60.72 |

C.D.((P= 0.05) varietal means = 2.642
C.D. (P= 0.05) Treatment means =2.183

**Table No. 11 (B) Mean Nodule Dry Weight pooled over growth stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 8.55 | 28.49 | 17.47 | 49.94 | 26.11 |
| 2. | Meteor | 17.91 | 52.68 | 32.44 | 70.03 | 43.26 |
| 3. | Early Badger | 8.26 | 18.09 | 13.10 | 49.64 | 22.27 |
| 4. | Little Marvel | 19.66 | 76.77 | 51.44 | 94.73 | 60.65 |
| 5. | Hara Bona | 31.72 | 104.45 | 68.26 | 115.49 | 79.98 |
| 6. | JP-829 | 18.03 | 67.00 | 31.32 | 99.71 | 54.01 |
| 7. | Jawahar Matar-4 | 17.09 | 45.91 | 33.33 | 91.59 | 46.97 |
| 8. | V.P.-7802 | 16.90 | 46.13 | 27.20 | 78.25 | 42.12 |
| 9. | V.P.-7839 | 14.87 | 61.42 | 40.91 | 81.42 | 49.65 |
| 10. | V.P.-8005 | 14.41 | 66.27 | 35.38 | 92.07 | 52.03 |
| 11. | Bonneville | 13.09 | 53.34 | 34.51 | 115.13 | 54.02 |
| 12. | Lincoln | 13.97 | 77.12 | 26.03 | 90.18 | 51.82 |
| 13. | Vipasa | 12.87 | 92.70 | 57.70 | 109.76 | 68.26 |
| 14. | VL-3 | 19.91 | 72.88 | 48.85 | 106.37 | 61.88 |
| 15. | Jawhar Matar-1 | 29.24 | 98.45 | 75.93 | 113.70 | 79.33 |
| 16. | KS-123 | 11.28 | 61.00 | 38.96 | 98.00 | 52.31 |
| 17. | IP-3 | 10.28 | 31.16 | 18.08 | 46.62 | 26.53 |
| 18. | VL-2 | 17.56 | 90.39 | 49.27 | 115.71 | 68.23 |
| 19. | Pb-88 | 11.22 | 43.03 | 27.02 | 85.70 | 42.24 |
| 20. | Sel. 222 | 6.62 | 20.96 | 12.50 | 33.69 | 18.44 |
| 21. | Early perfection | 17.97 | 83.14 | 42.63 | 106.86 | 62.65 |
| 22. | Selection-17 | 17.58 | 50.14 | 30.11 | 93.22 | 47.76 |
| 23. | Kala Nagini | 19.87 | 73.05 | 38.90 | 113.84 | 61.41 |
| 24. | JP-501 | 12.17 | 59.68 | 26.97 | 81.69 | 45.13 |
| 25. | P-388 | 13.90 | 64.24 | 29.42 | 81.99 | 47.39 |
| 26. | P-6587-1 | 10.74 | 42.89 | 22.60 | 60.42 | 34.16 |
| 27. | P-6588-1 | 13.26 | 43.21 | 23.63 | 63.98 | 36.02 |
| 28. | UU-2 | 15.39 | 59.66 | 38.58 | 88.88 | 50.63 |
| 29. | UU-3 | 12.05 | 45.66 | 18.13 | 70.86 | 36.67 |
| 30. | ACC-65 | 14.32 | 75.46 | 41.04 | 113.21 | 61.01 |

CD (P=0.05) varietal means = 1.668
CD (P=0.05) Treatment means = 1.828




1. Varieties showing minimum yield
2. Varieties showing maximum yield

Fig 5 – Effect of inoculation methods on module dry weight (Min. Max).

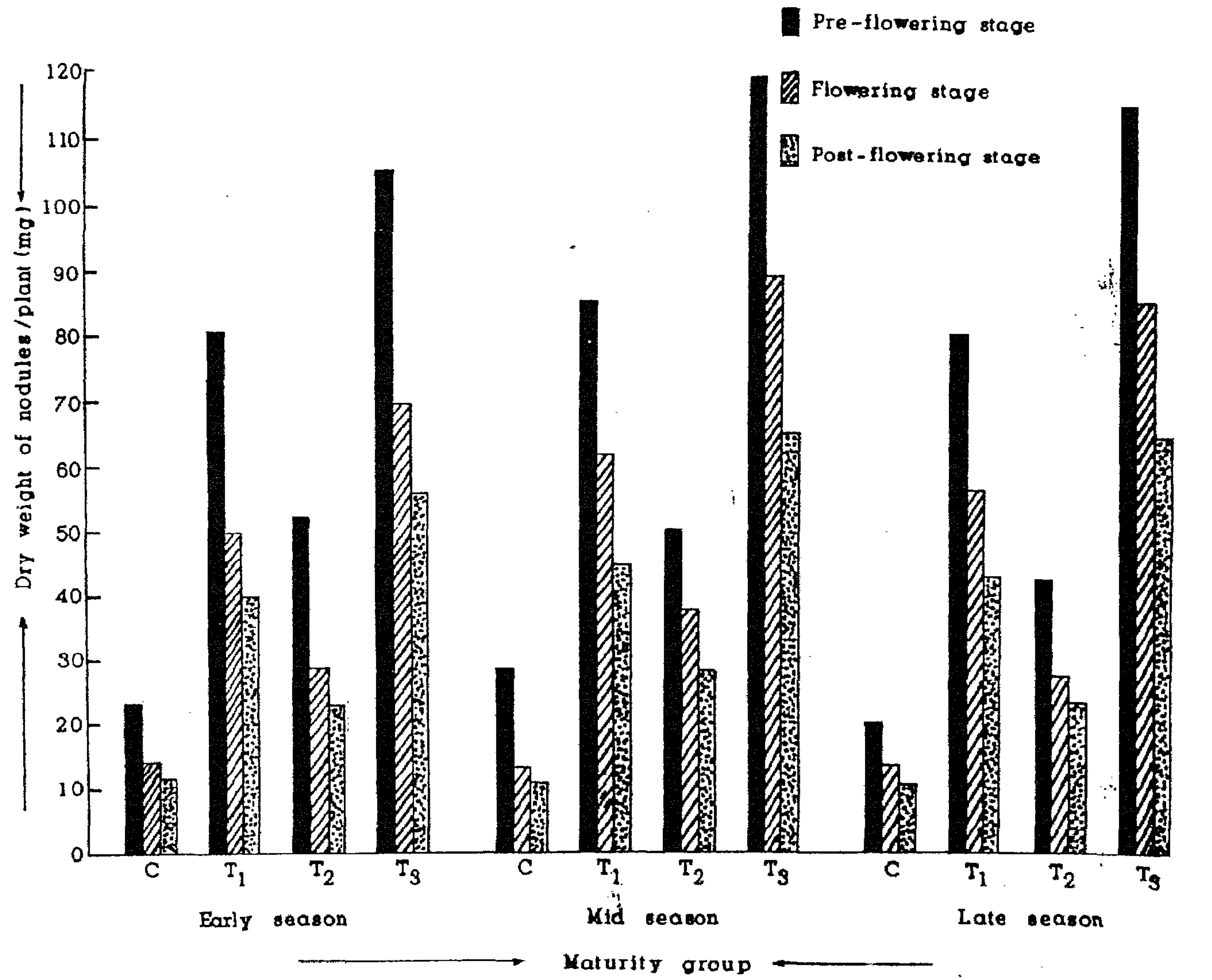



Fig. 6 Effect of inoculation methods on nodule dry weight at different growth stages.

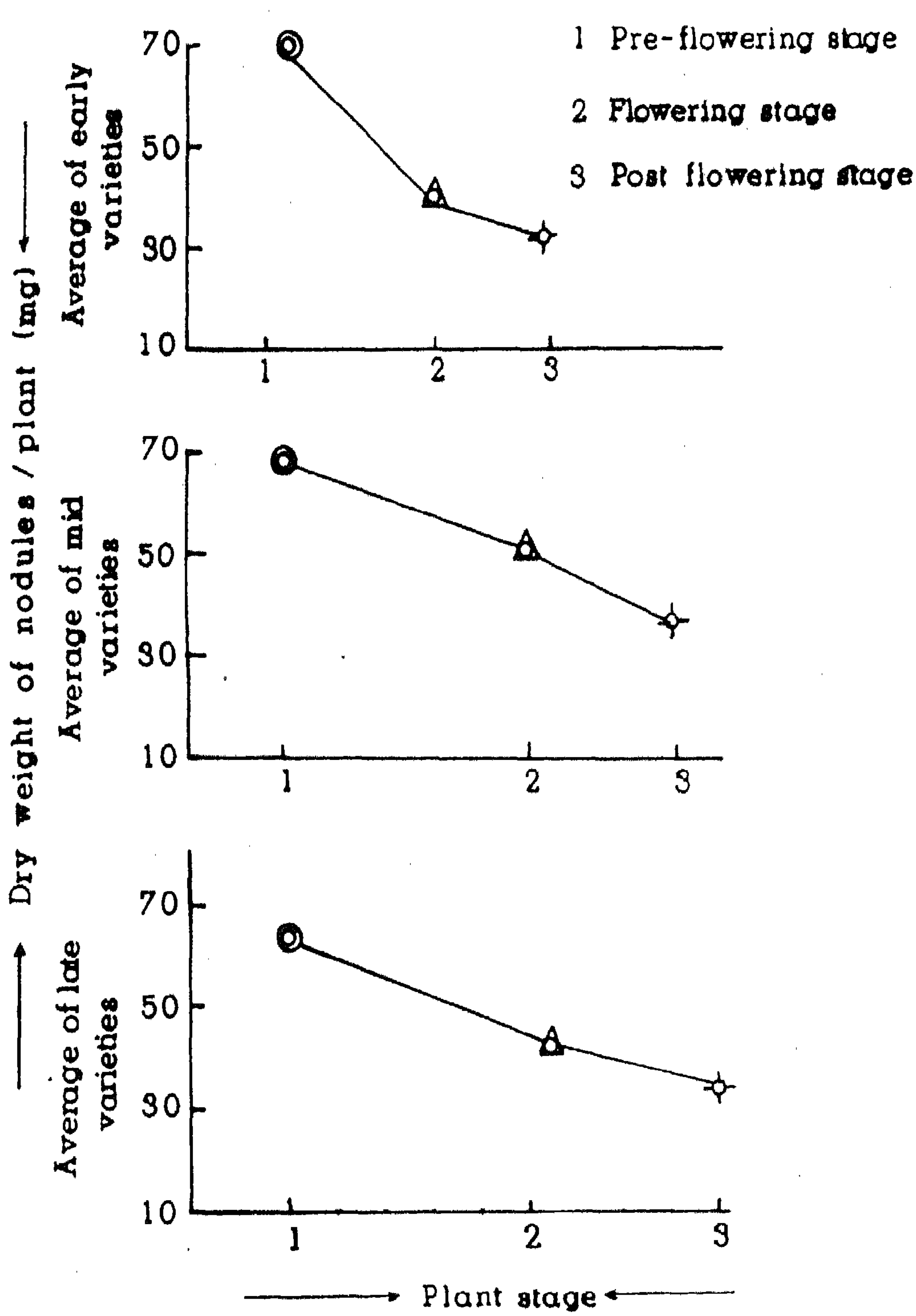



Fig. 7 - Variation in nodule dry weight with plant growth stages in early mid and laste cultivars.

ACC-65 was found to respond best (as was in post flowering results).

The pictorial depiction supported the inferences drawn out. Fig.(5) showed a distinct clarity in the pattern of varietal performances in the treatment combination. The relative increase of inoculated over control was found to be maximum in case of mid maturing group followed by early maturity group and late maturing group but the relative increase of combination effect over control was found to be maximum in the late maturing group followed by mid maturing group and early maturing group. The pelleted effects were found to be maximum in the mid maturing group followed by early and late maturing group. While studying the minimum values with different treatment combination, in all the three maturity groups the late maturing cultivars depicted the best result followed by early and mid maturing group (fig 5).

Considering all the growth stages together it was found that in all the treatment effects, pre flowering values were the highest with regard to nodule weight, followed by flowering and post flowering values. Also, the mid maturing groups showed the maximum nodule dry weight followed by late and early maturing groups. The relative decrease in nodule dry weight from pre flowering to flowering stage was much higher than the decrease from flowering to post flowering stage. In all the maturity groups studied the treatment combination responded maximum followed by inoculated and pelleted effects over control (Fig 6).

The line graph presented the same result more precisely. A sharp decrease was observed in early maturing group because the flowering stage falls early,while in mid and late maturing group, the decline was slow and linear due to relatively greater stretch of vegetative period. (Fig 7).

## 3. Plant fresh weight (gm)

Since the three maturity groups have different growth habits, a reasonable difference was observed in shoot weight among different maturing groups. The detailed study is laid down as follows:

### 3a Pre-flowering stage:

Sizeable variations were noticed in different maturity groups with regard to plant fresh weight in response to different methods of culture applications (Table No. 12A & 12B). In pre flowering stage, in both the years, the cultivars Meteor (94.50 and92.75 gm), Jawahar matar-1 (132.70 and 132.66 gm) and JP-501 (156.30 and 155.13 gm), responded maximum in the early, medium and late maturity groups.

Taking into account the individual treatment effects, the combination inoculated -pelleted significantly surpassed the individual application effect of inoculum and Pelletant. The trend was similar in all the three maturity groups considering all the 30 varieties together.

The interaction between variety and treatment reflected a significant multifold increase in relative performance over control. In the early group, it was found that inoculated- pelleted combination gave the best performance with the cultivar JP-829 yielding higher shoot weight, both in the absolute and relative values in both the years. Inoculum when conventionally applied yielded the next best result in relative terms over control with the variety Jawahar Matar-4 in both the years. The highest absolute value was shown by Metear, when only Pelletant was applied to the seeds. The results thus obtained revealed that in both the years result the same trend was followed. In the mid maturing group, the cultivar Jawahar Matar-1 was the best in inoculated- pelleted combination. Both the absolute as well the relative values over control were highest in Jawahar Matar-1 in both the years. When the inoculation was applied conventionally to the seeds, the same result was obtained. When Pelletant effect was studied, VL-2 in first year and VL-3 in the second year performed maximum.

Dealing with the late maturing group, it was interesting to note that selection-17 and JP-501 yielded highest shoot weight in inoculated and inoculated in combination with pellet in both the years. However, when only Pellet was applied without culture different effects were obtained in different years. For example, in the first year P-6588-1 and in the second year UU-2 gave the highest results. However the absolute value was found to be remarkably high in JP-501.

### 3 b flowering stage:

The treatment Means or the varietal performance in early maturing group remarkably established the cultivar, Meteor (116.11 gm) to respond maximum followed by Hara Bona (104.68 gm) in both the years

**Table No. 12 (A) Mean plant Fresh Weight at pre flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 26.53 | 56.60 | 52.33 | 63.47 | 49.73 |
| 2. | Meteor | 77.80 | 104.27 | 82.73 | 113.20 | 94.50 |
| 3. | Early Badger | 31.53 | 66.80 | 63.13 | 86.60 | 62.01 |
| 4. | Little Marvel | 42.40 | 54.00 | 41.87 | 98.93 | 59.10 |
| 5. | Hara Bona | 34.87 | 54.53 | 41.53 | 73.53 | 51.11 |
| 6. | JP-829 | 19.93 | 53.67 | 37.67 | 103.93 | 53.80 |
| 7. | Jawahar Matar-4 | 25.00 | 65.33 | 40.80 | 91.33 | 55.61 |
| 8. | V.P.-7802 | 18.07 | 30.87 | 22.93 | 47.47 | 29.83 |
| 9. | V.P.-7839 | 21.20 | 37.60 | 24.60 | 46.87 | 32.57 |
| 10. | V.P.-8005 | 36.00 | 40.27 | 38.47 | 44.73 | 39.87 |
| 11. | Bonneville | 51.93 | 88.87 | 57.67 | 104.13 | 75.65 |
| 12. | Lincoln | 66.67 | 85.20 | 70.07 | 104.93 | 81.72 |
| 13. | Vipasa | 63.07 | 79.27 | 76.60 | 87.73 | 76.67 |
| 14. | VL-3 | 83.53 | 124.47 | 99.40 | 150.93 | 114.58 |
| 15. | Jawhar Matar-1 | 96.20 | 143.67 | 98.87 | 192.07 | 132.70 |
| 16. | KS-123 | 40.67 | 82.80 | 50.07 | 104.40 | 69.48 |
| 17. | IP-3 | 62.60 | 77.00 | 71.73 | 99.60 | 77.73 |
| 18. | VL-2 | 54.53 | 77.73 | 72.60 | 107.87 | 78.18 |
| 19. | Pb-88 | 40.20 | 62.80 | 52.60 | 97.53 | 63.28 |
| 20. | Sel. 222 | 41.40 | 53.53 | 44.40 | 86.07 | 56.35 |
| 21. | Early perfection | 31.47 | 46.93 | 33.93 | 52.00 | 41.08 |
| 22. | Selection-17 | 61.60 | 126.87 | 71.47 | 134.20 | 98.53 |
| 23. | Kala Nagini | 53.60 | 62.80 | 59.40 | 73.60 | 62.35 |
| 24. | JP-501 | 119.60 | 164.60 | 129.40 | 211.60 | 156.30 |
| 25. | P-388 | 46.93 | 65.53 | 51.33 | 73.47 | 59.31 |
| 26. | P-6587-1 | 39.53 | 67.33 | 50.13 | 112.93 | 67.48 |
| 27. | P-6588-1 | 24.47 | 53.87 | 27.67 | 92.27 | 49.57 |
| 28. | UU-2 | 28.27 | 57.47 | 33.87 | 105.47 | 56.27 |
| 29. | UU-3 | 56.47 | 76.67 | 59.47 | 87.00 | 69.90 |
| 30. | ACC-65 | 21.60 | 35.60 | 26.73 | 47.20 | 32.78 |

C.D.((P= 0.05) varietal means = 2.428
C.D. (P= 0.05) Treatment means =2.662

**Table No. 12 (B) Mean Plant Fresh Weight at pre flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 24.93 | 58.87 | 53.73 | 61.33 | 49.71 |
| 2. | Meteor | 75.67 | 101.73 | 81.73 | 111.87 | 92.75 |
| 3. | Early Badger | 30.13 | 66.60 | 64.07 | 84.53 | 61.33 |
| 4. | Little Marvel | 40.40 | 53.67 | 40.93 | 97.87 | 58.22 |
| 5. | Hara Bona | 33.40 | 52.20 | 40.47 | 71.60 | 49.42 |
| 6. | JP-829 | 17.82 | 52.20 | 37.47 | 101.33 | 52.20 |
| 7. | Jawahar Matar-4 | 22.93 | 61.60 | 40.47 | 91.00 | 54.00 |
| 8. | V.P.-7802 | 16.53 | 33.33 | 20.73 | 47.27 | 29.46 |
| 9. | V.P.-7839 | 20.00 | 38.40 | 24.87 | 46.40 | 32.42 |
| 10. | V.P.-8005 | 34.40 | 40.33 | 36.27 | 43.20 | 38.55 |
| 11. | Bonneville | 51.87 | 88.60 | 57.13 | 102.13 | 74.93 |
| 12. | Lincoln | 65.93 | 85.13 | 69.13 | 105.00 | 81.30 |
| 13. | Vipasa | 63.13 | 78.60 | 76.67 | 84.60 | 75.75 |
| 14. | VL-3 | 81.80 | 124.40 | 98.40 | 149.20 | 113.95 |
| 15. | Jawhar Matar-1 | 96.40 | 145.33 | 98.33 | 190.60 | 132.66 |
| 16. | KS-123 | 39.47 | 83.23 | 50.37 | 100.73 | 68.45 |
| 17. | IP-3 | 61.80 | 75.00 | 73.07 | 97.27 | 76.78 |
| 18. | VL-2 | 55.13 | 78.93 | 70.93 | 107.33 | 78.08 |
| 19. | Pb-88 | 38.27 | 62.87 | 55.60 | 96.87 | 63.40 |
| 20. | Sel. 222 | 43.60 | 52.80 | 45.33 | 81.60 | 55.83 |
| 21. | Early perfection | 30.20 | 48.87 | 34.13 | 50.33 | 40.88 |
| 22. | Selection-17 | 59.40 | 127.73 | 69.93 | 132.73 | 97.45 |
| 23. | Kala Nagini | 51.80 | 62.20 | 57.87 | 72.80 | 61.17 |
| 24. | JP-501 | 119.07 | 161.73 | 128.60 | 211.13 | 155.13 |
| 25. | P-388 | 46.07 | 63.93 | 51.07 | 70.67 | 57.93 |
| 26. | P-6587-1 | 38.67 | 68.07 | 48.67 | 110.93 | 66.58 |
| 27. | P-6588-1 | 22.73 | 53.67 | 28.47 | 90.47 | 48.83 |
| 28. | UU-2 | 27.33 | 56.87 | 38.33 | 102.73 | 56.31 |
| 29. | UU-3 | 54.67 | 74.53 | 56.53 | 86.13 | 67.96 |
| 30. | ACC-65 | 21.13 | 35.33 | 26.13 | 46.33 | 32.23 |

CD (P=0.05) varietal means = 2.516

CD (P=0.05) Treatment means = 2.673

(Table 13A & 13B). In the mid maturing group Jawahar Matar-1 (227.95 gm in first year and 229.98 gm in second year respectively ) was found to excell among all the mid maturing varieties. Next to follow was VL-3 (156.68 gm and 157.41 gm respectively) in both the year's study. In the late maturing group JP -501 (334.77 gm and 336.08 gm in first and second year) performed the best, with values higher than what was found in early and mid maturing groups. Next to follow was Kala Nagini (217.55 gm and 219.169 gm, respectively in both years) and selection -17, with values 202.90 gm and 205.28 gm in first and second year respectively.

The treatment effects showed that the application of inoculant in combination with pelletant gave best result with regard to fresh weight of the plant. Next to follow was conventional inoculation without pellet application. When only pelletant was applied as seed treatment without the addition of bacterial inoculum, the result was found inferior to the conventionally inoculated treatment but comparatively found superior to control. The same trend of response was obtained in each maturity group as well as among all the cultivars, considered together.

The interaction study gave a different picture than what was found in the varietal performance studied earlier in early growing cultivars. Arkel was found to excell in all the treatments and their combinations in both the years. In the mid maturing group, inoculation in combination with pelletants gave the best result with the variety Jawahar Matar-1 in both the years. The conventionally inoculated treatment gave the next best result with Jawahar Matar-1 in both absolute and relative terms in both the years. When only pelletant application was studied, the cultivar VL-2 (97.80 g) was found to have the maximum relative increase over control in first year while in the second year, Jawahar Matar-1 (160.07 g) was found to excell among all other varieties studied followed by VL-2 (97.93g). In the late maturing groups also, inoculant in combination with pelletant gave the best result (512.49 g in first year and 513.73 g in second year ) with variety JP-501. Conventional inoculation performed next best by the cultivar Selection-17 (282.53 g in first year and 286.40 g in second year). Pelleted effect was found to be significantly superior over control (203.00 and 204.53 g, respectively in first and second year) in variety JP-501 (291.67 g in first year and 292.87 g in second year).

**Table No. 13(A) Mean plant fresh weight at flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 45.67 | 105.60 | 98.13 | 124.67 | 93.52 |
| 2. | Meteor | 105.00 | 124.73 | 105.80 | 128.93 | 116.11 |
| 3. | Early Badger | 84.33 | 102.20 | 98.17 | 103.87 | 95.89 |
| 4. | Little Marvel | 90.40 | 103.80 | 96.60 | 108.00 | 99.70 |
| 5. | Hara Bona | 99.27 | 106.27 | 103.87 | 109.33 | 104.68 |
| 6. | JP-829 | 39.33 | 91.20 | 72.60 | 110.73 | 78.46 |
| 7. | Jawahar Matar-4 | 43.20 | 83.27 | 68.60 | 109.00 | 76.02 |
| 8. | V.P.-7802 | 32.87 | 54.20 | 47.67 | 74.40 | 52.28 |
| 9. | V.P.-7839 | 38.53 | 67.53 | 51.67 | 76.27 | 58.50 |
| 10. | V.P.-8005 | 60.27 | 65.80 | 63.27 | 87.80 | 69.28 |
| 11. | Bonneville | 92.33 | 125.00 | 95.07 | 202.87 | 128.82 |
| 12. | Lincoln | 98.40 | 121.47 | 99.47 | 146.60 | 116.48 |
| 13. | Vipasa | 96.20 | 148.40 | 102.60 | 155.40 | 125.65 |
| 14. | VL-3 | 117.00 | 173.47 | 128.40 | 207.47 | 156.58 |
| 15. | Jawhar Matar-1 | 140.20 | 214.93 | 155.40 | 401.27 | 227.95 |
| 16. | KS-123 | 55.73 | 124.07 | 72.13 | 128.13 | 95.01 |
| 17. | IP-3 | 78.27 | 100.67 | 92.93 | 234.13 | 126.50 |
| 18. | VL-2 | 79.47 | 109.20 | 97.80 | 141.27 | 106.93 |
| 19. | Pb-88 | 51.93 | 64.20 | 58.87 | 154.47 | 82.37 |
| 20. | Sel. 222 | 77.20 | 102.13 | 81.67 | 113.27 | 93.57 |
| 21. | Early perfection | 68.53 | 73.73 | 73.07 | 88.33 | 75.91 |
| 22. | Selection-17 | 98.47 | 282.53 | 112.20 | 318.40 | 202.90 |
| 23. | Kala Nagini | 138.40 | 208.40 | 172.47 | 350.93 | 217.55 |
| 24. | JP-501 | 203.00 | 332.00 | 291.67 | 512.40 | 334.77 |
| 25. | P-388 | 125.47 | 219.13 | 188.20 | 241.27 | 193.52 |
| 26. | P-6587-1 | 153.47 | 173.47 | 153.53 | 203.20 | 170.92 |
| 27. | P-6588-1 | 55.47 | 144.40 | 67.93 | 180.20 | 112.00 |
| 28. | UU-2 | 43.00 | 170.20 | 53.07 | 201.13 | 116.85 |
| 29. | UU-3 | 94.20 | 116.33 | 98.40 | 162.00 | 117.73 |
| 30. | ACC-65 | 88.27 | 141.67 | 126.47 | 161.80 | 129.55 |

C.D.((P= 0.05) varietal means = 2.952
C.D. (P= 0.05) Treatment means =2.532

**Table No. 13 (B) Mean Plant Fresh weight at flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 49.40 | 106.20 | 96.93 | 123.13 | 93.91 |
| 2. | Meteor | 105.73 | 125.27 | 106.20 | 129.93 | 116.78 |
| 3. | Early Badger | 85.07 | 102.80 | 93.73 | 104.87 | 96.62 |
| 4. | Little Marvel | 93.53 | 102.60 | 98.67 | 108.40 | 100.80 |
| 5. | Hara Bona | 98.80 | 106.73 | 104.20 | 109.47 | 104.80 |
| 6. | JP-829 | 48.40 | 93.60 | 74.60 | 111.80 | 80.35 |
| 7. | Jawahar Matar-4 | 41.53 | 85.33 | 68.13 | 111.60 | 77.15 |
| 8. | V.P.-7802 | 32.80 | 55.53 | 48.27 | 76.90 | 53.37 |
| 9. | V.P.-7839 | 39.00 | 67.93 | 53.53 | 76.33 | 59.20 |
| 10. | V.P.-8005 | 62.60 | 67.47 | 64.93 | 88.40 | 70.85 |
| 11. | Bonneville | 94.27 | 127.27 | 97.60 | 205.53 | 131.17 |
| 12. | Lincoln | 99.40 | 123.67 | 100.40 | 147.53 | 117.75 |
| 13. | Vipasa | 97.27 | 149.33 | 101.73 | 156.40 | 126.18 |
| 14. | VL-3 | 118.40 | 174.33 | 128.80 | 208.13 | 157.91 |
| 15. | Jawhar Matar-1 | 141.53 | 215.80 | 160.07 | 402.53 | 229.98 |
| 16. | KS-123 | 58.07 | 126.27 | 72.47 | 130.47 | 96.82 |
| 17. | IP-3 | 81.40 | 101.13 | 94.47 | 232.20 | 127.30 |
| 18. | VL-2 | 79.80 | 108.80 | 97.93 | 143.47 | 107.50 |
| 19. | Pb-88 | 53.27 | 63.53 | 58.40 | 157.00 | 83.05 |
| 20. | Sel. 222 | 75.60 | 104.73 | 82.07 | 114.60 | 94.25 |
| 21. | Early perfection | 69.47 | 74.40 | 71.07 | 89.53 | 76.12 |
| 22. | Selection-17 | 99.53 | 286.40 | 114.60 | 320.60 | 205.28 |
| 23. | Kala Nagini | 141.53 | 209.40 | 173.60 | 352.13 | 219.16 |
| 24. | JP-501 | 204.53 | 333.20 | 292.87 | 513.73 | 336.08 |
| 25. | P-388 | 125.07 | 218.20 | 190.80 | 242.47 | 194.13 |
| 26. | P-6587-1 | 152.67 | 175.33 | 155.60 | 204.80 | 172.10 |
| 27. | P-6588-1 | 57.20 | 145.40 | 69.47 | 182.53 | 113.65 |
| 28. | UU-2 | 44.60 | 172.67 | 53.93 | 204.00 | 118.80 |
| 29. | UU-3 | 96.07 | 118.33 | 99.40 | 165.33 | 119.78 |
| 30. | ACC-65 | 89.47 | 142.67 | 128.07 | 163.93 | 131.03 |

CD (P=0.05) varietal means = 2.524

CD (P=0.05) Treatment means = 2.632

All the interaction studies responded highly significant in both the years.

## 3C Post flowering:

Significant differences were observed among varieties when individual performances were compared (Table 14A & 14B). In early maturing varieties the maximum (177.23 gm) fresh shoot weight was observed in Meteor and minimum was (84.62 g) shown by VP-7802. Hara Bona (114.48g) was the next to Meteor. The second year results showed the same trend as were in first year except little differences in magnitude. In the mid maturing group the varietal responses ranged from 336.05 g (Jawahar Matar-1) to a minimum of 136.13 g (VL-2) in the first year and from 336.07 g (Jawahar Matar-1 ) to 137.25 g (VL-2) in the second year. The next best in order of merit was VL-3 in both the year's study. In the late maturing group the range was much higher than what was observed in the early and mid groups. Here, the fresh weiht ranged from 368.18 g (Kala Nagini) to 120.03 g (Early Perfection) The second year study also revealed the same trend. JP-501 was to follow Kala Nagini in both the years.

The treatment effects also showed that the combination of inoculant and pelletant performed significantly higher (247.22 g) than the control (117.32 g). The conventional inoculation gave significantly higher value (189.23 g) than pelletant (143.73) application. Second year study was also at par with first year, both in terms of magnitude and behaviour.

Results revealed significant differences between variety and treatment interaction. In early maturing group, the maximum (250.00 g) varietal response was of Meter; in mid group, it was of Jawahar matar-1(624.93 g) and in late group it was of Kala Nagini (521.07 g). The second year results showed the same trend except with little magnitude differences. The values were superior over all the verities in both absolute as well as relative terms. Inoculation supplemented with pelleting was found superior than nearly pelleted. In the early maturing group the highest value obtained was 217.40 g (Meteor), in the mid group the highest value was 181.33 gm (KS-123) and in late the maturing group highest observed was 461.47 g ( Kala Nagini) in the first year study. Early and late groups showed highest values in both absolute as well as relative terms, but in mid maturing group the highest absolute value was depicted by the variety Jawahar Matar-1 (287.60g), while the relative value was found highest in KS-123 over control. In the second year,

**Table No. 14 ( A) Mean plant fresh weight at post flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 97.47 | 119.40 | 108.20 | 123.60 | 112.17 |
| 2. | Meteor | 117.07 | 217.40 | 124.47 | 250.00 | 177.23 |
| 3. | Early Badger | 105.40 | 109.93 | 106.00 | 112.20 | 108.38 |
| 4. | Little Marvel | 102.20 | 104.20 | 102.87 | 113.47 | 105.68 |
| 5. | Hara Bona | 107.13 | 113.20 | 108.20 | 129.40 | 114.48 |
| 6. | JP-829 | 61.87 | 111.93 | 107.40 | 121.27 | 100.62 |
| 7. | Jawahar Matar-4 | 59.20 | 117.40 | 113.60 | 125.80 | 104.00 |
| 8. | V.P.-7802 | 54.67 | 92.40 | 83.47 | 107.93 | 84.62 |
| 9. | V.P.-7839 | 70.53 | 98.33 | 80.40 | 103.87 | 88.28 |
| 10. | V.P.-8005 | 102.20 | 116.27 | 104.80 | 124.20 | 111.87 |
| 11. | Bonneville | 116.67 | 191.93 | 148.07 | 262.40 | 179.77 |
| 12. | Lincoln | 114.20 | 160.20 | 116.87 | 202.40 | 148.42 |
| 13. | Vipasa | 163.40 | 224.73 | 188.23 | 282.93 | 214.82 |
| 14. | VL-3 | 162.93 | 206.73 | 184.40 | 312.93 | 216.75 |
| 15. | Jawhar Matar-1 | 193.27 | 287.60 | 238.40 | 624.93 | 336.05 |
| 16. | KS-123 | 83.13 | 181.33 | 109.10 | 188.27 | 140.96 |
| 17. | IP-3 | 99.63 | 191.33 | 166.53 | 349.33 | 201.70 |
| 18. | VL-2 | 105.07 | 146.00 | 120.20 | 173.27 | 136.13 |
| 19. | Pb-88 | 66.20 | 177.87 | 112.33 | 241.47 | 149.47 |
| 20. | Sel. 222 | 113.07 | 143.40 | 118.13 | 208.27 | 145.72 |
| 21. | Early perfection | 107.67 | 126.47 | 112.27 | 133.73 | 120.03 |
| 22. | Selection-17 | 123.07 | 334.60 | 378.60 | 406.93 | 260.80 |
| 23. | Kala Nagini | 222.40 | 461.47 | 267.80 | 521.07 | 368.18 |
| 24. | JP-501 | 247.73 | 354.13 | 325.33 | 539.20 | 366.60 |
| 25. | P-388 | 156.73 | 245.00 | 194.20 | 276.20 | 218.03 |
| 26. | P-6587-1 | 184.33 | 287.93 | 193.00 | 437.40 | 275.66 |
| 27. | P-6588-1 | 70.60 | 187.33 | 94.47 | 246.27 | 149.67 |
| 28. | UU-2 | 61.20 | 198.27 | 84.47 | 259.00 | 150.73 |
| 29. | UU-3 | 140.47 | 196.47 | 169.20 | 244.47 | 187.65 |
| 30. | ACC-65 | 110.13 | 173.80 | 143.73 | 254.40 | 170.51 |

C.D.((P= 0.05) varietal means = 3.076
C.D. (P= 0.05) Treatment means =2.161

**Table No. 14 (B) Mean Plant Fresh weight at post flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 98.13 | 120.60 | 108.53 | 125.80 | 113.26 |
| 2. | Meteor | 116.67 | 213.00 | 126.93 | 250.27 | 176.72 |
| 3. | Early Badger | 106.27 | 109.93 | 107.27 | 113.60 | 109.27 |
| 4. | Little Marvel | 102.93 | 106.53 | 154.53 | 115.33 | 107.33 |
| 5. | Hara Bona | 107.53 | 116.13 | 109.13 | 130.20 | 115.75 |
| 6. | JP-829 | 62.60 | 114.93 | 106.67 | 126.27 | 102.62 |
| 7. | Jawahar Matar-4 | 58.47 | 119.40 | 114.53 | 126.67 | 104.77 |
| 8. | V.P.-7802 | 57.40 | 95.67 | 85.13 | 109.40 | 86.90 |
| 9. | V.P.-7839 | 72.20 | 100.40 | 82.73 | 104.93 | 90.06 |
| 10. | V.P.-8005 | 102.47 | 117.73 | 105.87 | 125.40 | 112.87 |
| 11. | Bonneville | 117.27 | 194.47 | 147.60 | 263.33 | 180.67 |
| 12. | Lincoln | 115.40 | 160.47 | 118.27 | 202.93 | 149.27 |
| 13. | Vipasa | 165.60 | 225.47 | 187.33 | 283.00 | 215.35 |
| 14. | VL-3 | 165.47 | 207.33 | 183.53 | 314.53 | 139.08 |
| 15. | Jawhar Matar-1 | 193.87 | 286.80 | 240.00 | 623.60 | 336.07 |
| 16. | KS-123 | 84.53 | 181.07 | 109.40 | 187.20 | 140.55 |
| 17. | IP-3 | 100.80 | 193.47 | 167.42 | 349.93 | 202.92 |
| 18. | VL-2 | 104.94 | 148.40 | 120.27 | 174.40 | 137.25 |
| 19. | Pb-88 | 67.40 | 179.81 | 112.40 | 243.47 | 150.78 |
| 20. | Sel. 222 | 114.67 | 144.87 | 120.00 | 209.47 | 147.25 |
| 21. | Early perfection | 106.47 | 129.60 | 115.80 | 136.93 | 122.20 |
| 22. | Selection-17 | 124.27 | 336.67 | 177.73 | 407.20 | 261.47 |
| 23. | Kala Nagini | 223.80 | 463.33 | 268.13 | 523.07 | 369.59 |
| 24. | JP-501 | 247.67 | 356.87 | 326.93 | 540.20 | 367.92 |
| 25. | P-388 | 156.87 | 243.53 | 197.80 | 277.27 | 218.87 |
| 26. | P-6587-1 | 185.80 | 288.13 | 194.47 | 436.73 | 276.28 |
| 27. | P-6588-1 | 72.93 | 187.27 | 96.93 | 248.00 | 151.28 |
| 28. | UU-2 | 63.47 | 199.87 | 87.33 | 192.80 | 135.87 |
| 29. | UU-3 | 141.40 | 197.33 | 170.93 | 245.47 | 188.78 |
| 30. | ACC-65 | 111.47 | 174.53 | 144.67 | 255.93 | 171.65 |

CD (P=0.05) varietal means = 2.654

CD (P=0.05) Treatment means = 2.067

study, the early (213.00 g) and late (463.37 g) maturing groups behaved exactly as the first year study. But in the mid maturing group both the years result were found different i.e. the first year showing the highest (181.33 g) in KS-123 and in second year maximum fresh shoot weight was shown by the variety Pb-88 (179.87 g). Pelleted effect was found to be lower in magnitude to inoculated when studied separately but a significant superiority of pelleted response over control was also noticed alongwith . Both the years study gave the same result except variations in magnitude, the highest yielders in early, mid and late maturing groups being Jawahar Matar-4 (113.60 g), IP-3 (166.53 g) and JP-501 (325.33 g) respectively. The second year study thus was found at par with the first year study.

## 3. D Pooled Analysis over three growth stages:

It was remarkable to note that use of culture, in general, proved beneficial with regard to fresh weight per plant as compared to no culture application (Table 15A & 15B). Further appraisal brought out the fact that culture application gave significantly higher fresh weight per plant, particularly at later stages of growth in the mid and late maturing groups. The effect of culture in combination with pelletant found to be significantly and consistently superior to no culture application, in all the growth stages studied in the pooled analysis. The treatment means showed the same behaviour as was in the three different growth stages studied in early and mid maturing groups but in late maturing group it behaved like pre and post flowering results. In the early maturing group, JP-829 yielded highest in response to treatment combination (inoculated -pelleted) , while in mid maturing group, the highest responder was Jawahar Matar-1. However, in late maturing group the highest performing cultivar JP-501 was found similar in performance of pre and post-flowering stages. When conventional inoculation method was studied under pooled analysis, early pooled effects were found similar to post flowering results and the mid and late maturing pooled effects were similar to pre flowering and flowering stages. But when pellet treatment was studied alone, early and late groups were not found similar to any of the growth stage results while the mid maturing was found to behave just like post flowering results.

When the results were graphically elaborated, the results from bar

**Table No. 15 (A) Mean plant fresh weight pooled over growth stages**

**Ist Year**

**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 56.91 | 94.62 | 86.69 | 103.20 | 85.35 |
| 2. | Meteor | 99.24 | 147.96 | 104.00 | 163.60 | 128.70 |
| 3. | Early Badger | 73.29 | 92.91 | 87.74 | 100.20 | 88.53 |
| 4. | Little Marvel | 77.67 | 87.22 | 80.13 | 106.44 | 87.86 |
| 5. | Hara Bona | 79.93 | 90.56 | 84.18 | 103.44 | 89.53 |
| 6. | JP-829 | 39.69 | 85.11 | 72.49 | 111.11 | 77.10 |
| 7. | Jawahar Matar-4 | 41.78 | 87.42 | 74.22 | 108.60 | 78.00 |
| 8. | V.P.-7802 | 34.69 | 59.98 | 50.62 | 76.53 | 55.45 |
| 9. | V.P.-7839 | 43.02 | 68.09 | 52.31 | 75.51 | 59.73 |
| 10. | V.P.-8005 | 65.62 | 74.13 | 68.11 | 85.07 | 73.23 |
| 11. | Bonneville | 86.96 | 135.18 | 100.36 | 189.13 | 127.91 |
| 12. | Lincoln | 92.84 | 122.27 | 95.16 | 151.33 | 115.40 |
| 13. | Vipasa | 107.58 | 150.58 | 122.50 | 174.31 | 138.74 |
| 14. | VL-3 | 120.58 | 168.20 | 137.07 | 223.20 | 162.26 |
| 15. | Jawhar Matar-1 | 143.89 | 215.96 | 162.04 | 405.60 | 231.72 |
| 16. | KS-123 | 59.44 | 129.54 | 77.20 | 139.04 | 101.30 |
| 17. | IP-3 | 79.90 | 122.33 | 110.84 | 226.91 | 134.99 |
| 18. | VL-2 | 79.89 | 111.38 | 96.31 | 140.62 | 107.05 |
| 19. | Pb-88 | 52.13 | 101.64 | 75.60 | 164.27 | 98.41 |
| 20. | Sel. 222 | 77.18 | 99.44 | 80.38 | 134.38 | 97.84 |
| 21. | Early perfection | 68.80 | 83.02 | 73.16 | 90.80 | 78.94 |
| 22. | Selection-17 | 93.64 | 248.29 | 120.24 | 286.02 | 187.05 |
| 23. | Kala Nagini | 137.53 | 243.69 | 224.98 | 314.93 | 230.28 |
| 24. | JP-501 | 189.93 | 282.62 | 248.53 | 420.91 | 285.50 |
| 25. | P-388 | 109.42 | 176.02 | 144.49 | 196.04 | 156.49 |
| 26. | P-6587-1 | 125.49 | 176.49 | 131.73 | 250.51 | 171.05 |
| 27. | P-6588-1 | 49.60 | 128.47 | 63.62 | 172.31 | 103.50 |
| 28. | UU-2 | 43.84 | 141.78 | 58.62 | 187.62 | 107.86 |
| 29. | UU-3 | 96.44 | 129.11 | 108.04 | 164.20 | 124.45 |
| 30. | ACC-65 | 73.18 | 116.93 | 98.78 | 154.18 | 110.77 |

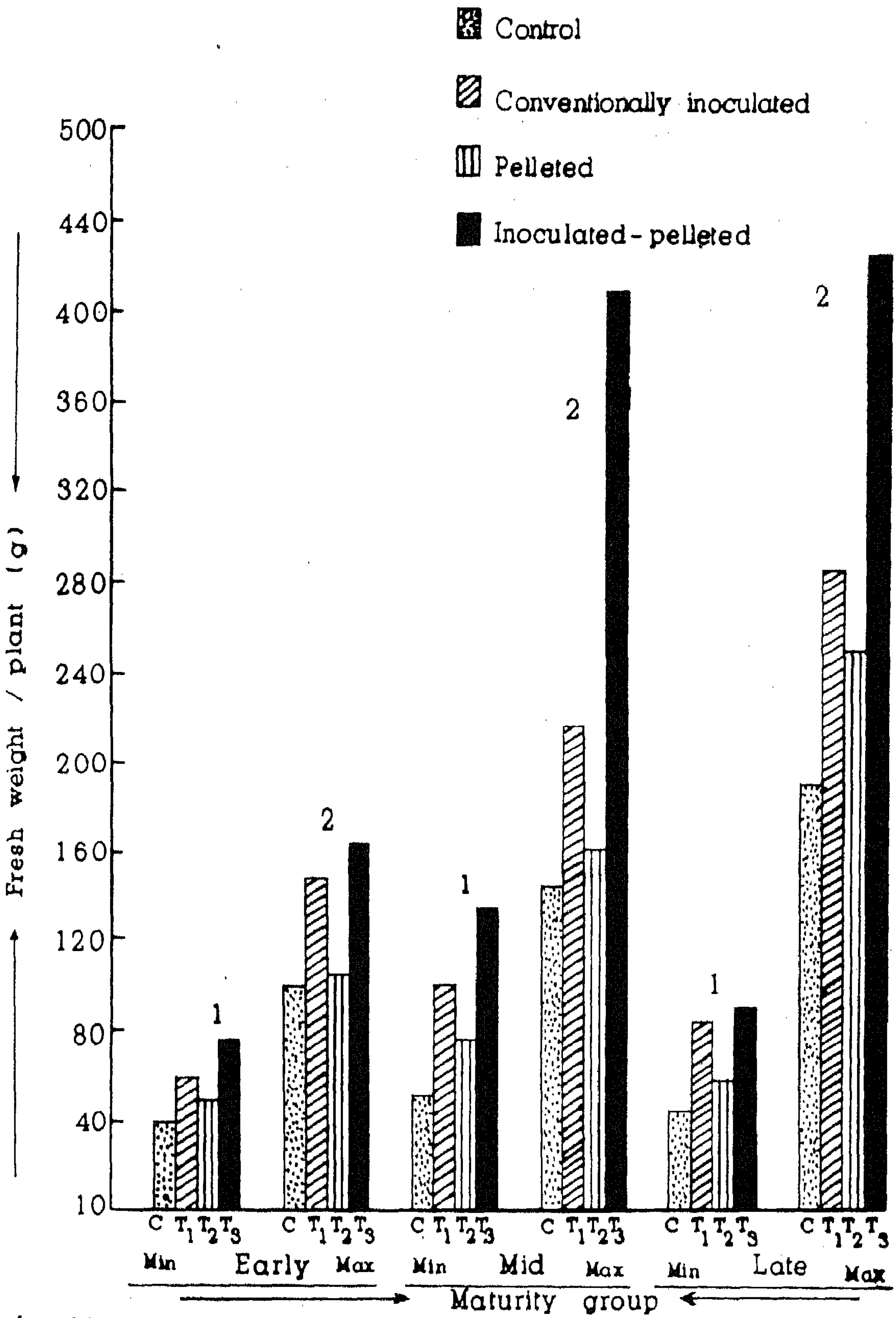
C.D.((P= 0.05) varietal means = 2.642

C.D. (P= 0.05) Treatment means =2.886

**Table No. 15 (B) Mean Plant Fresh weight pooled over growth stages**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 58.02 | 94.47 | 85.93 | 104.13 | 85.64 |
| 2. | Meteor | 100.07 | 147.51 | 105.29 | 164.47 | 129.33 |
| 3. | Early Badger | 74.29 | 93.18 | 88.04 | 101.69 | 89.30 |
| 4. | Little Marvel | 79.62 | 87.71 | 81.42 | 107.56 | 89.07 |
| 5. | Hara Bona | 80.40 | 92.47 | 84.96 | 104.40 | 90.56 |
| 6. | JP-829 | 41.31 | 87.40 | 72.98 | 114.00 | 78.92 |
| 7. | Jawahar Matar-4 | 42.33 | 90.02 | 74.49 | 109.87 | 79.18 |
| 8. | V.P.-7802 | 36.09 | 60.69 | 52.11 | 77.92 | 56.70 |
| 9. | V.P.-7839 | 44.13 | 68.64 | 53.62 | 76.04 | 60.61 |
| 10. | V.P.-8005 | 67.02 | 75.16 | 69.76 | 86.18 | 74.53 |
| 11. | Bonneville | 87.82 | 136.87 | 100.96 | 191.00 | 129.16 |
| 12. | Lincoln | 93.82 | 123.11 | 96.24 | 151.80 | 116.24 |
| 13. | Vipasa | 108.64 | 151.36 | 121.89 | 175.71 | 139.40 |
| 14. | VL-3 | 122.47 | 168.71 | 137.24 | 224.53 | 163.24 |
| 15. | Jawhar Matar-1 | 143.87 | 215.36 | 166.31 | 406.07 | 232.90 |
| 16. | KS-123 | 61.09 | 130.04 | 77.31 | 140.69 | 102.28 |
| 17. | IP-3 | 81.60 | 123.87 | 111.22 | 227.24 | 135.98 |
| 18. | VL-2 | 79.76 | 111.64 | 97.27 | 141.98 | 107.66 |
| 19. | Pb-88 | 53.62 | 102.07 | 74.47 | 166.00 | 99.04 |
| 20. | Sel. 222 | 77.22 | 101.04 | 82.16 | 136.71 | 99.28 |
| 21. | Early perfection | 69.13 | 83.64 | 73.60 | 92.82 | 79.80 |
| 22. | Selection-17 | 95.13 | 249.98 | 121.27 | 287.33 | 188.43 |
| 23. | Kala Nagini | 139.64 | 245.18 | 167.04 | 316.27 | 217.03 |
| 24. | JP-501 | 190.60 | 284.89 | 249.73 | 421.78 | 286.75 |
| 25. | P-388 | 109.62 | 175.76 | 146.64 | 197.73 | 157.44 |
| 26. | P-6587-1 | 126.00 | 176.93 | 133.40 | 251.49 | 171.95 |
| 27. | P-6588-1 | 51.53 | 128.84 | 64.69 | 174.27 | 104.83 |
| 28. | UU-2 | 45.44 | 143.33 | 58.38 | 167.42 | 103.64 |
| 29. | UU-3 | 97.98 | 130.78 | 109.93 | 165.93 | 126.15 |
| 30. | ACC-65 | 74.18 | 117.60 | 99.82 | 155.71 | 111.83 |

CD (P=0.05) varietal means = 3.242
CD (P=0.05) Treatment means = 2.616




1. Varieties showing minimum yield

2. Varieties showing maximum yield

Fig. 8 - Effect of inoculation methods oin plant fresh weight (Min., Max.,)

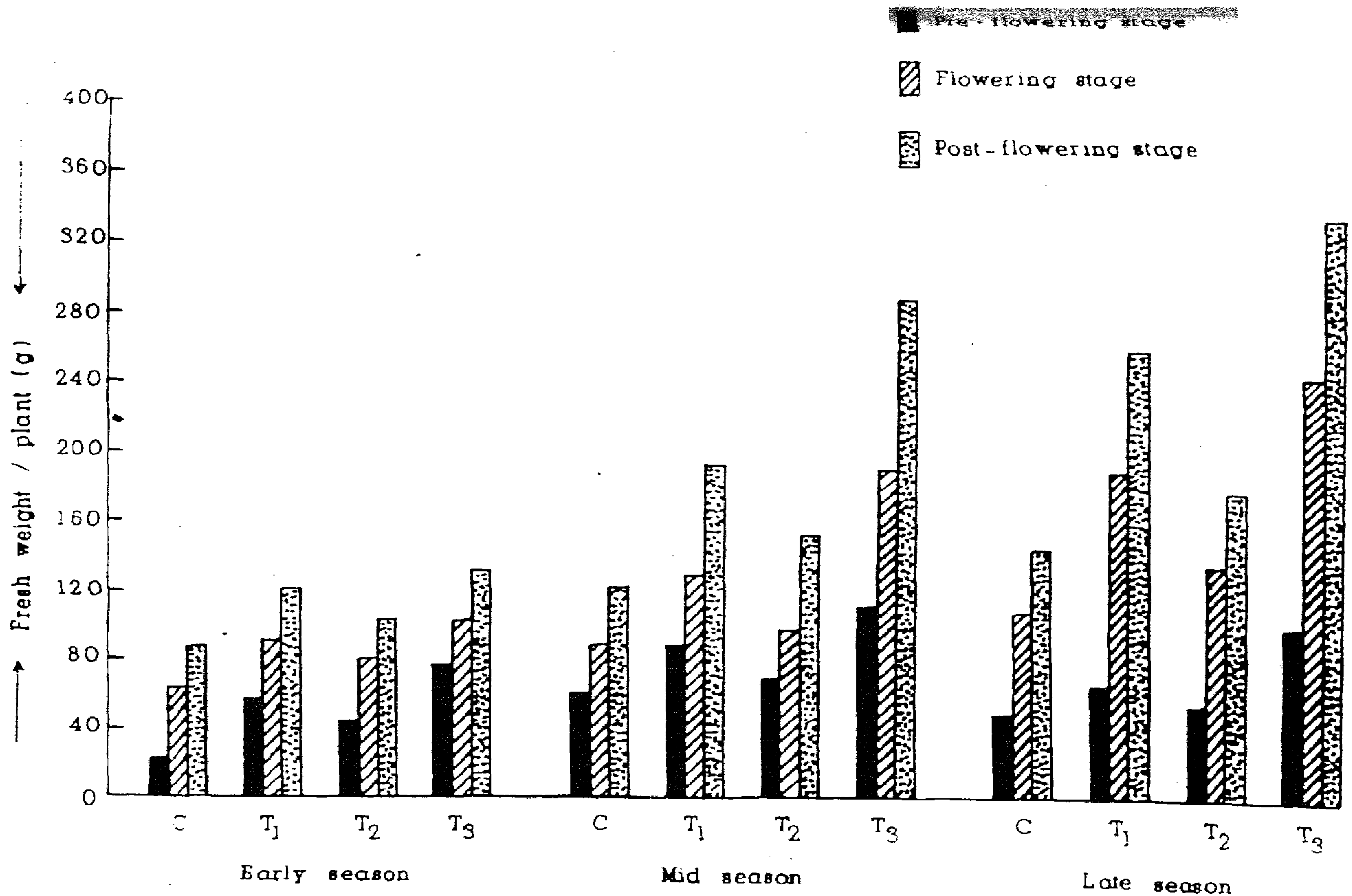



Fig 9 - Effect of inoculation methods on Plant fresh weight at different growth stages.

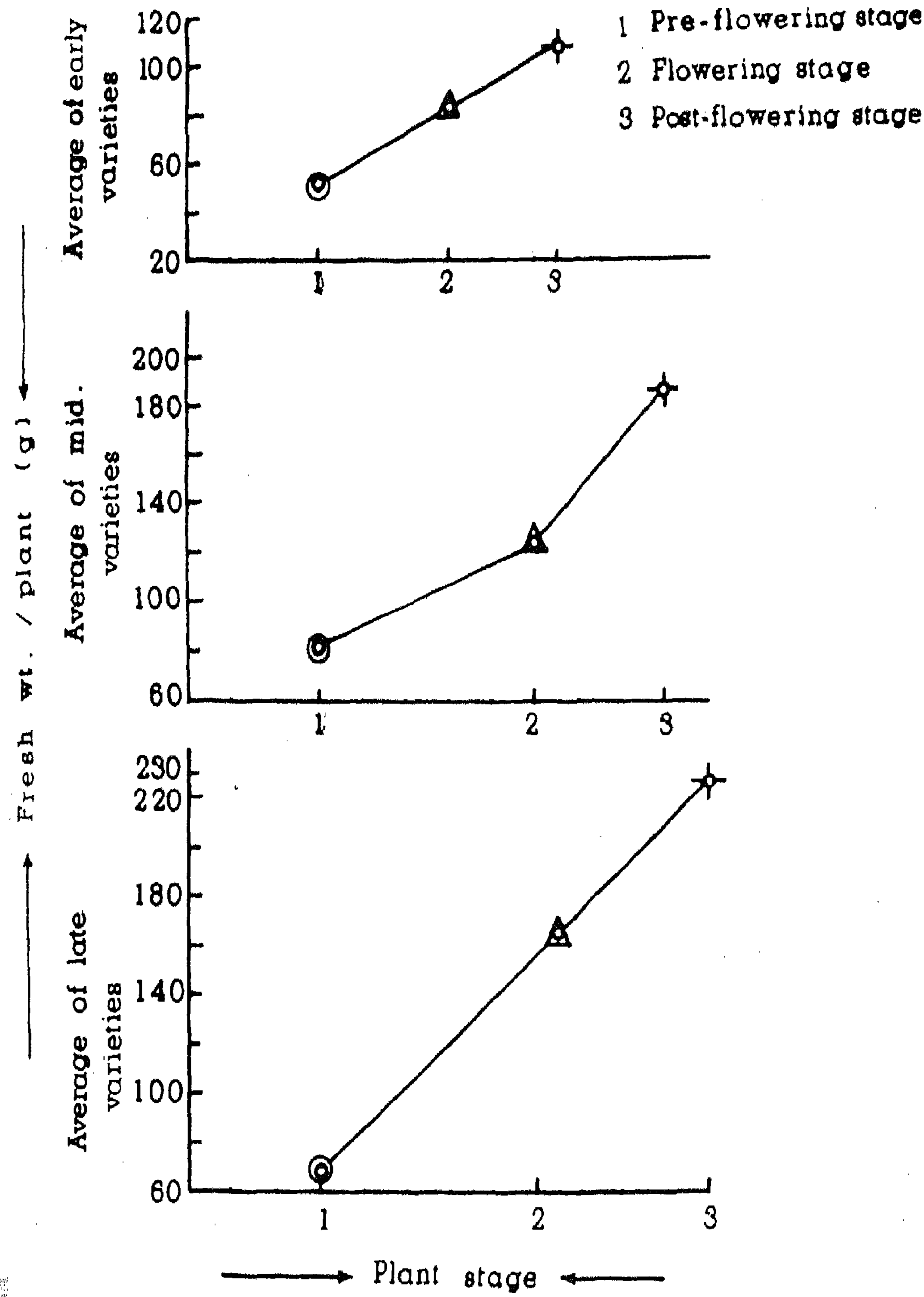



Fig 10 - Variation in plant fresh weight with plant growth stages the early mid and late cultivars.

diagrams showed a remarkable increase in plant fresh weight in treatment combination inoculated pelleted in late maturing group followed by mid maturing and then by early maturing group (fig 8). When the same result was studied with regard to different growth stages with another set of bar diagram (fig. 9 ), it was interesting to note that in early and late maturing groups the relative weight increase from pre flowering to flowering stage was higher than the increase from pre flowering to post flowering stages. But in mid maturing group, the relative increase in weight from one stage to another was almost similar or the magnitude of increase was little power during transition from pre flowering to flowering stage than from flowering to post flowering stage (fig 10) .

## 4. Plant Dry Weight (g)

It was obvious from the results that the use of microbial culture had significantly contributed to dry weight production per plant in pea. Alike the other growth characters reported earlier, Rhizobium could establish its significant superiority over control or over pellet application, right from early stage of crop growth till the reproductive phase set in. The differential findings by periodic observations of different cultivars are presented below.

### 4a. Pre flowering stage.

The analysis of variance revealed significant differences among treatment means of the varieties studied (Table 16A & 16B). The maximum response in the early, mid and late maturing groups were shown by Meteor (11.03 g), Jawahar Matar-1 (25.98 g) and JP-501 (25.26 g) respectively. The second year results also revealed that the same varieties as the best performances but the magnitude was comparatively of low order than those of the previous years. The varieties with next best performance in early, mid and late maturing groups were Arkel (6.25 g and 6.66 g in the first and second year respectively), VL-3 (17.71 and 17.46 g in both the years) and Selection-17 (19.15 and 18.43 g in both the years).

The treatment effects gave exactly the same picture as was found in earlier growth characters. Inoculated (11.74 g) and pelleted (8.96 g)when studied singly, performed quite inferior than when studied in combination (16.02 g), over control (7.35 g). The result was similar when different maturing groups were studied individually.

## Table No. 16(A) Mean plant dry weight at pre flowering stage

**Ist Year**

**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 2.97 | 7.40 | 6.17 | 8.47 | 6.25 |
| 2. | Meteor | 7.60 | 11.20 | 7.87 | 17.47 | 11.03 |
| 3. | Early Badger | 2.73 | 6.47 | 6.00 | 8.47 | 6.11 |
| 4. | Little Marvel | 3.80 | 4.80 | 4.33 | 11.13 | 6.01 |
| 5. | Hara Bona | 3.93 | 5.33 | 4.13 | 6.73 | 5.03 |
| 6. | JP-829 | 2.93 | 5.47 | 4.40 | 11.60 | 6.10 |
| 7. | Jawahar Matar-4 | 2.93 | 7.40 | 4.00 | 9.00 | 5.83 |
| 8. | V.P.-7802 | 1.20 | 3.47 | 1.73 | 4.07 | 2.61 |
| 9. | V.P.-7839 | 1.53 | 3.40 | 2.20 | 4.00 | 2.78 |
| 10. | V.P.-8005 | 2.53 | 3.33 | 2.73 | 3.73 | 3.08 |
| 11. | Bonneville | 11.07 | 13.13 | 11.13 | 18.53 | 13.46 |
| 12. | Lincoln | 10.20 | 17.20 | 13.60 | 20.27 | 15.31 |
| 13. | Vipasa | 12.47 | 15.60 | 14.73 | 17.40 | 15.05 |
| 14. | VL-3 | 4.53 | 18.27 | 15.47 | 22.60 | 17.71 |
| 15. | Jawhar Matar-1 | 19.13 | 27.33 | 20.27 | 37.20 | 25.98 |
| 16. | KS-123 | 7.60 | 17.20 | 8.20 | 20.73 | 13.43 |
| 17. | IP-3 | 11.13 | 15.20 | 14.47 | 20.33 | 15.28 |
| 18. | VL-2 | 11.40 | 15.53 | 13.47 | 21.40 | 15.45 |
| 19. | Pb-88 | 7.20 | 12.40 | 11.53 | 18.47 | 12.40 |
| 20. | Sel. 222 | 8.33 | 10.53 | 8.73 | 16.93 | 11.13 |
| 21. | Early perfection | 5.40 | 8.40 | 6.47 | 9.40 | 7.41 |
| 22. | Selection-17 | 11.53 | 24.53 | 12.27 | 28.27 | 19.15 |
| 23. | Kala Nagini | 8.53 | 12.40 | 10.53 | 13.20 | 11.16 |
| 24. | JP-501 | 18.60 | 27.07 | 21.20 | 34.20 | 25.26 |
| 25. | P-388 | 5.20 | 11.00 | 9.60 | 13.60 | 9.86 |
| 26. | P-6587-1 | 6.33 | 12.47 | 9.27 | 21.40 | 12.36 |
| 27. | P-6588-1 | 4.47 | 10.87 | 5.20 | 18.00 | 9.63 |
| 28. | UU-2 | 4.33 | 7.20 | 4.87 | 16.87 | 8.31 |
| 29. | UU-3 | 4.53 | 8.40 | 7.13 | 11.73 | 7.94 |
| 30. | ACC-65 | 3.47 | 6.20 | 5.13 | 8.60 | 5.85 |

C.D.((P= 0.05) varietal means = 1.400

C.D. (P= 0.05) Treatment means =1.340

**Table No. 16 (B) Mean Plant Dry Weight at pre flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 3.33 | 7.73 | 6.33 | 9.27 | 6.66 |
| 2. | Meteor | 7.20 | 10.93 | 7.93 | 17.60 | 10.91 |
| 3. | Early Badger | 3.00 | 6.27 | 6.93 | 7.60 | 5.95 |
| 4. | Little Marvel | 3.60 | 4.73 | 3.93 | 10.67 | 5.73 |
| 5. | Hara Bona | 3.60 | 4.80 | 4.00 | 7.00 | 4.85 |
| 6. | JP-829 | 2.87 | 5.40 | 4.93 | 11.27 | 6.05 |
| 7. | Jawahar Matar-4 | 2.47 | 7.80 | 3.60 | 9.27 | 5.78 |
| 8. | V.P.-7802 | 1.47 | 3.47 | 1.47 | 4.67 | 2.77 |
| 9. | V.P.-7839 | 1.73 | 3.53 | 2.07 | 4.40 | 2.93 |
| 10. | V.P.-8005 | 2.27 | 2.93 | 2.53 | 3.53 | 2.81 |
| 11. | Bonneville | 10.60 | 13.27 | 11.07 | 17.73 | 13.16 |
| 12. | Lincoln | 10.47 | 16.93 | 12.40 | 19.93 | 14.93 |
| 13. | Vipasa | 11.87 | 15.13 | 13.60 | 16.27 | 14.21 |
| 14. | VL-3 | 14.81 | 17.60 | 14.87 | 22.60 | 17.46 |
| 15. | Jawhar Matar-1 | 18.20 | 26.47 | 20.27 | 36.80 | 25.43 |
| 16. | KS-123 | 7.20 | 17.27 | 7.73 | 20.40 | 13.15 |
| 17. | IP-3 | 10.73 | 14.47 | 13.87 | 19.13 | 14.55 |
| 18. | VL-2 | 11.33 | 15.07 | 13.27 | 21.20 | 15.21 |
| 19. | Pb-88 | 7.00 | 11.80 | 11.33 | 17.87 | 12.00 |
| 20. | Sel. 222 | 8.20 | 10.20 | 8.87 | 16.47 | 10.93 |
| 21. | Early perfection | 5.00 | 8.47 | 5.87 | 9.93 | 7.11 |
| 22. | Selection-17 | 10.93 | 23.60 | 11.73 | 27.47 | 18.43 |
| 23. | Kala Nagini | 8.53 | 12.13 | 10.47 | 12.80 | 10.98 |
| 24. | JP-501 | 17.60 | 27.20 | 20.60 | 33.87 | 24.81 |
| 25. | P-388 | 5.20 | 10.60 | 9.20 | 13.20 | 9.55 |
| 26. | P-6587-1 | 6.47 | 11.73 | 9.07 | 20.87 | 12.03 |
| 27. | P-6588-1 | 4.27 | 10.80 | 4.80 | 18.40 | 9.56 |
| 28. | UU-2 | 4.33 | 6.93 | 4.87 | 17.20 | 8.33 |
| 29. | UU-3 | 4.33 | 8.60 | 7.40 | 11.88 | 8.03 |
| 30. | ACC-65 | 3.47 | 6.33 | 5.20 | 8.20 | 5.80 |

CD (P=0.05) varietal means = 0.782
CD (P=0.05) Treatment means = 0.776

Making an observation into variety and treatment interactions under different maturing groups, the treatment combination inoculated-pelleted gave the best result. The relative increase in response to treatment interaction was mainly considered for result interpretation. In early, mid and late maturing groups, the cultivars were Meteor (17.47 g) followed by JP-829 (11.60 g); Jawahar Matar-1 (37.20 g) followed by VL-3 (22.60 g); and selection-17 (28.27 g) followed by JP-501 (though in absolute terms JP-501 was superior (34.2g) to selection-17 but in relative terms JP -501 was found lower than Sel-17 in magnitude). Second year analysis also gave the same result with little variation in magnitude in early, mid and late maturing groups. Conventionally inoculated performed next best to in early, mid and late maturing groups as Jawahar Matar-4 and Arkel (performed at par in early group 7.40g ), KS-123 (17.20 g) and selection-17 (24.53 g) respectively. The second year's performance was found almost at par. In pelleted effect, the maximum relative yielders were Early Badger (6.80 g) , Pb-88 (11.53 g) and P-388 (9.60g) in the early, mid and late groups respectively.

## 4b. Flowering Stage.

The varietal responses at flowering stage showed the same effects as was shown at pre flowering stage (Table 17A & 17B). The cultivars Meteor (17.43 g), Jawahar Matar-1 (44.18 g) and JP-501 (64.46 g) were found to perform best in early, mid and late maturing groups respectively, in both the years. The treatment effects also showed the superiority of the method application, where after seed inoculation, pelleting was done with calcium sulphate. The value was found to be significantly higher (32.23 g) in this combined effect than inoculated (22.54 g) and pelleted (17.84 g), when studied individually over control (14.39 g). The three maturing groups, when examined individually, also gave the same trend of response .

The interaction was found statistically much significant taking into consideration the relative performance over control . The inoculant in combination with pelletant gave the best result in early, mid and late groups. Arkel (20.20 g), Jawahar Matar-1 (80.87 g) and JP-501 (98.93g) were found to perform best in early, mid and late maturing groups in both the years. In conventionally inoculated study the cultivars Arkel (13.73 g), KS-123 (24.37 g) and Selection-17 (49.07) were found to give maximum dry weight per plant. However, Hara Bona (17.93 g), Jawahar

# Table No. 17(A) Mean plant dry weight at flowering stage

**Ist Year**

**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 4.27 | 13.73 | 9.60 | 20.20 | 11.95 |
| 2. | Meteor | 12.60 | 17.13 | 14.73 | 25.27 | 17.43 |
| 3. | Early Badger | 8.07 | 13.00 | 9.27 | 15.33 | 11.41 |
| 4. | Little Marvel | 8.93 | 15.60 | 10.40 | 17.43 | 13.21 |
| 5. | Hara Bona | 10.93 | 17.93 | 13.27 | 18.73 | 15.21 |
| 6. | JP-829 | 4.60 | 9.00 | 7.60 | 14.87 | 9.01 |
| 7. | Jawahar Matar-4 | 5.53 | 9.20 | 7.07 | 11.60 | 8.10 |
| 8. | V.P.-7802 | 2.80 | 5.53 | 4.93 | 7.27 | 15.13 |
| 9. | V.P.-7839 | 3.47 | 6.40 | 4.80 | 8.67 | 5.83 |
| 10. | V.P.-8005 | 6.00 | 8.20 | 7.40 | 15.60 | 9.30 |
| 11. | Bonneville | 15.07 | 18.47 | 16.67 | 35.40 | 21.40 |
| 12. | Lincoln | 19.20 | 23.33 | 19.93 | 27.80 | 22.31 |
| 13. | Vipasa | 19.33 | 29.40 | 20.47 | 32.07 | 25.31 |
| 14. | VL-3 | 19.60 | 27.73 | 21.80 | 32.73 | 25.26 |
| 15. | Jawhar Matar-1 | 29.00 | 36.20 | 30.67 | 80.87 | 44.18 |
| 16. | KS-123 | 10.60 | 24.37 | 14.60 | 26.53 | 19.02 |
| 17. | IP-3 | 16.53 | 20.40 | 18.47 | 45.97 | 25.21 |
| 18. | VL-2 | 15.27 | 21.53 | 20.40 | 25.60 | 20.70 |
| 19. | Pb-88 | 11.40 | 13.47 | 12.40 | 31.33 | 17.15 |
| 20. | Sel. 222 | 14.80 | 19.73 | 16.27 | 22.27 | 18.26 |
| 21. | Early perfection | 10.33 | 12.87 | 12.00 | 17.53 | 13.18 |
| 22. | Selection-17 | 18.53 | 49.07 | 20.40 | 59.07 | 36.76 |
| 23. | Kala Nagini | 24.40 | 38.27 | 31.93 | 65.40 | 40.00 |
| 24. | JP-501 | 37.93 | 61.67 | 59.33 | 98.93 | 64.43 |
| 25. | P-388 | 22.47 | 44.00 | 36.93 | 45.73 | 37.28 |
| 26. | P-6587-1 | 27.07 | 33.20 | 28.20 | 40.67 | 32.28 |
| 27. | P-6588-1 | 11.00 | 23.20 | 13.33 | 33.80 | 20.33 |
| 28. | UU-2 | 6.60 | 15.13 | 9.20 | 28.20 | 14.78 |
| 29. | UU-3 | 19.73 | 24.20 | 20.60 | 29.00 | 23.38 |
| 30. | ACC-65 | 16.87 | 24.40 | 23.53 | 33.07 | 24.46 |

C.D.((P= 0.05) varietal means = 1.172

C.D. (P= 0.05) Treatment means =0.980

**Table No. 17 (B) Mean Plant Dry Weight at flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 2.50 | 30.87 | 8.80 | 19.93 | 15.52 |
| 2. | Meteor | 18.80 | 16.53 | 13.73 | 24.53 | 18.39 |
| 3. | Early Badger | 7.87 | 11.80 | 9.13 | 14.87 | 10.91 |
| 4. | Little Marvel | 8.93 | 15.47 | 10.20 | 17.47 | 13.01 |
| 5. | Hara Bona | 11.40 | 17.87 | 12.07 | 18.40 | 14.93 |
| 6. | JP-829 | 4.33 | 8.67 | 6.93 | 13.87 | 8.45 |
| 7. | Jawahar Matar-4 | 3.87 | 8.27 | 7.13 | 11.93 | 7.80 |
| 8. | V.P.-7802 | 2.80 | 5.27 | 4.20 | 7.00 | 4.81 |
| 9. | V.P.-7839 | 3.13 | 6.33 | 5.33 | 8.40 | 5.79 |
| 10. | V.P.-8005 | 5.80 | 7.87 | 7.20 | 14.93 | 8.95 |
| 11. | Bonneville | 14.20 | 17.60 | 16.13 | 35.27 | 20.80 |
| 12. | Lincoln | 18.40 | 22.93 | 18.73 | 27.60 | 21.91 |
| 13. | Vipasa | 18.53 | 29.40 | 19.80 | 30.93 | 24.66 |
| 14. | VL-3 | 17.73 | 27.73 | 21.07 | 31.73 | 24.56 |
| 15. | Jawhar Matar-1 | 28.93 | 35.33 | 30.87 | 80.27 | 43.85 |
| 16. | KS-123 | 10.07 | 23.87 | 13.80 | 25.87 | 18.40 |
| 17. | IP-3 | 15.93 | 20.53 | 18.53 | 44.40 | 24.84 |
| 18. | VL-2 | 15.53 | 20.93 | 20.33 | 24.93 | 20.43 |
| 19. | Pb-88 | 4.20 | 12.87 | 12.60 | 30.73 | 16.85 |
| 20. | Sel. 222 | 13.87 | 18.73 | 15.73 | 21.80 | 17.42 |
| 21. | Early perfection | 9.87 | 12.93 | 11.73 | 16.93 | 12.86 |
| 22. | Selection-17 | 17.40 | 48.73 | 19.87 | 58.87 | 36.21 |
| 23. | Kala Nagini | 23.27 | 37.40 | 31.40 | 65.20 | 39.31 |
| 24. | JP-501 | 37.40 | 61.07 | 59.47 | 99.53 | 64.36 |
| 25. | P-388 | 21.87 | 42.93 | 36.27 | 45.53 | 36.65 |
| 26. | P-6587-1 | 26.13 | 31.80 | 27.13 | 40.07 | 31.28 |
| 27. | P-6588-1 | 10.27 | 22.93 | 13.00 | 34.33 | 20.13 |
| 28. | UU-2 | 6.40 | 14.47 | 8.93 | 28.93 | 14.68 |
| 29. | UU-3 | 19.00 | 20.07 | 19.40 | 31.67 | 22.53 |
| 30. | ACC-65 | 16.80 | 25.20 | 23.97 | 32.40 | 24.48 |

CD (P=0.05) varietal means =1.022
CD (P=0.05) Treatment means = 1.121

Matar -1 (36.20 g) and JP-501 (61.67 ) gave the highest absolute figures in early, mid and late groups, respectively. Pelleting was found to respond best in Arkel (9.60g) only in relative terms but in case of VL-2 (20.40 g) and JP-501 (59.33 g) the performance was highest both in relative as well as absolute terms.

## 4.c Post flowering stage:

Dry weight per plant at post flowering stage was found to be significantly higher as compared to the pre flowering and flowering stages (Table 18A & 18B). The treatment means depicted Meteor (30.43 g), Jawahar Matar-1 (66.70 g) and Kala Nagini (70.66 g) to respond maximum in early, mid and late maturing groups respectively. The next best to follow were Hara Bona (20.55 g) in early, Vipasa (42.31 g) in mid and JP-501 (70.10 g) in late maturing groups respectively.

The treatment effects followed exactly the earlier trend showing inoculation in combination with pelletants to give the best result (45.79 g), followed by inoculated (33.03 g) and then pelleted (25.41 g) over control (14.39 g). Individual studies of the three maturity groups also gave the same response.

The interaction study in early mid and late groups in case of combination treatment revealed that the cultivars, Meteor (38.07 g), Jawahar Matar-1 (121.47g) and JP-501 (112.40 g) with the maximum relative increase in dry weight. The inoculated effects showed in early group, Meteor (35.33); in mid group, Jawahar Matar- 1 (60.20 g) and in late group Kala Nagini (85.47 g) as the best ones. In pelleted, cultivar JP-829 (11.60 g) in the early group was found to perform best over control, while in mid group IP-3 (33.00g) was found to respond best over control. In late maturing group, JP-501 (61.00 g)was found to give maximum dry weight per plant. Both the year's study revealed similarity of response.

## 4d Pooled Analysis over three growth stages.

In the pooled analysis, the early and mid group's varietal responses revealed similarity to all the three growth stages studied individually (Table 19 A & 19B). However, in late maturing group the response was similar to that in pre flowering and flowering growth stages only. The cultivars Meteor (19.63 g ) followed by Hara Bona (13.76 g); Jawahar Matar -1 (45.65 g) followed by Vipasa (27.56 g); JP-501 (53.27 g) followed by Kala Nagini (40.61 g) were found to be the superior cultivars in the three maturing groups, respectively.

**Table No. 18 (A) Mean plant dry weight at post flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 9.80 | 21.53 | 12.20 | 23.93 | 16.86 |
| 2. | Meteor | 23.27 | 35.33 | 25.07 | 38.07 | 30.43 |
| 3. | Early Badger | 13.87 | 18.27 | 15.07 | 20.40 | 16.90 |
| 4. | Little Marvel | 12.13 | 19.47 | 13.40 | 20.80 | 16.45 |
| 5. | Hara Bona | 16.27 | 22.53 | 17.53 | 24.87 | 20.55 |
| 6. | JP-829 | 6.33 | 14.60 | 11.60 | 19.73 | 13.06 |
| 7. | Jawahar Matar-4 | 5.87 | 13.00 | 11.00 | 17.73 | 11.90 |
| 8. | V.P.-7802 | 5.13 | 8.93 | 7.93 | 9.60 | 31.59 |
| 9. | V.P.-7839 | 6.47 | 9.87 | 8.20 | 10.40 | 8.73 |
| 10. | V.P.-8005 | 8.67 | 11.67 | 10.87 | 19.40 | 12.65 |
| 11. | Bonneville | 21.67 | 28.00 | 24.13 | 51.53 | 31.33 |
| 12. | Lincoln | 24.87 | 31.07 | 28.20 | 40.40 | 31.13 |
| 13. | Vipasa | 32.00 | 43.87 | 37.27 | 56.13 | 42.31 |
| 14. | VL-3 | 26.67 | 32.00 | 29.53 | 53.07 | 35.31 |
| 15. | Jawhar Matar-1 | 38.93 | 60.20 | 46.60 | 121.47 | 66.70 |
| 16. | KS-123 | 16.40 | 32.87 | 21.20 | 35.03 | 26.37 |
| 17. | IP-3 | 19.67 | 35.73 | 33.00 | 66.27 | 38.66 |
| 18. | VL-2 | 20.40 | 27.07 | 24.27 | 35.27 | 25.00 |
| 19. | Pb-88 | 12.20 | 34.40 | 22.00 | 44.87 | 28.36 |
| 20. | Sel. 222 | 21.80 | 27.93 | 24.40 | 42.60 | 29.18 |
| 21. | Early perfection | 20.33 | 23.33 | 20.93 | 23.67 | 22.06 |
| 22. | Selection-17 | 21.93 | 55.20 | 34.53 | 68.13 | 44.94 |
| 23. | Kala Nagini | 41.07 | 85.47 | 54.40 | 101.73 | 70.66 |
| 24. | JP-501 | 44.07 | 62.93 | 61.00 | 112.40 | 70.10 |
| 25. | P-388 | 28.07 | 48.00 | 41.60 | 52.07 | 42.43 |
| 26. | P-6587-1 | 31.13 | 56.47 | 37.40 | 80.87 | 51.46 |
| 27. | P-6588-1 | 13.93 | 35.87 | 18.33 | 44.93 | 28.26 |
| 28. | UU-2 | 11.33 | 23.00 | 13.00 | 45.13 | 23.11 |
| 29. | UU-3 | 24.80 | 37.87 | 33.27 | 45.27 | 35.30 |
| 30. | ACC-65 | 20.73 | 34.60 | 24.40 | 47.93 | 31.91 |

C.D.((P= 0.05) varietal means = 1.248
C.D. (P= 0.05) Treatment means =1.019

**Table No. 18 (B) Mean Plant Dry Weight at post flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 9.27 | 21.33 | 11.67 | 23.53 | 16.45 |
| 2. | Meteor | 23.47 | 33.73 | 23.93 | 37.40 | 29.63 |
| 3. | Early Badger | 13.33 | 18.20 | 14.80 | 20.40 | 16.68 |
| 4. | Little Marvel | 11.80 | 18.40 | 13.07 | 20.67 | 15.98 |
| 5. | Hara Bona | 16.23 | 21.73 | 16.67 | 23.87 | 19.62 |
| 6. | JP-829 | 6.27 | 14.27 | 11.27 | 18.87 | 12.67 |
| 7. | Jawahar Matar-4 | 5.33 | 13.07 | 9.53 | 16.73 | 8.93 |
| 8. | V.P.-7802 | 5.27 | 8.80 | 7.60 | 9.33 | 7.75 |
| 9. | V.P.-7839 | 6.47 | 9.47 | 8.40 | 10.20 | 8.63 |
| 10. | V.P.-8005 | 8.27 | 11.40 | 10.40 | 19.40 | 12.36 |
| 11. | Bonneville | 20.73 | 27.13 | 23.73 | 51.67 | 30.81 |
| 12. | Lincoln | 24.33 | 29.73 | 27.73 | 40.20 | 30.49 |
| 13. | Vipasa | 31.33 | 42.07 | 36.40 | 56.20 | 41.50 |
| 14. | VL-3 | 26.13 | 31.80 | 28.73 | 52.60 | 34.81 |
| 15. | Jawhar Matar-1 | 38.80 | 58.93 | 45.60 | 120.73 | 66.01 |
| 16. | KS-123 | 15.73 | 32.93 | 20.87 | 34.20 | 25.93 |
| 17. | IP-3 | 19.07 | 34.73 | 33.07 | 64.60 | 37.86 |
| 18. | VL-2 | 19.60 | 26.13 | 23.40 | 34.73 | 25.96 |
| 19. | Pb-88 | 12.07 | 34.00 | 21.40 | 44.07 | 27.88 |
| 20. | Sel. 222 | 21.80 | 28.07 | 23.60 | 42.80 | 29.06 |
| 21. | Early perfection | 19.33 | 23.33 | 20.53 | 24.13 | 21.83 |
| 22. | Selection-17 | 21.73 | 54.60 | 34.27 | 67.73 | 44.58 |
| 23. | Kala Nagini | 40.73 | 84.73 | 53.40 | 101.80 | 70.16 |
| 24. | JP-501 | 42.93 | 62.33 | 59.93 | 110.80 | 68.99 |
| 25. | P-388 | 27.40 | 46.67 | 41.00 | 51.13 | 41.55 |
| 26. | P-6587-1 | 30.73 | 55.73 | 36.40 | 81.07 | 50.98 |
| 27. | P-6588-1 | 12.93 | 35.67 | 17.53 | 44.87 | 27.75 |
| 28. | UU-2 | 10.93 | 22.93 | 13.00 | 44.20 | 22.76 |
| 29. | UU-3 | 24.93 | 38.07 | 32.80 | 44.67 | 35.11 |
| 30. | ACC-65 | 20.67 | 34.33 | 24.00 | 48.20 | 31.80 |

CD (P=0.05) varietal means = 1.244
CD (P=0.05) Treatment means = 0.999

**Table No. 19 (A) Mean plant dry weight at pooled over growth stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.68 | 15.56 | 9.32 | 19.87 | 12.60 |
| 2. | Meteor | 14.49 | 21.22 | 18.89 | 26.93 | 19.63 |
| 3. | Early Badger | 8.22 | 12.58 | 10.11 | 14.73 | 11.41 |
| 4. | Little Marvel | 8.29 | 13.29 | 9.38 | 16.62 | 11.89 |
| 5. | Hara Bona | 11.38 | 15.27 | 11.64 | 16.78 | 13.76 |
| 6. | JP-829 | 4.62 | 9.69 | 7.87 | 15.40 | 9.39 |
| 7. | Jawahar Matar-4 | 5.44 | 9.53 | 7.36 | 12.78 | 8.77 |
| 8. | V.P.-7802 | 3.04 | 5.98 | 4.87 | 6.98 | 5.21 |
| 9. | V.P.-7839 | 3.82 | 6.56 | 5.07 | 7.69 | 5.78 |
| 10. | V.P.-8005 | 5.73 | 7.73 | 7.00 | 12.91 | 8.34 |
| 11. | Bonneville | 15.93 | 19.87 | 17.31 | 35.16 | 22.06 |
| 12. | Lincoln | 18.09 | 23.89 | 20.24 | 29.49 | 22.92 |
| 13. | Vipasa | 21.27 | 29.62 | 24.16 | 35.20 | 27.56 |
| 14. | VL-3 | 20.27 | 26.00 | 22.27 | 36.13 | 26.16 |
| 15. | Jawhar Matar-1 | 29.02 | 41.24 | 32.51 | 79.84 | 45.65 |
| 16. | KS-123 | 11.53 | 24.81 | 14.67 | 27.43 | 19.61 |
| 17. | IP-3 | 15.78 | 23.78 | 21.98 | 44.02 | 26.39 |
| 18. | VL-2 | 15.69 | 21.38 | 19.38 | 27.42 | 20.96 |
| 19. | Pb-88 | 10.27 | 20.09 | 15.31 | 31.56 | 19.30 |
| 20. | Sel. 222 | 14.98 | 19.40 | 16.47 | 27.27 | 19.53 |
| 21. | Early perfection | 12.02 | 14.87 | 13.13 | 16.87 | 14.22 |
| 22. | Selection-17 | 17.33 | 42.93 | 22.40 | 51.82 | 33.62 |
| 23. | Kala Nagini | 24.67 | 45.38 | 32.29 | 60.11 | 40.61 |
| 24. | JP-501 | 33.53 | 50.56 | 47.18 | 81.84 | 53.27 |
| 25. | P-388 | 18.58 | 34.33 | 29.38 | 37.13 | 29.85 |
| 26. | P-6587-1 | 21.51 | 34.04 | 24.96 | 47.64 | 32.03 |
| 27. | P-6588-1 | 9.80 | 23.31 | 12.29 | 32.24 | 19.41 |
| 28. | UU-2 | 7.42 | 15.11 | 9.02 | 30.07 | 15.40 |
| 29. | UU-3 | 16.36 | 23.49 | 20.33 | 29.78 | 22.49 |
| 30. | ACC-65 | 13.69 | 21.73 | 17.69 | 29.87 | 20.70 |

C.D.((P= 0.05) varietal means = 1.362
C.D. (P= 0.05) Treatment means =1.246

**Table No. 19 (B) Mean Plant Dry Weight pooled over growth stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 5.47 | 15.38 | 8.93 | 19.58 | 12.34 |
| 2. | Meteor | 14.16 | 20.40 | 15.20 | 26.51 | 19.06 |
| 3. | Early Badger | 8.07 | 12.09 | 9.96 | 14.29 | 11.10 |
| 4. | Little Marvel | 8.11 | 12.87 | 9.07 | 16.27 | 11.58 |
| 5. | Hara Bona | 11.24 | 14.80 | 10.91 | 16.42 | 13.59 |
| 6. | JP-829 | 4.49 | 9.44 | 7.71 | 14.67 | 17.21 |
| 7. | Jawahar Matar-4 | 3.89 | 9.24 | 6.76 | 12.64 | 8.13 |
| 8. | V.P.-7802 | 3.18 | 5.84 | 4.42 | 7.00 | 5.11 |
| 9. | V.P.-7839 | 3.78 | 6.44 | 5.27 | 7.67 | 5.79 |
| 10. | V.P.-8005 | 5.44 | 7.40 | 6.71 | 12.62 | 8.04 |
| 11. | Bonneville | 15.18 | 19.33 | 16.98 | 34.89 | 21.59 |
| 12. | Lincoln | 17.73 | 23.20 | 19.62 | 29.24 | 22.44 |
| 13. | Vipasa | 20.58 | 28.87 | 23.27 | 34.47 | 26.79 |
| 14. | VL-3 | 19.56 | 25.71 | 21.56 | 35.64 | 25.61 |
| 15. | Jawhar Matar-1 | 28.64 | 40.24 | 32.24 | 79.27 | 45.09 |
| 16. | KS-123 | 11.00 | 24.69 | 14.13 | 26.82 | 19.16 |
| 17. | IP-3 | 15.24 | 23.24 | 21.82 | 42.71 | 25.75 |
| 18. | VL-2 | 15.49 | 20.71 | 19.00 | 26.96 | 20.54 |
| 19. | Pb-88 | 10.09 | 19.56 | 15.11 | 30.89 | 18.91 |
| 20. | Sel. 222 | 14.62 | 19.00 | 16.07 | 27.02 | 19.17 |
| 21. | Early perfection | 11.40 | 14.91 | 12.71 | 17.00 | 14.00 |
| 22. | Selection-17 | 16.69 | 42.31 | 21.96 | 51.36 | 33.08 |
| 23. | Kala Nagini | 24.18 | 44.76 | 31.76 | 59.93 | 40.15 |
| 24. | JP-501 | 32.64 | 50.20 | 46.67 | 81.40 | 52.72 |
| 25. | P-388 | 18.16 | 33.40 | 28.82 | 36.62 | 29.25 |
| 26. | P-6587-1 | 21.11 | 33.09 | 24.20 | 47.33 | 31.43 |
| 27. | P-6588-1 | 9.16 | 23.13 | 11.78 | 32.53 | 19.15 |
| 28. | UU-2 | 7.22 | 14.78 | 9.93 | 30.11 | 15.26 |
| 29. | UU-3 | 16.09 | 22.24 | 19.87 | 29.38 | 21.89 |
| 30. | ACC-65 | 13.64 | 21.96 | 17.56 | 29.60 | 20.69 |

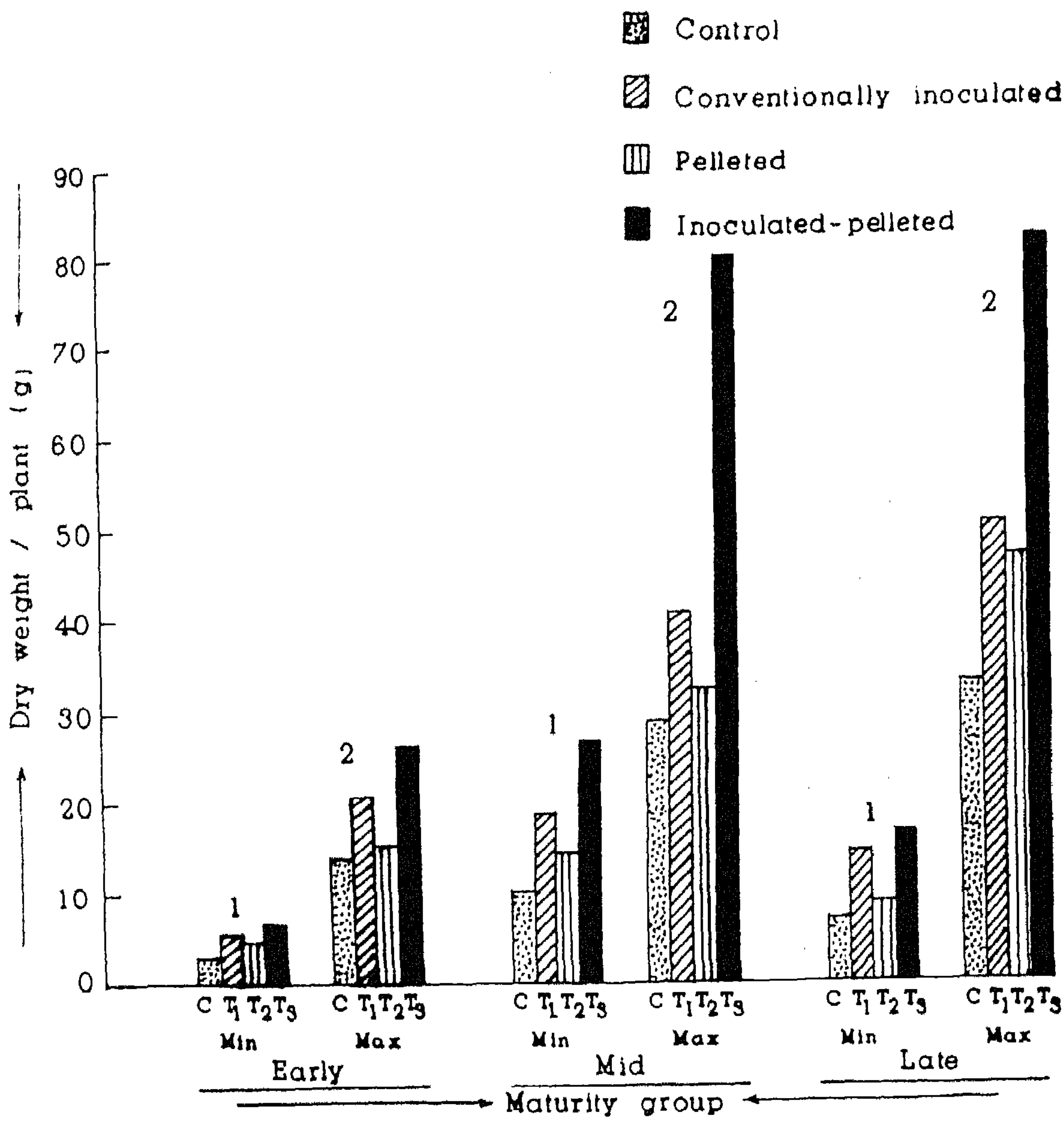
CD (P=0.05) varietal means = 0.826
CD (P=0.05) Treatment means = 1.226

The treatment effects showed exactly the same trend as studied earlier, collectively as well as separately on maturity group basis.

The interaction showed that the combined application of microbial culture and pellet surpassed the effect of individual application of the two very significantly, as was in the earlier studies. All the treatments and their combinations in early maturing groups were found to behave as recorded at flowering stage. In mid maturing group, the treatment combination was found similar to all the three growthstage studies, but the inoculated and pelleted was found to act selectively. The inoculated effect in mid maturing varieties was similar in behaviour to pre flowering and flowering stages while pelleted behaved like post flowering findings. The late maturing groups behaved exactly as flowering stage.

The pictorial support to the findings revealed that the dry weight per plant were found to have a two fold increase over control in all the three maturity groups in case of inoculation in combination with pelletant applied (fig 11). While comparing the three growth stages with another set of bar diagrams (fig 12), it was again remarkable to note that in late maturing group the dry weight increase per plant was high during transition from pre flowering to flowering stage, but from flowering to post flowering stage the relative increase was relatively lower. However, in early and mid maturing groups the rate of dry matter increase was almost equal during transition from one growth stage to another. The mid and late maturing groups had remarkably higher magnitude of dry weight increase in case of culture application in combination with pelleting (Fig 13).

A combined behaviour of dry weight of nodules per plant and plant dry weight were studied with line graphs drawn, taking the values at Y-axis and plant growth stage on X - axis (Fig. 14). It was interesting to note that the dry weight of nodules were highest (mg) at pre flowering growth stage (30 Days) when the plant dry weight (g) was the lowest. As the nodule weight went on decreasing with the plant age advances, the dry weight of plant went on increasing being maximum at post flowering stage. The dry weight of nodules (mg) was maximum in mid maturing group (70 mg) followed by Early maturing group (68 mg) and late maturing group (64 mg) at 30 days after sowing. A drastic reduction in nodule weight was observed during transition from pre flowering to flowering stage in early and late maturing groups the reduced weight accounting for 40 mg and




1. Varieties showing minimum yield
2. Varieties showing maximum yield

Fig. 11- Effect of inoculation methods on plant dry weight (Min., Max.,)

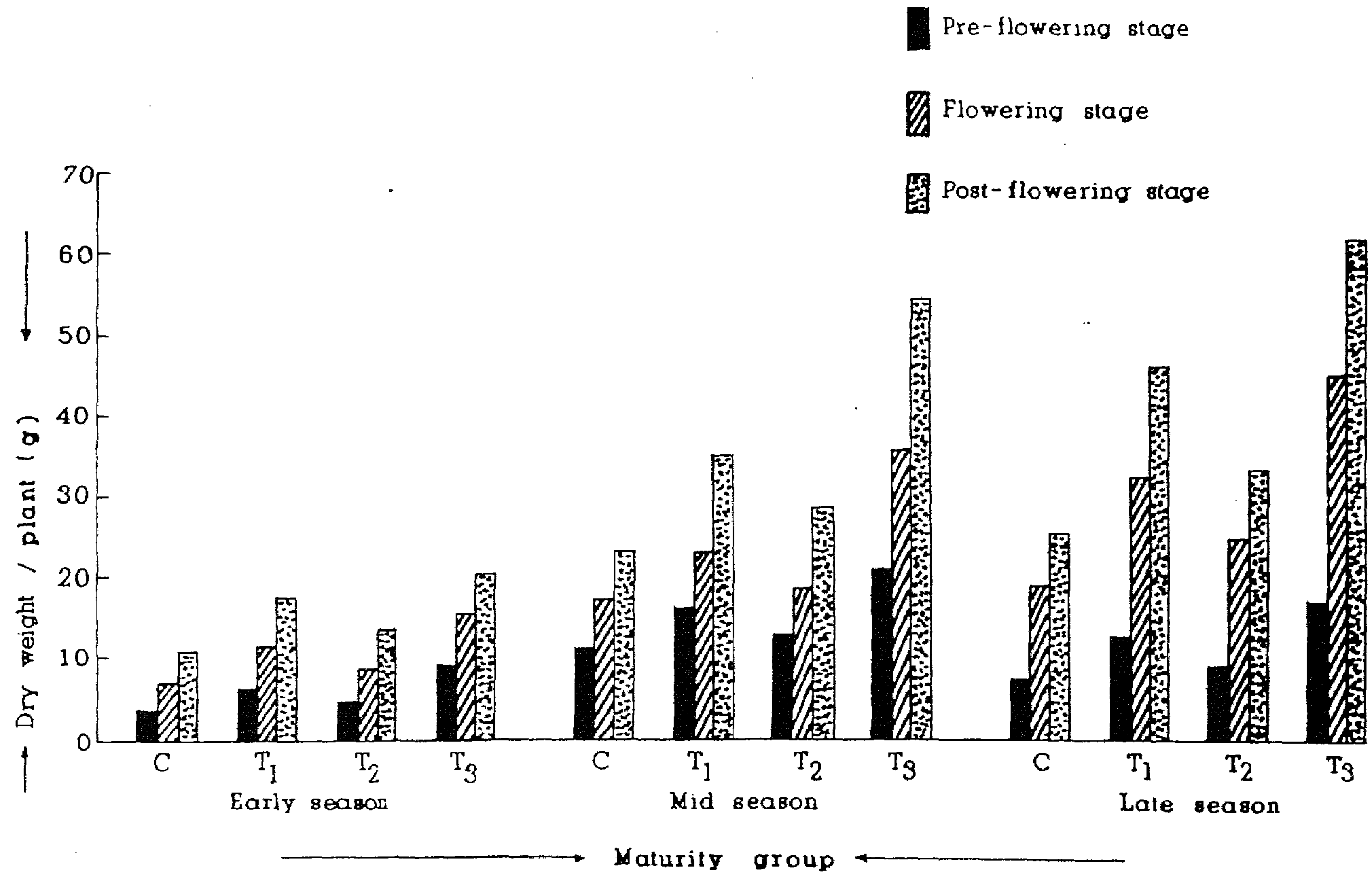



Fig. 12 - Effect of inoculation methods on plant dry weight at different growth stages.

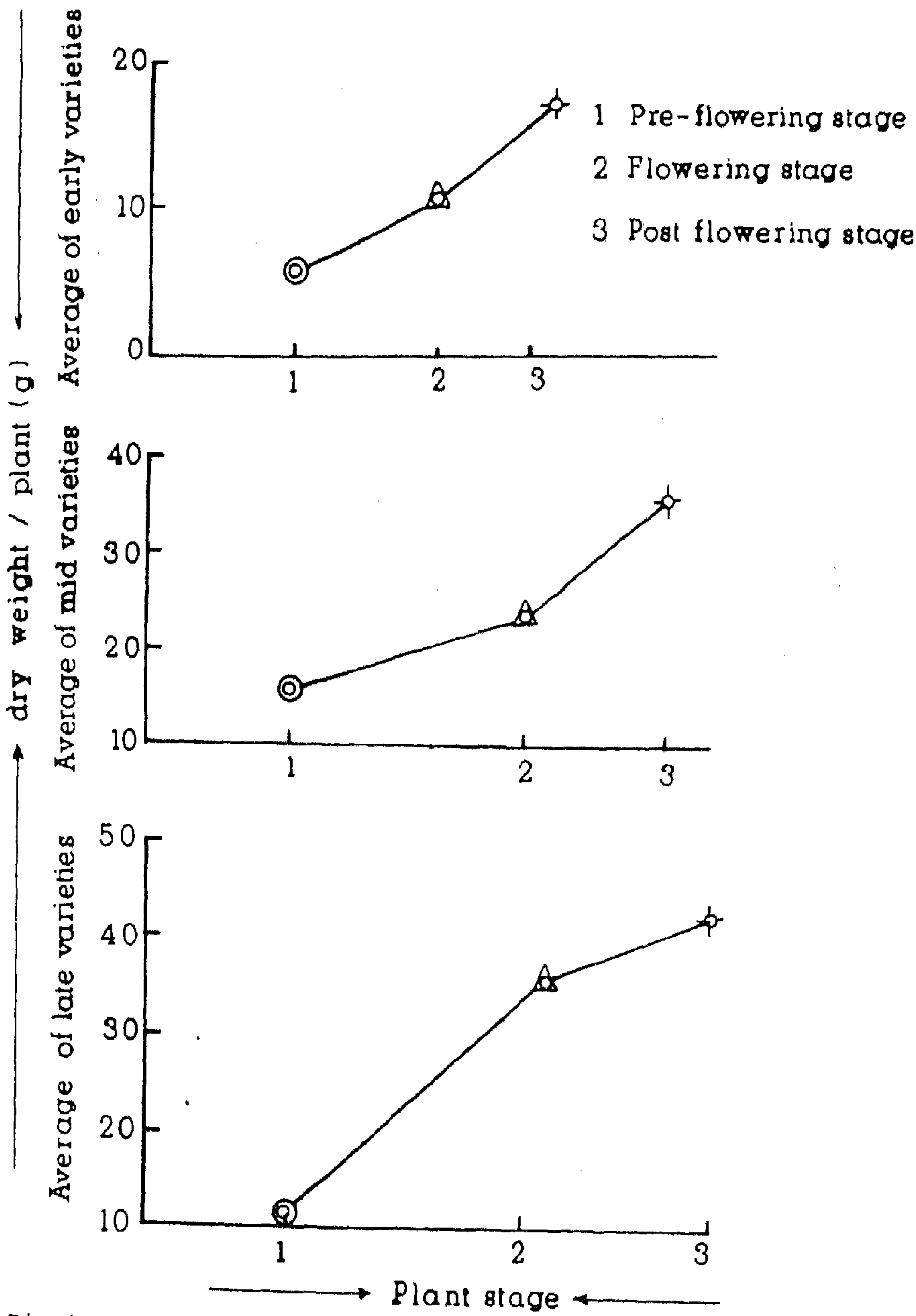



Fig 13 - Variation in plant dry weight with plant growth stages in early, mid and late cultivars.

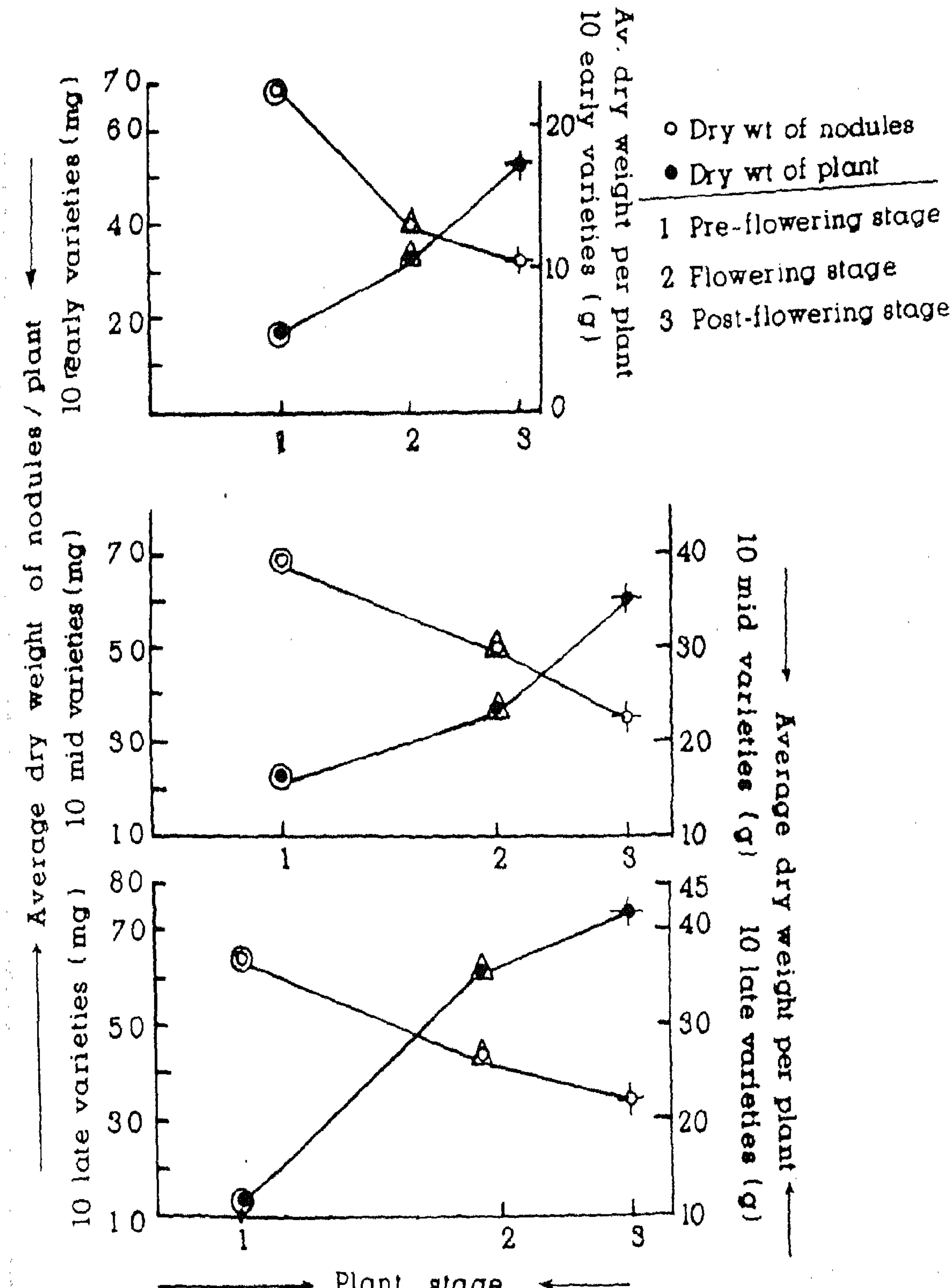



Fig. 14- Variation in dry weight of nodule Vs dry weight of plant with plant growth stages the early, mid and late cultivars.

43 mg respectively, whereas comparatively slow rate of decrease was found in mid maturing group, the weight being 50 mg. However, the rate of increase of plant weight from pre flowering to flowering stage was remarkably high in late maturing group (35.5 gm), as compared to mid maturing (23.5 gm) and early maturing (910.5. gm) groups. The rate of decrease of nodule weight from flowering to post flowering stage in early and late maturing groups was found to be of similar nature being relatively lower than what was observed during transition from pre flowering to flowering stage whereas rate of decrease in mid maturing group was found to be increased relatively. On the other hand the increase in plant dry weight in early and mid maturing groups was found relatively enhanced than what was during transition from pre flowering to flowering stage. In case of late maturing the rate of increase of plant dry weight was found to be relatively lower than that during the transition from pre flowering to flowering stage. The nodule weight was found minimum at the point where the plant dry weight was found maximum, that is, at post flowering stage.

## 5. Plant Height

The varietal responses as observed for plant height, showed significant differences among themselves. The treatment effects also revealed pronounced differences. The study over three growth stages were as follow.

### 5.a Pre-flowering stage

The varietal performance in the early maturing group ranged from 30.30 cm (VP-7839) to 68.47 cm (Early Badger) (Table 20A & 20B) . The next best variety was found to be 60.47 cm tall (Little Marvel), and then was VP 8005 (58.17 cm). In the mid maturing group the range was between 57.21 cm ( Lincoln) and 165.55 cm. (sel-222). Next best was IP-3 (81.97 cm) and then was Bonneville (78.87 cm). In the late maturing group the treatment means ranged from 66.25 cm (UU-2) to 203.71 cm (JP-501). Next best was Kala Nagini (195.74 cm) followed by selection-17 (185.08 cm).

The treatment effects significantly differed from each other showing inoculated seeds when pelleted giving the best result followed by inoculated and then by pelleted when tested individually. In all the three maturity groups studied separately and also in over all effect the results found were similar.

**Table No. 20 (A) Mean plant height at pre flowering stage**
**Ist year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 46.33 | 56.47 | 48.67 | 63.73 | 53.80 |
| 2. | Meteor | 46.07 | 54.67 | 47.73 | 60.87 | 52.33 |
| 3. | Early Badger | 59.20 | 73.20 | 61.40 | 81.20 | 68.75 |
| 4. | Little Marvel | 52.87 | 60.80 | 54.27 | 73.93 | 60.47 |
| 5. | Hara Bona | 42.13 | 55.27 | 43.27 | 64.60 | 51.32 |
| 6. | JP-829 | 37.67 | 50.20 | 39.40 | 65.73 | 48.25 |
| 7. | Jawahar Matar-4 | 38.07 | 51.53 | 40.93 | 56.73 | 46.81 |
| 8. | V.P.-7802 | 34.13 | 47.07 | 36.53 | 50.20 | 41.98 |
| 9. | V.P.-7839 | 24.47 | 32.47 | 25.67 | 38.60 | 30.30 |
| 10. | V.P.-8005 | 52.20 | 58.03 | 53.87 | 68.60 | 58.17 |
| 11. | Bonneville | 76.27 | 78.00 | 77.80 | 83.40 | 78.87 |
| 12. | Lincoln | 51.53 | 60.13 | 54.07 | 63.13 | 57.21 |
| 13. | Vipasa | 61.40 | 66.87 | 64.53 | 68.53 | 65.33 |
| 14. | VL-3 | 61.33 | 67.60 | 63.80 | 68.80 | 65.38 |
| 15. | Jawhar Matar-1 | 63.80 | 65.53 | 64.67 | 70.33 | 66.08 |
| 16. | KS-123 | 65.40 | 68.47 | 66.00 | 70.97 | 67.71 |
| 17. | IP-3 | 78.00 | 81.60 | 79.07 | 89.20 | 81.97 |
| 18. | VL-2 | 61.33 | 67.00 | 62.27 | 76.87 | 66.87 |
| 19. | Pb-88 | 59.40 | 65.33 | 61.27 | 73.53 | 64.88 |
| 20. | Sel. 222 | 160.33 | 167.00 | 163.33 | 171.53 | 165.55 |
| 21. | Early Perfection | 74.47 | 81.73 | 75.53 | 84.07 | 78.95 |
| 22. | Selection-17 | 182.53 | 184.73 | 183.60 | 189.47 | 185.08 |
| 23. | Kala Nagini | 188.53 | 199.33 | 190.57 | 204.53 | 195.74 |
| 24. | JP-501 | 196.40 | 205.60 | 197.33 | 215.53 | 203.71 |
| 25. | P-388 | 160.73 | 167.60 | 161.73 | 172.67 | 165.63 |
| 26. | P-6587-1 | 154.47 | 162.27 | 155.70 | 176.87 | 162.33 |
| 27. | P-6588-1 | 152.73 | 165.97 | 153.60 | 179.47 | 162.82 |
| 28. | UU-2 | 62.40 | 67.13 | 64.07 | 71.40 | 66.25 |
| 29. | UU-3 | 139.40 | 147.27 | 140.53 | 153.07 | 145.07 |
| 30. | ACC-65 | 169.00 | 179.33 | 171.60 | 186.27 | 176.55 |

C.D.((P= 0.05) varietal means = 3.958
C.D. (P= 0.05) Treatment means =2.836

## Table No. 20 (B) Mean Plant Height at pre flowering stage
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 45.53 | 54.13 | 48.93 | 59.53 | 52.03 |
| 2. | Meteor | 46.00 | 52.80 | 47.47 | 60.80 | 51.77 |
| 3. | Early Badger | 59.53 | 73.67 | 62.00 | 75.80 | 67.75 |
| 4. | Little Marvel | 51.60 | 60.33 | 53.07 | 77.27 | 60.56 |
| 5. | Hara Bona | 41.93 | 51.53 | 44.27 | 61.60 | 49.83 |
| 6. | JP-829 | 39.47 | 48.80 | 42.33 | 62.20 | 48.20 |
| 7. | Jawahar Matar-4 | 39.60 | 48.73 | 41.20 | 54.93 | 46.11 |
| 8. | V.P.-7802 | 40.00 | 45.53 | 42.00 | 50.47 | 44.50 |
| 9. | V.P.-7839 | 28.53 | 32.47 | 30.27 | 39.33 | 32.65 |
| 10. | V.P.-8005 | 52.27 | 60.60 | 56.60 | 67.33 | 59.20 |
| 11. | Bonneville | 78.27 | 80.40 | 79.13 | 83.60 | 80.35 |
| 12. | Lincoln | 52.00 | 59.27 | 56.13 | 63.33 | 57.68 |
| 13. | Vipasa | 60.33 | 66.93 | 64.67 | 71.33 | 65.81 |
| 14. | VL-3 | 61.53 | 67.47 | 64.07 | 71.20 | 66..07 |
| 15. | Jawhar Matar-1 | 65.07 | 67.67 | 65.93 | 72.87 | 67.88 |
| 16. | KS-123 | 67.00 | 69.47 | 67.93 | 72.53 | 69.23 |
| 17. | IP-3 | 78.87 | 83.47 | 79.87 | 91.73 | 83.48 |
| 18. | VL-2 | 63.33 | 67.33 | 64.00 | 76.33 | 67.80 |
| 19. | Pb-88 | 61.07 | 66.53 | 61.53 | 71.80 | 65.23 |
| 20. | Sel. 222 | 162.27 | 166.80 | 163.07 | 172.20 | 166.08 |
| 21. | Early Perfection | 75.60 | 82.60 | 77.80 | 85.60 | 80.40 |
| 22. | Selection-17 | 177.60 | 185.20 | 181.53 | 187.93 | 183.06 |
| 23. | Kala Nagini | 189.40 | 199.80 | 191.53 | 204.80 | 196.38 |
| 24. | JP-501 | 196.33 | 207.07 | 198.60 | 214.27 | 204.07 |
| 25. | P-388 | 161.53 | 167.80 | 163.27 | 173.00 | 166.40 |
| 26. | P-6587-1 | 157.53 | 165.00 | 158.80 | 177.33 | 164.66 |
| 27. | P-6588-1 | 152.87 | 167.47 | 155.27 | 180.27 | 163.97 |
| 28. | UU-2 | 63.73 | 67.80 | 65.00 | 74.00 | 67.63 |
| 29. | UU-3 | 141.53 | 147.80 | 143.00 | 153.07 | 146.35 |
| 30. | ACC-65 | 170.60 | 181.07 | 172.33 | 186.23 | 177.56 |

CD (P=0.05) varietal means =2.468
CD (P=0.05) Treatment means =3.884

The variety and treatment interaction showed significant differences in individual varietal responses. The application of inoculants in combination with pelletant gave the best plant height showing early Badger to give tallest plants but the highest relative increase was observed in case of Hara Bona (64.60 cm) over control among the early maturing varieties in the first year, while in the second year Little Marvel (77.27 cm) relatively performed best. The mid maturing sel. -222 gave the highest result (171.53 cm) while the maximum relative increase in height was observed in VL-2 (76.87 cm), and the same trend was observed in Second year also. In the late maturing group JP-501 (215.53 cm) was found to perform best in absolute terms but highest increase over control was found in P-6588-1 (179.47 cm). The second year results followed the same trend. The inoculated was found to perform second best in this study. The early maturing group, Early Badger (73.20 cm) was found to give maximum plant height both in absolute and relative terms in both the years. In mid maturing group, Lincoln (60.13 cm) was found to show the maximum relative increase over control though the highest absolute value was shown by Sel-222 (167.00 cm). Second year results showed the same trend. In the late maturing group P-6568-1 (165.47 cm) was best over control whereas in absolute terms JP-501 (205.60 cm) performed best. The second year study followed the trend. Pelleted effect was found maximum in relative terms in early maturing Jawahar Matar-4 (40.93 cm); in mid maturing Lincoln (60.13 cm) and in late maturing p-6588-1 (165.47 cm) over control in the first year, whereas VP 8005 in early (56.60 cm) , Vipasa (64.67) in mid and selection -17 (181.53 cm) in late maturing groups respectively in the second year's study.

## 5.b Flowering stage

At flowering stage the magnitude of height increase was found to be enhanced as compared to preflowering stage, as the plant was still in growing phase (Table No. 21A & 21B). The cultivar Early Badger (75.31 cm) was found to respond best followed by Little Marvel, VP-8005 and Hara Bona in early maturing varieties in first year and in the second year the same trend was shown. In the mid maturing, Sel-222 (159.35 cm) was found responding maximum followed by IP-3, Bonneville and VL-2 in the first year, however, in second year the cultivars sel-222 (174.73 cm) performed best, followed by

**Table No. 21 (A) Mean plant height at flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 48.87 | 59.20 | 51.13 | 69.73 | 57.23 |
| 2. | Meteor | 49.33 | 59.40 | 51.73 | 64.60 | 56.26 |
| 3. | Early Badger | 66.93 | 78.33 | 69.33 | 86.67 | 75.31 |
| 4. | Little Marvel | 59.20 | 65.07 | 60.07 | 80.47 | 66.20 |
| 5. | Hara Bona | 48.80 | 62.87 | 50.67 | 77.67 | 60.00 |
| 6. | JP-829 | 45.13 | 61.53 | 47.20 | 77.13 | 57.75 |
| 7. | Jawahar Matar-4 | 47.80 | 57.80 | 51.07 | 68.00 | 56.17 |
| 8. | V.P.-7802 | 38.87 | 53.13 | 41.60 | 64.40 | 49.50 |
| 9. | V.P.-7839 | 30.20 | 40.47 | 31.93 | 48.53 | 37.78 |
| 10. | V.P.-8005 | 55.20 | 68.80 | 57.33 | 74.27 | 63.90 |
| 11. | Bonneville | 78.87 | 85.07 | 80.27 | 90.87 | 83.77 |
| 12. | Lincoln | 55.33 | 62.33 | 57.53 | 73.93 | 62.28 |
| 13. | Vipasa | 70.33 | 74.13 | 71.33 | 81.67 | 74.36 |
| 14. | VL-3 | 68.33 | 73.20 | 70.13 | 81.53 | 73.30 |
| 15. | Jawhar Matar-1 | 69.07 | 74.47 | 71.40 | 80.40 | 73.83 |
| 16. | KS-123 | 70.27 | 77.33 | 72.20 | 82.20 | 75.50 |
| 17. | IP-3 | 78.53 | 85.27 | 81.13 | 91.07 | 84.00 |
| 18. | VL-2 | 68.67 | 78.93 | 70.20 | 88.93 | 76.68 |
| 19. | Pb-88 | 66.40 | 72.33 | 68.07 | 87.80 | 73.65 |
| 20. | Sel. 222 | 163.80 | 171.20 | 172.02 | 184.33 | 159.35 |
| 21. | Early perfection | 80.40 | 86.87 | 80.60 | 95.27 | 85.78 |
| 22. | Selection-17 | 192.73 | 196.07 | 193.13 | 198.33 | 195.06 |
| 23. | Kala Nagini | 195.07 | 203.80 | 195.87 | 216.93 | 202.92 |
| 24. | JP-501 | 204.73 | 221.07 | 206.20 | 235.80 | 216.95 |
| 25. | P-388 | 173.80 | 175.93 | 174.00 | 191.27 | 178.75 |
| 26. | P-6587-1 | 162.73 | 176.73 | 164.27 | 190.20 | 173.48 |
| 27. | P-6588-1 | 166.67 | 177.87 | 168.60 | 196.80 | 177.48 |
| 28. | UU-2 | 64.93 | 77.53 | 65.87 | 94.33 | 75.66 |
| 29. | UU-3 | 144.53 | 159.33 | 146.20 | 168.80 | 154.71 |
| 30. | ACC-65 | 176.80 | 191.33 | 177.87 | 202.67 | 187.17 |

C.D.((P= 0.05) varietal means = 4.204
C.D. (P= 0.05) Treatment means =4.231

**Table No. 21 (B) Mean Plant Height at flowering stage**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 49.80 | 62.53 | 52.07 | 70.53 | 58.73 |
| 2. | Meteor | 49.20 | 59.13 | 52.60 | 66.53 | 56.86 |
| 3. | Early Badger | 66.47 | 79.13 | 70.93 | 87.27 | 75.95 |
| 4. | Little Marvel | 60.00 | 67.20 | 62.53 | 78.13 | 66.96 |
| 5. | Hara Bona | 50.53 | 59.93 | 52.60 | 73.80 | 59.21 |
| 6. | JP-829 | 49.27 | 58.40 | 51.13 | 75.73 | 58.63 |
| 7. | Jawahar Matar-4 | 49.93 | 55.33 | 52.07 | 64.80 | 55.53 |
| 8. | V.P.-7802 | 38.67 | 51.47 | 41.53 | 64.53 | 49.05 |
| 9. | V.P.-7839 | 30.60 | 40.53 | 32.07 | 47.87 | 37.77 |
| 10. | V.P.-8005 | 56.00 | 69.00 | 59.93 | 71.53 | 64.11 |
| 11. | Bonneville | 80.87 | 86.33 | 83.40 | 91.80 | 85.60 |
| 12. | Lincoln | 60.53 | 66.20 | 62.53 | 74.13 | 65.85 |
| 13. | Vipasa | 66.93 | 73.47 | 69.73 | 80.47 | 72.65 |
| 14. | VL-3 | 71.73 | 75.80 | 74.33 | 82.87 | 76.18 |
| 15. | Jawhar Matar-1 | 70.13 | 74.93 | 72.07 | 79.93 | 74.26 |
| 16. | KS-123 | 68.20 | 74.60 | 71.60 | 83.20 | 74.40 |
| 17. | IP-3 | 81.53 | 86.07 | 83.20 | 90.73 | 85.38 |
| 18. | VL-2 | 70.33 | 79.00 | 73.40 | 88.73 | 77.86 |
| 19. | Pb-88 | 69.93 | 74.33 | 72.47 | 87.80 | 76.13 |
| 20. | Sel. 222 | 165.40 | 178.93 | 170.87 | 183.73 | 174.73 |
| 21. | Early perfection | 81.13 | 90.47 | 83.53 | 96.73 | 87.96 |
| 22. | Selection-17 | 189.87 | 195.67 | 191.07 | 197.60 | 193.55 |
| 23. | Kala Nagini | 186.67 | 196.60 | 190.33 | 212.53 | 196.53 |
| 24. | JP-501 | 196.67 | 213.87 | 199.53 | 233.60 | 210.91 |
| 25. | P-388 | 170.20 | 175.33 | 173.00 | 185.67 | 176.05 |
| 26. | P-6587-1 | 163.07 | 174.73 | 166.53 | 186.27 | 172.65 |
| 27. | P-6588-1 | 160.27 | 174.80 | 164.00 | 187.07 | 171.53 |
| 28. | UU-2 | 68.47 | 76.27 | 70.87 | 91.80 | 76.85 |
| 29. | UU-3 | 143.27 | 153.33 | 146.73 | 166.00 | 152.33 |
| 30. | ACC-65 | 170.40 | 189.67 | 174.40 | 198.20 | 183.16 |

CD (P=0.05) varietal means = 3.646
CD (P=0.05) Treatment means = 4.628

Bonneville, IP-3 VL-2, VL-3 and Pb-88.

The interaction result between variety and treatment gave significant result with differences over individual varietal responses in terms of relative increase in height over control. Inoculated in combination with pelletant performed best in both the years, showing JP-829 (77.13 cm), Pb-88 (87.80 cm) and JP-501 (235.80 cm) in early, mid and late groups, respectively in the first year study, while in the second year though the early and late groups showed the same trend with little variation due to environmental effects, the mid group behaved differently, projecting VL-2 (88.73cm) to perform best over control. The conventionally inoculated seeds with no pellet application showed the next best performance in height, projecting JP-829 (61.53 cm), Sel. 222 (177.20 cm) and JP-501 (221.07) in the first year and VP-8005 (69.00 cm) sel-222 (178.93 cm) and ACC-65 (189.67 cm) in the second year in early mid and late maturing groups respectively. When the performance of pelleted seeds without any culture application was studied separately, in early, mid and late maturing the cultivars, 'Jawahar Motar' 4(51.07 cm),'Sel-222' (172.07 cm) and 'P-6588-1' (168.60 cm) were found to give highest plant height respectively in the first year while in the second year Early Badger (70.93 cm), sel-222 (170.87 cm) and ACC-65 (174.40 cm) accounted remarkably for plant height.

## 5.C Post flowering stage

Post flowering observations revealed a significant relative increase over pre flowering and flowering stages for plant height (Table 22A & 22B). The treatment means of various early cultivars showed that Early Badger (78.33 cm) attained the highest plant height followed by VP -8005 (71.63 cm). The mid maturing cultivars showed a range of 73.58 cm (Lincoln) to 186.29 cm (sel-222), IP-3 (97.56 cm) was found to perform the next best. In late maturing group, the minimum height was noted in UU-2 (85.81 cm) while the highest value was observed in JP-501 (229.76 cm) followed by Kala Nagini (219.65 cm).

Among treatment effects significant differences were observed between different methods of treatment application. Inoculation in combination with pellet application performed best as reported in earlier studies followed by inoculated and pelleted when studied individually. Studying the interaction effects

**Table No. 22 (A)Mean plant height at post flowering stage**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 54.60 | 64.40 | 55.20 | 74.67 | 62.21 |
| 2. | Meteor | 54.87 | 61.20 | 55.00 | 67.93 | 59.75 |
| 3. | Early Badger | 70.20 | 81.27 | 72.60 | 89.27 | 78.33 |
| 4. | Little Marvel | 60.20 | 70.20 | 61.93 | 83.53 | 68.96 |
| 5. | Hara Bona | 57.93 | 67.47 | 60.27 | 81.07 | 66.68 |
| 6. | JP-829 | 50.33 | 62.33 | 52.00 | 84.27 | 62.23 |
| 7. | Jawahar Matar-4 | 51.13 | 61.73 | 52.20 | 77.73 | 60.69 |
| 8. | V.P.-7802 | 43.93 | 59.93 | 44.07 | 74.40 | 55.58 |
| 9. | V.P.-7839 | 36.47 | 47.33 | 37.73 | 55.27 | 55.27 |
| 10. | V.P.-8005 | 61.13 | 73.53 | 62.60 | 87.27 | 71.63 |
| 11. | Bonneville | 86.53 | 92.07 | 88.80 | 101.47 | 92.21 |
| 12. | Lincoln | 63.87 | 77.27 | 64.20 | 89.00 | 73.58 |
| 13. | Vipasa | 75.53 | 89.27 | 77.53 | 92.73 | 83.76 |
| 14. | VL-3 | 80.73 | 86.27 | 81.60 | 97.07 | 86.41 |
| 15. | Jawhar Matar-1 | 78.07 | 89.47 | 81.13 | 98.20 | 86.71 |
| 16. | KS-123 | 73.80 | 88.53 | 75.27 | 92.27 | 82.46 |
| 17. | IP-3 | 93.60 | 98.27 | 94.33 | 104.07 | 97.56 |
| 18. | VL-2 | 78.33 | 95.53 | 79.13 | 104.40 | 89.34 |
| 19. | Pb-88 | 72.60 | 90.33 | 74.07 | 102.40 | 84.85 |
| 20. | Sel. 222 | 177.33 | 189.53 | 179.00 | 199.33 | 186.29 |
| 21. | Early perfection | 85.93 | 97.27 | 86.27 | 103.47 | 93.23 |
| 22. | Selection-17 | 193.53 | 200.47 | 194.53 | 209.53 | 199.51 |
| 23. | Kala Nagini | 212.47 | 222.40 | 214.20 | 229.53 | 219.65 |
| 24. | JP-501 | 218.27 | 232.20 | 219.73 | 248.87 | 229.76 |
| 25. | P-388 | 178.67 | 190.07 | 179.20 | 198.47 | 186.60 |
| 26. | P-6587-1 | 172.27 | 190.33 | 173.93 | 200.73 | 184.31 |
| 27. | P-6588-1 | 178.70 | 191.33 | 179.33 | 204.33 | 188.42 |
| 28. | UU-2 | 73.53 | 89.40 | 74.53 | 105.80 | 85.81 |
| 29. | UU-3 | 153.47 | 173.80 | 154.13 | 179.47 | 165.21 |
| 30. | ACC-65 | 187.20 | 198.07 | 189.53 | 214.33 | 197.28 |

C.D.((P= 0.05) varietal means = 4.836
C.D. (P= 0.05) Treatment means =4.384

## Table No. 22 (B) Mean Plant Height at post flowering stage

**IInd Year**

**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 55.40 | 66.07 | 55.13 | 76.60 | 63.30 |
| 2. | Meteor | 54.80 | 63.47 | 56.70 | 69.40 | 61.09 |
| 3. | Early Badger | 75.00 | 81.20 | 76.00 | 85.67 | 79.47 |
| 4. | Little Marvel | 63.00 | 72.40 | 64.00 | 85.87 | 71.31 |
| 5. | Hara Bona | 59.73 | 69.33 | 62.33 | 82.80 | 68.54 |
| 6. | JP-829 | 52.67 | 64.07 | 54.07 | 87.00 | 64.45 |
| 7. | Jawahar Matar-4 | 53.20 | 63.60 | 54.80 | 80.07 | 62.91 |
| 8. | V.P.-7802 | 43.73 | 62.07 | 44.27 | 75.60 | 56.41 |
| 9. | V.P.-7839 | 38.00 | 48.60 | 39.13 | 57.53 | 45.81 |
| 10. | V.P.-8005 | 62.87 | 75.00 | 64.73 | 89.67 | 73.06 |
| 11. | Bonneville | 88.40 | 94.13 | 89.47 | 101.40 | 93.35 |
| 12. | Lincoln | 66.53 | 79.60 | 66.73 | 92.93 | 76.44 |
| 13. | Vipasa | 77.07 | 89.40 | 79.07 | 93.87 | 84.85 |
| 14. | VL-3 | 80.53 | 87.27 | 81.27 | 96.07 | 86.28 |
| 15. | Jawhar Matar-1 | 79.53 | 91.33 | 81.87 | 99.87 | 88.15 |
| 16. | KS-123 | 75.33 | 87.87 | 77.93 | 93.27 | 83.60 |
| 17. | IP-3 | 96.67 | 99.47 | 96.80 | 106.53 | 99.86 |
| 18. | VL-2 | 80.20 | 95.73 | 84.27 | 104.13 | 91.08 |
| 19. | Pb-88 | 75.67 | 90.93 | 76.13 | 105.67 | 87.08 |
| 20. | Sel. 222 | 177.27 | 189.40 | 178.20 | 201.27 | 186.53 |
| 21. | Early perfection | 87.60 | 99.00 | 88.47 | 103.47 | 94.63 |
| 22. | Selection-17 | 194.73 | 202.20 | 196.93 | 211.93 | 201.44 |
| 23. | Kala Nagini | 215.33 | 223.40 | 215.80 | 231.47 | 221.50 |
| 24. | JP-501 | 219.53 | 233.20 | 221.20 | 247.93 | 230.46 |
| 25. | P-388 | 180.40 | 193.60 | 182.13 | 200.13 | 189.06 |
| 26. | P-6587-1 | 173.87 | 188.93 | 175.00 | 204.20 | 185.50 |
| 27. | P-6588-1 | 180.53 | 193.53 | 181.47 | 205.20 | 190.18 |
| 28. | UU-2 | 75.73 | 92.07 | 77.13 | 108.07 | 88.25 |
| 29. | UU-3 | 156.40 | 176.87 | 156.93 | 182.13 | 168.08 |
| 30. | ACC-65 | 189.33 | 201.40 | 190.33 | 216.53 | 199.39 |

CD (P=0.05) varietal means = 3.622

CD (P=0.05) Treatment means = 3.468

for variety and treatments, the treatment combination was found to perform best. In the early, mid and late varieties JP-829 (84.27 cm), Pb-88 (102.40 cm) and JP-501 (248.87 cm) found to give maximum heightsrespectively in first year, while, in the second year, early and mid varieties behaved similarly. In the late group, P-6587-1 (204.20 cm) was found best. When the interaction between variety and conventional inoculation was studied in the early maturing cultivars, VP-7802 (59.93 cm) was the best responder over control. And the maximum absolute increase in height was observed in the variety Early Badger (81.27 cm) as it was also observed in pre flowering and flowering stages. Both the year's study showed the same trend. The mid maturing cultivar Pb-88 (90.33 cm) was the highest performer over control but the highest absolute value was shown by Sel-222 (189.53 cm), in the first year study. The second year study showed that VL-2 (95.73 cm) was with maximum increase over control, but the highest absolute value was found in sel-222 as was in first year study. In the late varieties UU-3 performed best in both the years. However, the highest absolute value was noted in JP-501 (232.20 cm & 233.20cm in first and second year respectively). The interaction between variety and pellet treatment gave a different picture depicting 'Hara Bona' (60.27 cm), 'Jawahar Matar'-1 (81.13 cm) and 'ACC-65' (189.53 cm) with maximum plant heights in early, mid and late maturing groups over control. In the second year study, the highest relative increase in plant height was observed in early, mid and late maturing group as 62.33 cm (Hara Bona), 84.27 cm (VL-2) and 196.913 cm (selection-17) respectively.

## Pooled Analysis over three growth stages

The varietal performance ranged from 37.43 cm to 216.81 cm (Minimum VP-7839, Maximum JP-501) when the 30 varieties together were taken into consideration (Table 23A & 23B). When the three maturity groups studied separately, the varietal means ranged from 37.43 cm (VP-7839) to 74.38 cm (Early Badger) in the early group, in the mid maturing group, it varied from 64.36 cm (Lincoln) to 167.40 cm (Sel-222) and the late maturing group it showed a fluctuation between 85.99 cm (Early Perfection) and 216.81 cm (JP-501). A thorough study revealed that the average performance of the 10 late cultivars was 164.69 cm, the highest, followed by the mid (85.70cm) and early maturing cultivars (57.42 cm). The varieties which were found with maximum plant

## Table No. 23 (A) Mean plant height pooled over growth stages

**Ist Year**

**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 49.93 | 59.98 | 51.67 | 69.38 | 57.74 |
| 2. | Meteor | 50.09 | 58.42 | 51.49 | 64.47 | 56.12 |
| 3. | Early Badger | 66.44 | 77.60 | 67.78 | 85.71 | 74..38 |
| 4. | Little Marvel | 57.42 | 65.31 | 58.76 | 79.31 | 65.20 |
| 5. | Hara Bona | 49.62 | 61.87 | 51.40 | 74.44 | 59.33 |
| 6. | JP-829 | 44.38 | 58.02 | 46.20 | 75.71 | 56.07 |
| 7. | Jawahar Matar-4 | 45.67 | 57.02 | 48.07 | 67.49 | 54.56 |
| 8. | V.P.-7802 | 38.98 | 53.38 | 40.73 | 63.00 | 49.02 |
| 9. | V.P.-7839 | 30.38 | 40.09 | 31.78 | 47.47 | 37.43 |
| 10. | V.P.-8005 | 56.18 | 66.79 | 57.93 | 76.71 | 64.40 |
| 11. | Bonneville | 80.56 | 85.04 | 82.29 | 91.91 | 84.95 |
| 12. | Lincoln | 56.91 | 66.58 | 58.60 | 75.36 | 64.36 |
| 13. | Vipasa | 69.09 | 76.76 | 71.13 | 80.98 | 74.49 |
| 14. | VL-3 | 70.47 | 75.69 | 71.84 | 82.47 | 75.12 |
| 15. | Jawhar Matar-1 | 70.31 | 76.49 | 72.40 | 82.98 | 75.54 |
| 16. | KS-123 | 69.82 | 78.11 | 71.16 | 81.81 | 75.22 |
| 17. | IP-3 | 83.38 | 88.38 | 84.84 | 94.78 | 87.84 |
| 18. | VL-2 | 69.44 | 80.49 | 70.53 | 90.07 | 77.63 |
| 19. | Pb-88 | 66.13 | 76.00 | 67.80 | 87.91 | 74.46 |
| 20. | Sel. 222 | 147.16 | 175.91 | 161.47 | 185.07 | 167.40 |
| 21. | Early perfection | 80.27 | 88.62 | 80.80 | 94.27 | 85.99 |
| 22. | Selection-17 | 189.60 | 193.76 | 190.42 | 199.11 | 193.22 |
| 23. | Kala Nagini | 198.69 | 208.51 | 200.21 | 217.00 | 206.10 |
| 24. | JP-501 | 204.97 | 219.62 | 207.76 | 233.40 | 216.81 |
| 25. | P-388 | 171.07 | 159.98 | 171.64 | 187.47 | 176.29 |
| 26. | P-6587-1 | 163.16 | 176.44 | 164.63 | 189.27 | 173.37 |
| 27. | P-6588-1 | 166.03 | 178.22 | 167.18 | 193.53 | 176.24 |
| 28. | UU-2 | 67.07 | 78.02 | 68.16 | 90.91 | 75.94 |
| 29. | UU-3 | 145.80 | 160.13 | 146.96 | 167.11 | 155.00 |
| 30. | ACC-65 | 177.67 | 191.58 | 179.67 | 201.09 | 187.50 |

C.D.((P= 0.05) varietal means = 2.623

C.D. (P= 0.05) Treatment means = 3.426

**Table No. 23 (B) Mean Plant Height pooled over growth stages**

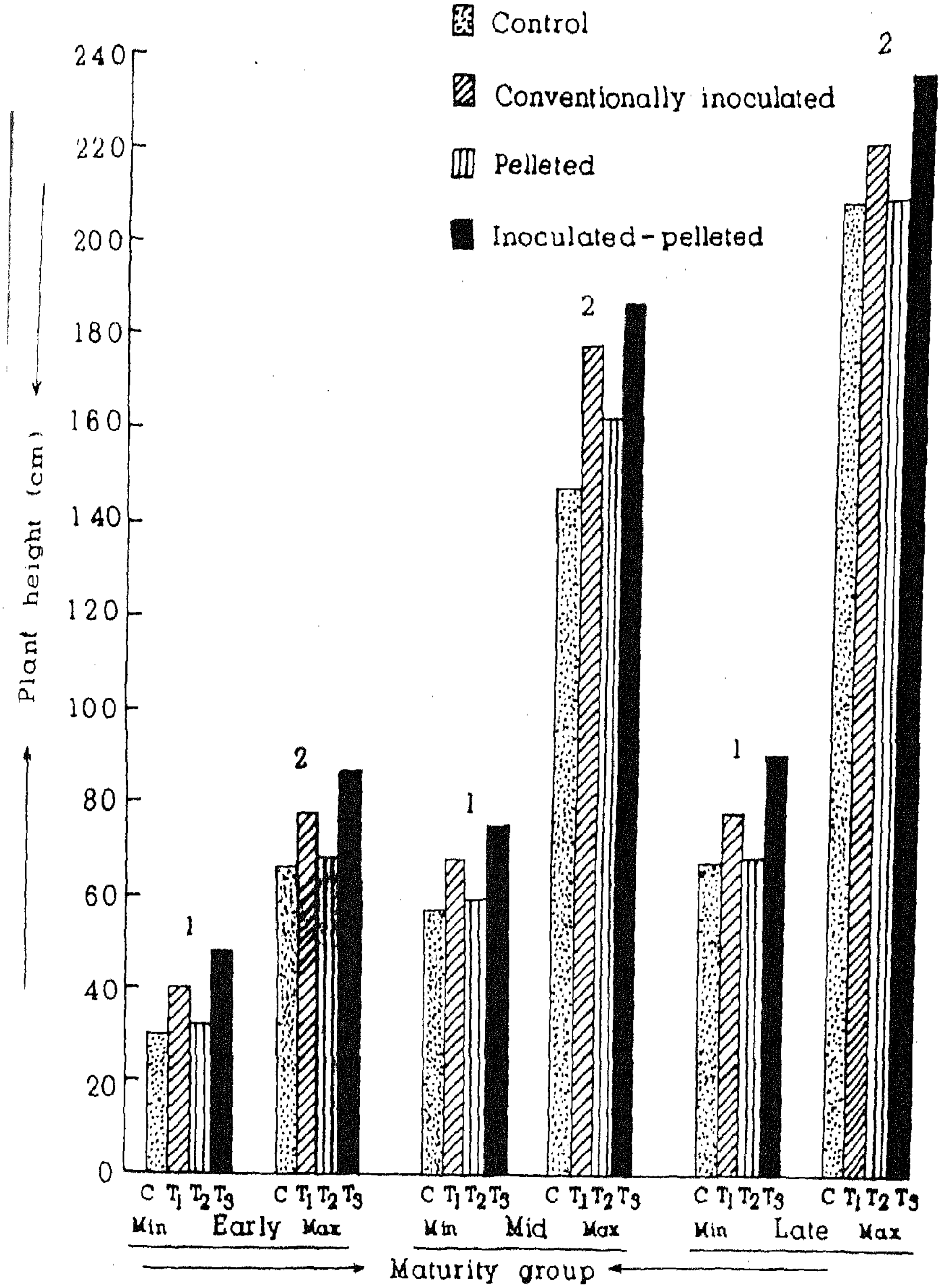
**IInd Year**

**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated +Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 50.24 | 60.91 | 52.04 | 68.89 | 58.02 |
| 2. | Meteor | 50.67 | 58.47 | 52.26 | 65.58 | 56.74 |
| 3. | Early Badger | 65.00 | 75.33 | 67.98 | 80.24 | 72.14 |
| 4. | Little Marvel | 58.20 | 66.64 | 59.87 | 80.42 | 66.28 |
| 5. | Hara Bona | 50.73 | 60.27 | 53.07 | 72.73 | 59.20 |
| 6. | JP-829 | 47.13 | 57.09 | 49.18 | 74.98 | 57.09 |
| 7. | Jawahar Matar-4 | 47.58 | 55.89 | 49.36 | 66.60 | 54.66 |
| 8. | V.P.-7802 | 41.13 | 53.02 | 42.60 | 63.53 | 50.07 |
| 9. | V.P.-7839 | 32.38 | 40.53 | 33.82 | 48.24 | 38.74 |
| 10. | V.P.-8005 | 57.04 | 68.20 | 60.42 | 76.18 | 65.46 |
| 11. | Bonneville | 82.51 | 86.96 | 84.00 | 92.27 | 86.43 |
| 12. | Lincoln | 58.36 | 68.36 | 61.80 | 76.80 | 66.33 |
| 13. | Vipasa | 68.11 | 76.60 | 72.82 | 85.22 | 75.68 |
| 14. | VL-3 | 69.93 | 76.84 | 73.22 | 83.38 | 75.84 |
| 15. | Jawhar Matar-1 | 71.58 | 77.98 | 73.29 | 84.22 | 76.76 |
| 16. | KS-123 | 70.18 | 77.31 | 72.49 | 23.00 | 75.74 |
| 17. | IP-3 | 85.69 | 89.67 | 86.62 | 96.33 | 89.57 |
| 18. | VL-2 | 71.29 | 80.69 | 73.89 | 89.80 | 79.91 |
| 19. | Pb-88 | 68.89 | 77.27 | 70.04 | 88.42 | 76.15 |
| 20. | Sel. 222 | 149.31 | 177.38 | 160.91 | 185.73 | 168.53 |
| 21. | Early perfection | 85.44 | 90.69 | 23.27 | 95.27 | 87.66 |
| 22. | Selection-17 | 187.40 | 194.36 | 189.84 | 199.16 | 192.66 |
| 23. | Kala Nagini | 197.13 | 206.60 | 199.22 | 216.27 | 204.80 |
| 24. | JP-501 | 204.18 | 218.04 | 206.44 | 231.93 | 215.14 |
| 25. | P-388 | 170.71 | 178.91 | 172.80 | 186.27 | 177.17 |
| 26. | P-6587-1 | 164.82 | 176.22 | 166.78 | 189.27 | 174.27 |
| 27. | P-6588-1 | 164.56 | 178.60 | 166.91 | 190.84 | 175.22 |
| 28. | UU-2 | 69.31 | 78.71 | 71.00 | 91.29 | 77.57 |
| 29. | UU-3 | 147.07 | 159.33 | 148.89 | 167.07 | 155.59 |
| 30. | ACC-65 | 176.78 | 190.71 | 179.02 | 200.32 | 186.70 |

CD (P=0.05) varietal means = 3.660

CD (P=0.05) Treatment means = 3.284




1. Varieties showing minimum yield

2. Varieties showing maximum yield

Fig. 15 - Effect of inoculation methods on plant height (Min., Max.,)

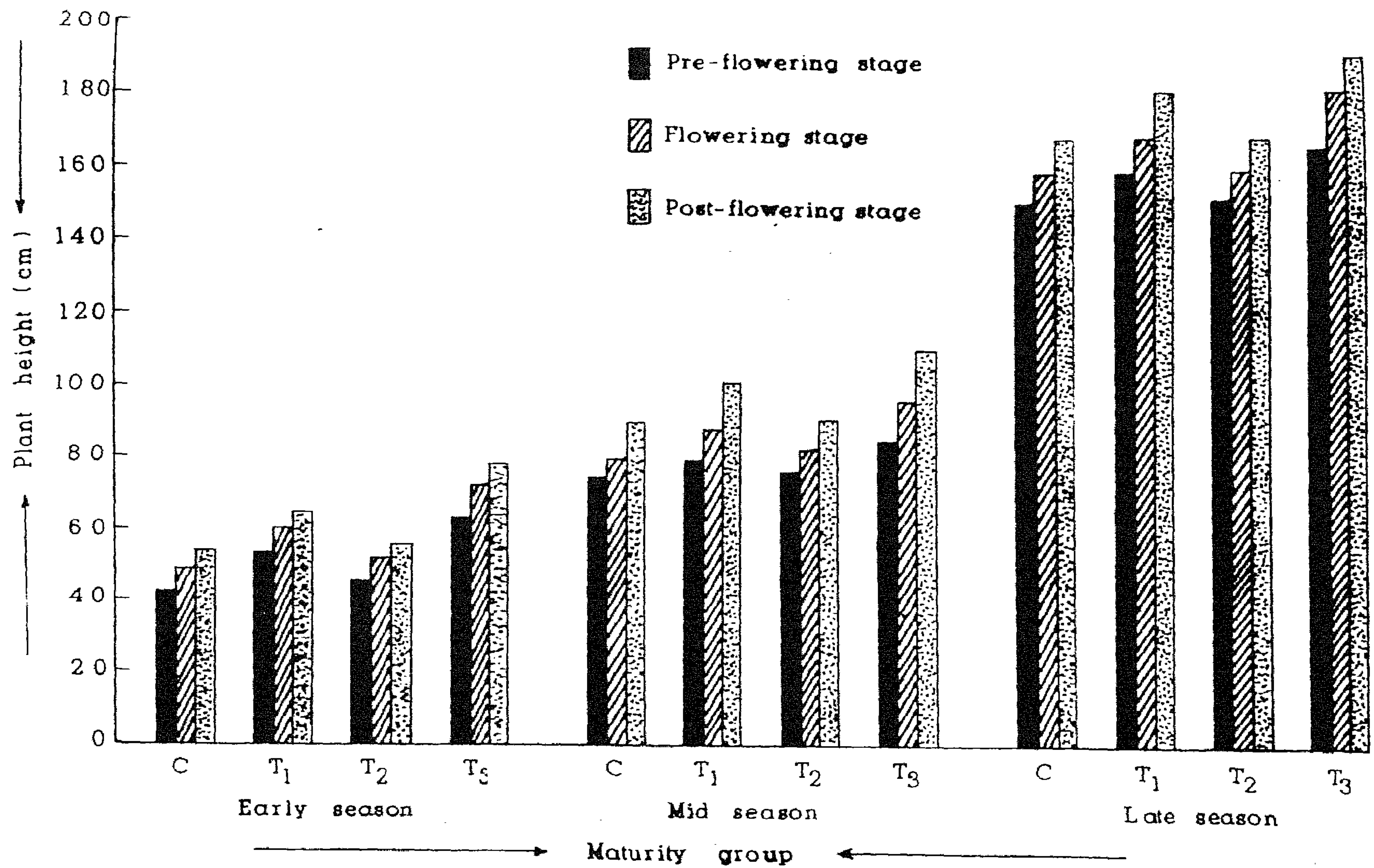



Fig. 16 - Effect of inoculation methods on plant height at different growth stages.

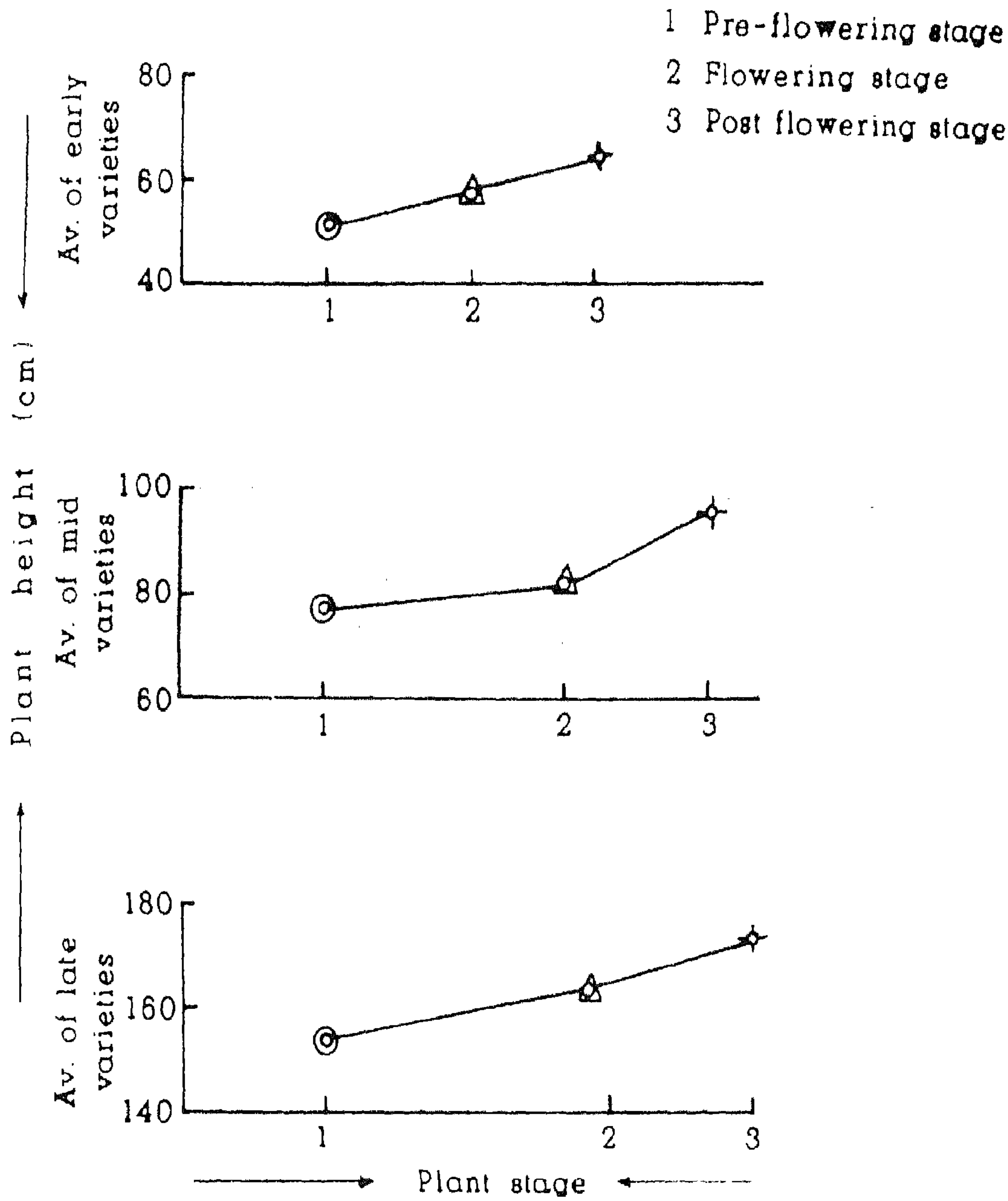



Fig. 17 - Variation in height with plant growth stages in early, mid and late cultivars.

height in all the three maturing groups also showed highest in all the pre flowering, flowering and post flowering growth stages.

Considering the treatment effects, it was found that the pelletants when applied to the seeds performed better than the seeds which were sown without any seed treatment. When the seeds were inoculated with the *Rhizobium* culture with a conventional method, the performance was better over pellet application, but when the culture in combination with pelletant was applied the response in terms of height was significantly outstanding over control. The same effect was observed when the three maturing groups were studied separately and individually .

The interaction was significant for variety as well as treatment effects. In the first year study, in case of incoulated seeds, the early and late maturing highest performers (VP -7802 and UU-3) did exactly as post flowering performance, but the mid maturing highest value was found not similar to any of the growth stage studies and showed entirely a different expression. The second year study showed a different picture, with late and mid maturing group showing little dissimilarity in performances. In case of pelletant application, it was found that the maximum relative increase in height over control was same in early maturing variety as pre flowering and flowering stages. The mid maturing varieties also showed the same trend. However, the late maturing varieties showed similarity to none. When the seeds were inoculated along with pelletants the response was highest in all the three maturity groups. The performance of early group was exactly similar to the performance of flowering and post flowering stages while in the late maturing group the highest performance was similar to those of pre flowering stage only. The mid-maturing group behaved differently. Pictorial illustrations supported the inferences (Fig.15,16,17).

## 6. Grain yield per plant

Grain yield per plant was the prime concern in the entire investigation . The results obtained regarding individual varietal responses to different treatment means revealed significant outcomes with regard to certain increase or decrease in yield. This was because the plant growth conditions had been excited by the artificial inclusion of bacteria for extra atmospheric nitrogen to the rhizospheres for extra nitrogen availability to the crop concerned (Table 24A & 24B).

Examining the individual varietal performances in the early maturing cultivars, VP-8005 (276.03 g in first year and 276.36 g in second year) was the best responder followed by 'Jawahar Matar-4' 'Hara-Bona', ~Little Marvel", 'Arkel' and 'Meteor'. In mid maturing crops the varietal responses were found to touch the maximum limit surpassing the highest values of both early and late maturing groups. The cultivar Jawahar Matar-1 was found to be the best responder (288.82 g and 289.17 g in first and second year respectively), followed by Pb-88,Ks-123, Bonneville, VL-3 and VL-2. In the late maturing group, P-6588-1 was the best yielder (243.33 g in first year and 243.49 g in second year). The next best performers were P-388, 'Early Perfection', 'UU-2,P-6587-1' and 'UU-3'.

The treatment effects when studied revealed the same trend as was observed in the earlier findings. Ignoring the individual varietal response, when the inoculation with bacterial culture was followed by pelleting with Calcium sulphate,the response was found to be more superior than inoculated and pelleted when studied separately in absence of the other. However, it was note worthy that when inoculated was studied alone, the result was far superior than what was obtained with pelleted without the inclusion of culture. There was also found a difference in performance between control (seeds without any treatment) and pelleted seeds but the difference was not remarkable. The average performance of the 30 varieties together, in case of inoculated seeds in combination with pelletant was 181.73 g in first year and 183.39 g in the second year. The conventionally inoculated seeds gave the yield as 174.89 g in the first year and 175.48 g in the second year study. When pelleted alone was studied, the grain yield was 163.50 g in the first year and 163.56 g in the second year, however, the average performances of the control was 161.53 g and 161.67 g in first and second year respectively. When the three maturity groups viz; early mid and late with 10 varieties each, were studied separately the same performance trend was found.

The interaction between variety and treatment was highly significant. When seed inoculation in combination with pelletant was studied, the maximum relative increase in grain yield was observed in Hara Bona in early maturing cultivars (229.60 g in first year and 219.11 g in second year, Linclon in the mid maturing group and Kala Nagini in the late maturing group. in both the years. When the

**Table No. 24 (A) Average Yield Per Plant**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | inoculated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 141.39 | 157.35 | 145.50 | 162.27 | 151.62 |
| 2. | Meteor | 126.53 | 140.88 | 128.59 | 146.75 | 135.68 |
| 3. | Early Badger | 84.51 | 99.65 | 86.64 | 109.03 | 94.95 |
| 4. | Little Marvel | 162.39 | 174.09 | 163.97 | 179.19 | 169.91 |
| 5. | Hara Bona | 180.23 | 201.63 | 185.58 | 229.60 | 199.27 |
| 6. | JP-829 | 91.63 | 104.69 | 93.41 | 111.21 | 100.23 |
| 7. | Jawahar Matar-4 | 209.31 | 231.40 | 211.29 | 241.94 | 223.48 |
| 8. | V.P.-7802 | 95.67 | 110.65 | 96.83 | 117.96 | 105.27 |
| 9. | V.P.-7839 | 85.89 | 109.79 | 87.47 | 114.87 | 99.50 |
| 10. | V.P.-8005 | 256.85 | 282.21 | 277.82 | 287.24 | 276.03 |
| 11. | Bonneville | 214.22 | 228.75 | 215.39 | 235.84 | 223.55 |
| 12. | Lincoln | 167.39 | 183.45 | 169.14 | 190.76 | 177.68 |
| 13. | Vipasa | 127.41 | 142.00 | 129.48 | 148.76 | 136.91 |
| 14. | VL-3 | 195.35 | 211.78 | 197.44 | 217.43 | 205.50 |
| 15. | Jawhar Matar-1 | 281.16 | 292.38 | 283.10 | 298.65 | 288.82 |
| 16. | KS-123 | 178.67 | 192.84 | 180.31 | 200.55 | 232.76 |
| 17. | IP-3 | 137.34 | 151.23 | 139.94 | 156.64 | 146.28 |
| 18. | VL-2 | 184.77 | 198.90 | 187.11 | 204.91 | 193.92 |
| 19. | Pb-88 | 229.99 | 239.76 | 232.20 | 248.10 | 237.51 |
| 20. | Sel. 222 | 78.16 | 86.83 | 80.76 | 95.09 | 85.21 |
| 21. | Early perfection | 187.77 | 197.38 | 189.85 | 204.79 | 194.94 |
| 22. | Selection-17 | 124.22 | 117.05 | 105.89 | 123.77 | 112.73 |
| 23. | Kala Nagini | 130.71 | 140.99 | 132.53 | 152.37 | 138.40 |
| 24. | JP-501 | 137.93 | 148.11 | 139.15 | 157.51 | 145.67 |
| 25. | P-388 | 207.31 | 217.24 | 208.67 | 224.70 | 214.48 |
| 26. | P-6587-1 | 169.59 | 179.37 | 171.59 | 185.12 | 176.41 |
| 27. | P-6588-1 | 235.17 | 247.05 | 237.98 | 253.12 | 243.33 |
| 28. | UU-2 | 185.43 | 195.70 | 187.23 | 202.14 | 192.62 |
| 29. | UU-3 | 146.02 | 155.71 | 148.09 | 163.17 | 153.24 |
| 30. | ACC-65 | 92.95 | 105.08 | 95.11 | 111.52 | 101.16 |

C.D.((P= 0.05) varietal means = 2.128
C.D. (P= 0.05) Treatment means =1.828

**Table No. 24 (B) Average Yield per plant**
**IInd Year**
**Mean values of interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | Pelleted | inoculated + Pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 143.77 | 157.63 | 145.25 | 162.08 | 152.18 |
| 2. | Meteor | 127.71 | 141.08 | 128.59 | 147.29 | 136.16 |
| 3. | Early Badger | 85.37 | 100.75 | 87.14 | 109.73 | 95.74 |
| 4. | Little Marvel | 163.25 | 174.37 | 169.32 | 180.01 | 170.48 |
| 5. | Hara Bona | 190.01 | 202.09 | 192.11 | 211.11 | 198.83 |
| 6. | JP-829 | 92.34 | 105.17 | 93.77 | 112.21 | 100.87 |
| 7. | Jawahar Matar-4 | 210.01 | 232.18 | 211.36 | 242.17 | 223.93 |
| 8. | V.P.-7802 | 96.29 | 111.66 | 98.36 | 118.03 | 106.08 |
| 9. | V.P.-7839 | 86.52 | 109.43 | 87.69 | 115.95 | 99.89 |
| 10. | V.P.-8005 | 266.30 | 282.89 | 268.00 | 288.27 | 276.36 |
| 11. | Bonneville | 210.25 | 228.49 | 214.52 | 236.23 | 222.37 |
| 12. | Lincoln | 167.83 | 184.20 | 169.29 | 192.13 | 178.36 |
| 13. | Vipasa | 127.51 | 142.19 | 129.33 | 148.56 | 136.89 |
| 14. | VL-3 | 195.29 | 212.89 | 196.43 | 217.92 | 205.63 |
| 15. | Jawhar Matar-1 | 280.84 | 293.93 | 282.42 | 299.99 | 289.17 |
| 16. | KS-123 | 178.85 | 193.73 | 180.43 | 202.71 | 188.93 |
| 17. | IP-3 | 136.73 | 152.05 | 140.25 | 157.41 | 146.61 |
| 18. | VL-2 | 186.03 | 199.69 | 188.05 | 238.61 | 203.09 |
| 19. | Pb-88 | 230.61 | 240.84 | 232.71 | 248.92 | 238.27 |
| 20. | Sel. 222 | 78.10 | 87.83 | 81.17 | 93.85 | 85.48 |
| 21. | Early perfection | 187.37 | 197.99 | 189.63 | 205.63 | 195.15 |
| 22. | Selection-17 | 105.83 | 118.18 | 106.70 | 125.3 | 113.93 |
| 23. | Kala Nagini | 130.84 | 142.31 | 132.52 | 149.31 | 138.74 |
| 24. | JP-501 | 137.42 | 147.73 | 139.19 | 156.85 | 145.29 |
| 25. | P-388 | 207.56 | 218.63 | 209.25 | 224.49 | 214.98 |
| 26. | P-6587-1 | 169.99 | 179.43 | 171.72 | 185.59 | 176.68 |
| 27. | P-6588-1 | 235.67 | 248.17 | 237.59 | 252.53 | 243.49 |
| 28. | UU-2 | 185.87 | 196.53 | 186.95 | 203.04 | 192.97 |
| 29. | UU-3 | 145.51 | 156.69 | 147.44 | 163.39 | 153.25 |
| 30. | ACC-65 | 92.99 | 106.33 | 94.98 | 111.87 | 101.54 |

CD (P=0.05) varietal means = 1.646
CD (P=0.05) Treatment means = 1.226

inoculated performance was observed critically the cultivars 'VP 8005' (282.21 g and 286.89 g) 'VL-3' (211.78 and 214.89 g) and selection -17 (117.05 g and 118.18 g) responded best in early, Mid and late maturing groups in both year respectively. Pelleted performance was comparatively inferior to inoculated but the cultivars VP- 8005 (277.82 g) IP-3 (139.94 g) and P-6588-1 and (237.98 g) in early, mid and late groups respectively.

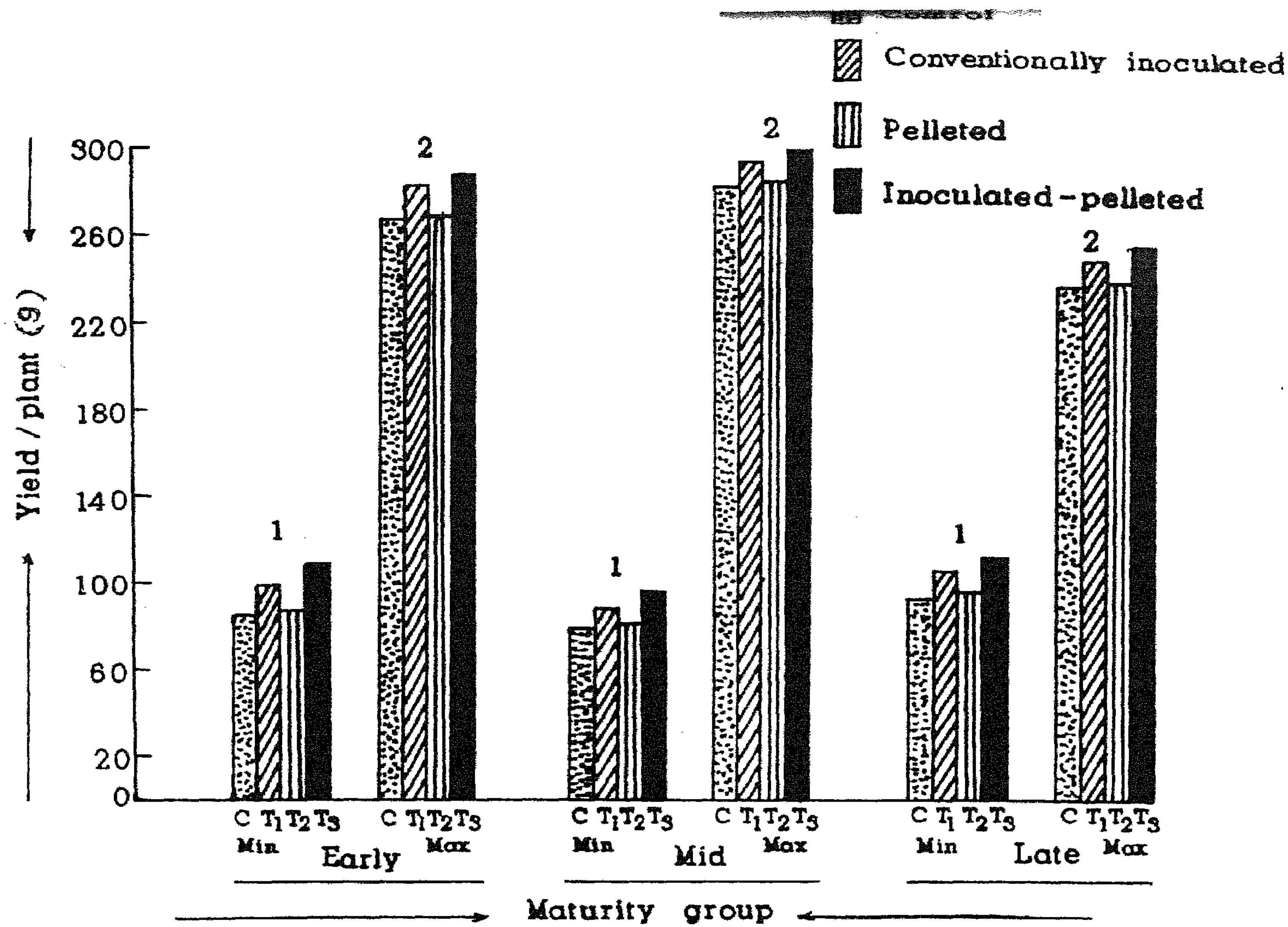
The pooled analysis revealed that the individual varietal responses in the early maturing group were VP -8005 Jawahar Matar-4, Hara Bona, Little Marvel, Arkel , Meteor VP-7802, JP-829, VP -7839 and Early Badger in descending order of yield ranking . Among the mid maturing group, 'Jawahar Matar-1' gave the highest grain yield followed by 'Pb-88', Bhneville, 'VL-3', 'VL-2', 'KS-123', 'Linclon, IP-3', 'Vipasa' and 'Sel-222'. Among the 10 late maturing varieties 'P-6588-1' gave the highest grain yield while ACC-65 gave the lowest yield. The cultivars which resulted next best in performance were 'P-6588-1' 'P-388' and Early perfection.

The treatment effect was found to follow the earlier trend showing inoculation in combination with pelletant to give maximum grain yield. The interaction study between the variety and different treatments revealed that inoculation in combination with pelletant gave the maximum yield depicting 'Jawahar Matar -4' as the best early producer (242.05 g), 'VL-2' as the best mid season producer (221.76 g) and JP -501 as the best late season variety (157.10 g). It was very much note worthy that maximum relative increase over control was found in the mid group variety (VL-2) followed by early variety (Jawahar Matar-4) and then by late cultivar (JP-501). The varietal response studied earlier also followed the same trend that is the mid maturing varieties gave the highest grain yield which was followed by early and late group varieties. The results gave the idea that though the highest performance in late cultivars was lower than the highest of the mid and early maturing performers, but in general, the performance of all the 10 late maturing cultivars were not with very much differences among themselves with regard to production potential. The conventionally inoculated method depicted the cultivars Jawahar Matar-4, VL-3 and ACC -65 to produce highest in early, Mid and late maturing cultivars respectively . When only pelletant was applied to the seed lots, the cultivars Arkel, IP-3, P-6588-1 were found best in their respective

**Table No. 25 Average yield per plant pooled over two years**
**Ist Year**
**Mean Values of Interactions (Main x Sub)**

| S.No. | Varieties | control | inoculated | pelleted | Incullated + pelleted | Mean |
|---|---|---|---|---|---|---|
| 1. | Arkel | 142.58 | 157.49 | 145.37 | 162.18 | 184.12 |
| 2. | Meteor | 127.12 | 140.98 | 128.59 | 147.02 | 198.96 |
| 3. | Early Badger | 84.94 | 100.20 | 86.89 | 109.38 | 188.84 |
| 4. | Little Marvel | 162.82 | 174.23 | 164.15 | 179.60 | 224.35 |
| 5. | Hara Bona | 190.12 | 203.36 | 192.35 | 210.35 | 199.04 |
| 6. | JP-829 | 91.99 | 104.93 | 93.59 | 111.71 | 100.55 |
| 7. | Jawahar Matar-4 | 209.66 | 231.79 | 211.32 | 242.05 | 223.70 |
| 8. | V.P.-7802 | 95.98 | 111.15 | 97.59 | 117.97 | 105.67 |
| 9. | V.P.-7839 | 86.20 | 109.61 | 87.58 | 115.41 | 99.70 |
| 10. | V.P.-8005 | 257.57 | 284.55 | 274.91 | 287.75 | 276.21 |
| 11. | Bonneville | 212.24 | 228.62 | 214.95 | 236.04 | 222.96 |
| 12. | Lincoln | 167.61 | 183.82 | 169.22 | 191.45 | 178.02 |
| 13. | Vipasa | 127.46 | 142.09 | 129.41 | 148.66 | 136.90 |
| 14. | VL-3 | 195.32 | 212.34 | 196.94 | 217.67 | 205.56 |
| 15. | Jåwhar Matar-1 | 281.00 | 292.90 | 282.76 | 299.32 | 288.99 |
| 16. | KS-123 | 178.76 | 193.29 | 180.37 | 201.63 | 188.51 |
| 17. | IP-3 | 137.03 | 151.64 | 144.10 | 157.02 | 146.44 |
| 18. | VL-2 | 185.40 | 199.30 | 187.58 | 221.76 | 198.51 |
| 19. | Pb-88 | 230.30 | 240.30 | 232.46 | 248.51 | 237.89 |
| 20. | Sel. 222 (EC 25564) | 78.13 | 87.33 | 80.96 | 94.97 | 85.34 |
| 21. | Early perfection | 187.57 | 197.68 | 189.74 | 205.21 | 195.05 |
| 22. | Selection-17 | 105.02 | 117.62 | 106.30 | 124.40 | 113.33 |
| 23. | Kala Nagini | 130.78 | 141.65 | 132.52 | 148.84 | 138.57 |
| 24. | JP-501 | 137.68 | 147.92 | 139.17 | 157.18 | 145.48 |
| 25. | P-388 | 207.43 | 217.93 | 208.96 | 224.60 | 214.73 |
| 26. | P-6587-1 | 169.79 | 179.40 | 171.65 | 185.35 | 176.54 |
| 27. | P-6588-1 | 235.42 | 247.61 | 2237.79 | 252.83 | 243.41 |
| 28. | UU-2 | 185.40 | 196.12 | 187.09 | 202.59 | 192.80 |
| 29. | UU-3 | 145.77 | 156.20 | 147.76 | 163.28 | 153.25 |
| 30. | ACC-65 | 92.97 | 105.71 | 95.04 | 111.69 | 101.35 |

C.D.((P= 0.05) varietal means = 3.264
C.D. (P= 0.05) Treatment means =2.986




1. Varieties showing minimum yield
2. Varieties showing maximum yield

Fig. 18 - Effect of inoculation methods on yield per plant (Min., Max.)

yields in early, mid and late maturing varieties.

The bar diagrams depicting the maximum and minimum values of production in early , mid and late cultivars also led support that in all the treatment methods, the maximum production was shown by mid maturing varieties followed by early and then by late maturing varieties (fig 18,19).

## Coefficient of Correlation:

The Coefficient of correlations were worked out among 30 varieties of garden peas ( *Pisum sativum* sub sp. *hortense*)for fifteen yield attributes to assess the overall performance. The study was conducted in two conscutive years that is in winter 1988-89 and winter 1989-1990.

### Correlation Coefficients (1988-1989)

The study of correlation among 30 varieties revealed that in general, the genotypic correlations were little higher in magnitude than the pnehotypic condition values (Table No.26). Since the ultimate aim of the study was to evaluate the yield attributes on their level of performance, it was remarkable to find that average yield per plant was positively and significantly correlated with primary branch number at 1% level of significance whereas for the character pod length, it was significant only at 5% level. This indicated that yield within the crop can be increased with the increase of number of primary branch and also with an increase in pod length. Yield per plant also was observed to be positively correlated with a number of characters like number of grains per pod, pod width, pod breadth, days to first green pod harvest, number of flowers per peduncle, node number at which first flower appeared, grain weight of 10 pods, days to first flower appearance, internodal length and number of pods per Kg weight.

Among different plant characters, inter nodal length was found to be very significantly and positively correlated with node number at which first flower appeared, days to first flower appearance, days to first green pod harvest and number of flowers per peduncle at 1% level of significance.

A remarkable positive correlation was observed between characters plant height and internode length, node number, days to first green pod harvest, days to first flower appearance, number of pods per Kg weight and shelling percentage in order of merit, at 1% level of significance. A negative but highly significant correlation was also observed with number of grains per pod , pod breadth, grain

**Table No. 26 COEFFICIENT OF CORRELATION (GENOTYPIC/PHENOTYPCI) IN 30 VARIETIES OF GARDEN PEA**

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x1 | - | 0.8494 | 0.8690 | 0.5866 | 0.8317 | 0.4242 | -0.2370 | -0.5887 | -0.6812 | -0.3281 | -0.4217 | 0.5769 | 0.4932 | 0.1926 | 0.7723 |
| x2 | 0.8441** | - | 0.9670 | 0.5376 | 0.6787 | 0.4621 | -0.2035 | -0.6149 | -0.6378 | -0.3481 | -0.4758 | 0.6209 | 0.3891 | 0.2218 | 0.6488 |
| x3 | 0.8639** | 0.9658** | - | 0.5195 | 0.6804 | 0.4608 | -0.1868 | -0.6627 | -0.6420 | -0.3357 | -0.4060 | 0.6914 | 0.4567 | 0.1971 | 0.6563 |
| x4 | 0.5599** | 0.5110** | 0.4954** | - | 0.5972 | 0.2359 | -0.0466 | -0.3300 | -0.3278 | -0.2042 | -0.3634 | 0.2744 | 0.0748 | 0.2120 | 0.5351 |
| x5 | 0.8178** | 0.6702** | 0.6723** | 0.5655** | - | 0.3549 | -0.4262 | -0.4740 | -0.6129 | -0.5377 | -0.4879 | 0.5625 | 0.6576 | 0.1122 | 0.8707 |
| x6 | 0.4828* | 0.4535* | 0.4530* | 0.2283 | 0.3406 | - | -0.1272 | -0.1758 | -0.2224 | -0.0544 | -0.3822 | 0.3266 | 0.3305 | 0.5614 | 0.3276 |
| x7 | -0.2151 | -0.1863 | -0.1675 | -0.0282 | -0.3670* | -0.1095 | - | 0.5213 | 0.6627 | 0.7274 | 0.6934 | -0.4294 | -0.5892 | 0.4780 | -0.5937 |
| x8 | -0.5605** | -0.5895** | -0.6350** | -0.2864 | -0.4516* | -0.1547 | 0.4702** | - | 0.8850 | 0.3673 | 0.5056 | -0.4877 | -0.4799 | 0.2878 | -0.5647 |
| x9 | -0.6386** | -0.6008** | -0.6060** | -0.3057 | -0.5754** | -0.2018 | 0.5586** | 0.8252** | - | 0.4517 | 0.7197 | -0.4866 | -0.6512 | 0.2635 | -0.6969 |
| x10 | -0.3121 | -0.3366 | -0.3244 | -0.1859 | -0.5171** | -0.0526 | 0.6707** | 0.3588* | 0.4111* | - | 0.6047 | -0.4618 | -0.4811 | 0.3242 | -0.7108 |
| x11 | -0.4091* | -0.4701** | -0.4010* | -0.3392 | -0.4804** | -0.3713* | 0.6241** | 0.4893** | 0.6616** | 0.5864** | - | -0.2364 | -0.5677 | 0.1665 | -0.6469 |
| x12 | 0.5726** | 0.6173** | 0.6875** | 0.2526 | 0.5532** | 0.3213 | -0.3824** | -0.4655** | -0.4582** | -0.4481* | -0.2306 | - | 0.4223 | -0.0727 | 0.5774 |
| x13 | 0.4891** | 0.3877* | 0.4557** | 0.0754 | 0.6480** | 0.3231 | -0.5354** | -0.4620** | -0.6101** | -0.4664** | -0.5633** | 0.4200* | - | 0.0051 | 0.5968 |
| x14 | 0.1916 | 0.2197 | 0.1949 | 0.1928 | 0.1113 | 0.5384** | 0.4372* | 0.2746 | 0.2446 | 0.3149 | 0.1644 | -0.0716 | 0.0050 | - | -0.1426 |
| x15 | 0.7675* | 0.6482** | 0.6558** | 0.5059** | 0.8607** | 0.3211 | -0.5407** | -0.5410** | -0.5667** | -0.6883** | -0.6392** | 0.5748** | 0.5955** | -0.1418 | - |

** - Significant at 1% (0.456). Level of significance

* - Significant at 5% (0.355). Level of Significance.

weight of 10 pods, pod width and pod length. A non significant but positive correlation was observed with number of primary branches and with average yield per plant.

Poor and non significant correlated were observed between pod length and node number at which first flower appeared, days to first flower appearance, days to first green pod harvest, number of flowers per peduncle and number of primary branches but a significant correlation at 5% level was also observed with internode length. Pod width and pod breadth were found to be negatively but significantly correlated with node number at which first flower appeared, days to first flower appearance, days to first green pod harvest internode length where as a non-significant but negative correlation was also observed with number of flowers per peduncle and number of primary branches. A positive significant correlation at 1% level was also found between pod width and pod length and also between pod breadth and pod length. The pod width indicated that an increase in pod length will be possible with the increase in pod width.

Negative and non significant association was observed between number of grains per pod and node number at which first flower appeared, days to first flower appearance, days to first green pod harvest, number of flower per peduncle and number of primary branches. A significant correlation at 1% level was also observed with internode length but the association was negative, while with pod length the association was found positive. A correlation at 5% level of significance was also observed with pod breadth and pod width.

Association of primary branch number with node number, days to first flower appearance and days to first green pod harvest was positive and significant at 5% level which indicated that with more number of nodes, lateness in flowering and green pod harvest increases the primary branch number and ultimately increases the average yield per plant. This is because, the primary branches had a positive correlation with average yield. A highly significant but negative correlation was found between number of pods per Kg weight and pod breadth, grain weight of 10 pods, pod length, number of grains per pod and pod width in ascending order of magnitude. A positive association at 5% level of significance was observed with shelling percentage and days to first flower appearance while at 1% level the associaton with node number, days to first green pod harvest and internode length. Shelling percentage was found to be positively and significantly associated at 1% level with days to first green pod harvest, days to first flower appearance, node number and internode length. A negative and significant correlation was observed with pod length and number of grains per pod. Number of flowers per peduncle and primary branch number were found to be non significantly associated with shelling percentage whereas with grain weight of 10 pods the association was negative and non significant.

Grain weight of 10 pods showed a highly significant positive association at 1% level with pod breadth, pod length, number of grains per pod and with pod width in order of merit where as a negatively significant association at 1% level was observed with internode length and days to first flower appearance. A negative correlation was also observed, but at 5% level, with node number, days to first green pod harvest-and primary branch number.

A number of positive and highly significant association were observed among a pair of character which were as follows:

Days to first flower appearance with node number; days to first green pod harvest with days to first flower appearance and node number; number of flowers per peduncle with node number; days to first flower appearance with days to first green pod harvest in ascending order of magnitude.

## Correlation study (1989-90):

Since the study was conducted again in winter 1989-90 with the same experimental materials so, the results obtained for character association are described herewith (Table No. 27). A perusal of table revealed that the results showed similar trend as were in the first year study. The estimation for the genotypic correlations were comparatively of higher magnitude than the corresponding estimate for phenotypic correlation values. The findings are presented below follows:

The results revealed that likewise the previous year the average yield per plant was found to be highly and positively correlated at 1% level with number of primary branch and pod length as well. A number of other yield attributes showed positive but non significant correlations with average yield, they were ask number of grains per pod, node number, days to first green pod harvest, number of

Table No. 27 COEFFICIENT OF CORRELATION (GENOTYPIC /PHENOTYPIC) IN 30 VARIETIES OF GARDEN PEAS

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x1 | - | 0.8438 | 0.8754 | 0.5986 | 0.8268 | 0.4566 | -0.1915 | -0.6324 | -0.8074 | -0.1752 | -0.3797 | 0.5217 | 0.5229 | 0.1729 | 0.7641 |
| x2 | 0.8369** | - | 0.9686 | 0.5194 | 0.6796 | 0.4890 | -0.1767 | -0.6025 | -0.7458 | -0.2575 | -0.4225 | 0.5694 | 0.3816 | 0.1794 | 0.6548 |
| x3 | 0.8709** | 0.9648** | - | 0.5122 | 0.6791 | 0.4905 | -0.1569 | -0.6212 | -0.7612 | -0.2406 | -0.3675 | 0.6320 | 0.4521 | 0.1662 | 0.6575 |
| x4 | 0.5742** | 0.5019** | 0.4941** | - | 0.6244 | 0.2378 | -0.0023 | -0.3251 | -0.3694 | -0.0702 | -0.3044 | 0.1997 | 0.1090 | 0.1698 | 0.5287 |
| x5 | 0.8041** | 0.6613** | 0.6649** | 0.5936** | - | 0.3588 | -0.3605 | -0.1666 | -0.7492 | -0.3853 | -0.4397 | 0.5345 | 0.6690 | 0.0432 | 0.8667 |
| x6 | 0.4471* | 0.4830** | 0.4848** | 0.2345 | 0.3499 | - | -0.0396 | -0.1871 | -0.3783 | 0.0214 | -0.3427 | 0.2891 | 03410 | 0.5327 | 0.3871 |
| x7 | -0.1856 | -0.1735 | -0.1531 | 0.0027 | -0.3377 | -0.0374 | - | 0.6490 | 0.5862 | 0.7465 | 0.6875 | -0.3891 | -0.492 | 0.4681 | -0.5511 |
| x8 | -0.5020** | -0.4783** | -0.4783** | -0.2468 | -0.4363* | -0.1386 | 0.4933** | - | 0.9776 | 0.4855 | 0.5046 | 0.5402 | -0.5251 | 0.1938 | -0.6024 |
| x9 | -0.7420** | -0.6887** | -0.7028** | -0.3316 | -0.6633** | -0.3434 | 0.5593** | 0.7154** | - | 0.4203 | 0.6345 | -0.6454 | -0.6444 | 0.1704 | -0.7798 |
| x10 | -0.1669 | 0.2456 | -0.2299 | -0.0568 | -0.3625** | 0.0094 | 0.6979** | 0.3375 | 0.3976* | - | -0.6360 | -0.4234 | -0.3966 | 0.3504 | -0.5762 |
| x11 | -0.3746* | -0.4175* | -0.3651* | -0.2994 | -0.4316* | -0.3363 | 0.6685** | 0.3958* | 0.5789** | 0.5968** | - | -0.2098 | -0.5460 | 0.1629 | -0.5973 |
| x12 | 0.4924** | 0.5443** | 0.6071** | 0.1762 | 0.5079** | 0.2768 | -0.3716* | -0.3743* | -0.5601** | -0.3913* | -0.2030 | - | -0.4579 | -0.1536 | 0.5771 |
| x13 | 0.5077** | 0.3723* | 0.4416* | 0.0912 | 0.6435** | 0.3252 | -0.4742** | -0.3817* | -0.6113** | -0.3715* | 0.5258** | 0.4290* | - | 0.0176 | 0.5958 |
| x14 | 0.1713 | 0.1792 | 0.1659 | 0.1636 | 0.0431 | 0.7331** | 0.4585** | 0.1515 | 0.1562 | 0.3349 | 0.1620 | -0.1488 | 0.0163 | - | 0.1511 |
| x15 | 0.7605** | 0.6524** | 0.6569** | 0.5092** | 0.8493** | 0.3828* | -0.5405** | -0.4681** | -0.7220** | -0.5523** | -0.5940** | 0.5561** | 0.5827** | -0.1511 | - |

** Significant at 1% (0.4560) level of significance

* Significant at 5% (0.3550) level of significance.

flowers per peduncle, grain weight of 10 pods, pod breadth, pod width, internode length, days to first flower appearance and number of pods per Kg weight in descending order of magnitude. A positive but non significant correlation was observed between average yield per plant and shelling percentage.

Exact as the previous year the finding from present situation revealed that internodal length's association with node number, days to first green pod harvest, day to first flower appearance and number of flowers per peduncle was found to be highly significant at 1% level with a positive sign.

A high level of significance was observed in the correlation found between plant height and all other characters except with average yield per plant to which it was negatively and non significantly associated and with primary branch number to which the level of significance was only at 5%. A positively significance (1% level) was observed for internode length, node number, days to first green pod harvest, days to first flower appearance, number of pods per kg weight, shelling percentage and number of flowers per peduncle in order of merit, while a negative association at 1% level was observed with pod breadth, grain weight of 10 pods, number of grains per pod, pod length and pod width in ascending order of magnitude.

Pod width and pod breadth found to be associated negatively but significantly with node number at which first flower appeared, days to first flower appearance and days to first green pod harvest at 1% level of significance where as internode length was found to be associated at 5% level with pod width and at 1% with pod breadth. A non significant and negative correlation was observed with number of flowers per peduncle and primary branch number with both the characters i.e. pod width and pod breadth. A positive and significant correlation at 1% level only with pod breadth.

Number of grains per pod showed a poor and non significant correlations with node number, days to first green pod harvest, number of flowers per peduncle days to first flower appearance, number of primary branches and pod width where the first three character were negatively correlated than the last three which were positively correlated. A very highly positive and significant association was observed between number of grains per pod and pod length at 5% level, while with pod breadth it was found to be positively correlated and and internode length to be negatively correlated.

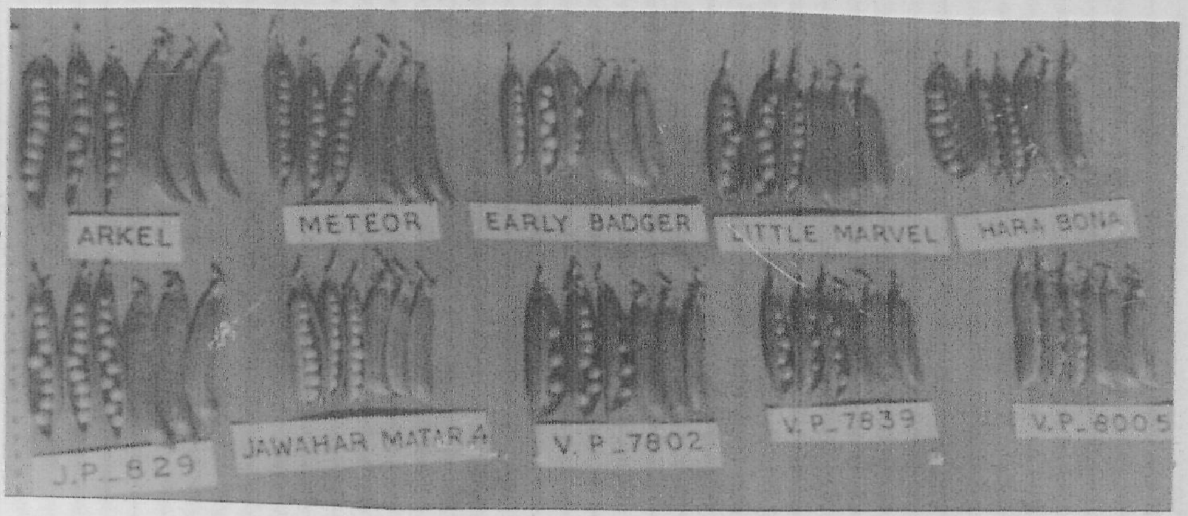
The correlation between number of primary branch and days to first flower appearance and days to first green pod harvest was observed to be positively significant at 1% level while with node number it was found to be positively associated at 5% level of significance. With number of flowers per peduncle and internode length the association was found to be positive but non significant.

A significant but negative correlation was observed between number of pods per Kg weight and pod breadth and pod length at 1% level but with pod width and number of grains per pod the association was significant at 5% level. A positive correlation was also observed with internode length grain weight of 10 pods and node number at which first flower appeared at 1% level of significance but with days to first green pod harvest, shelling percentage and days to first flower appearance the association was positive and significant at 5% level. Number of flowers per peduncle and primary branch number were non significantly but positively associated with number of pods per Kg weight. Study reveals that association of shelling percentage with days to first green pod harvest, days to first flower appearance, internode length and node number were highly significant at 1% level and positive. A positive but non significant association was also faced out with primary branch number and number of flowers per peduncle while a negative and non significant association was also observed with grain weight of 10 pods.

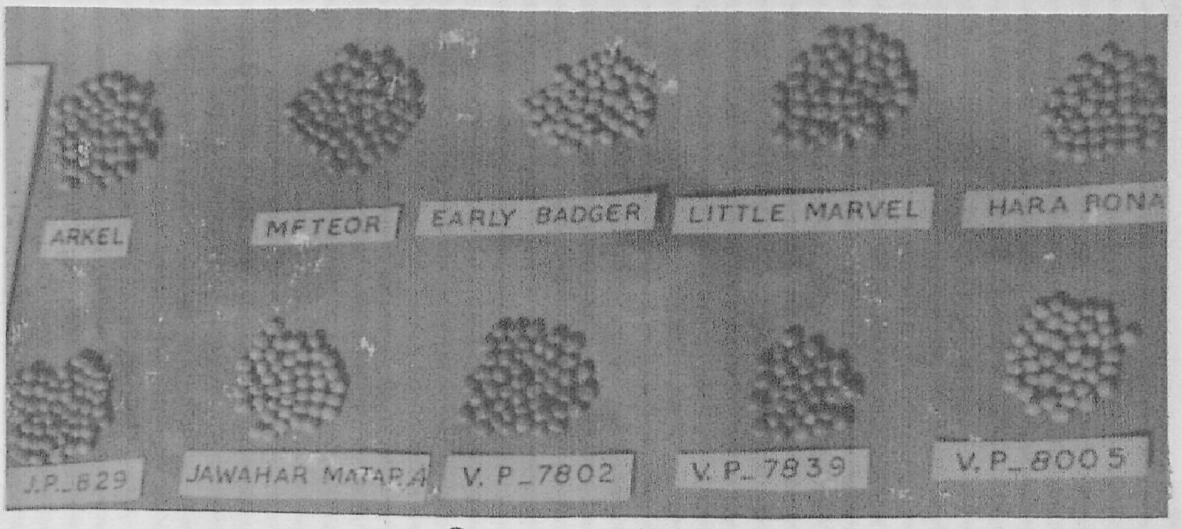
Grain weight of 10 pods was negatively and significantly associated at 5% level with internode length, days to first flower appearance, node number and days to first green pod harvest. However, a positive association at 5% level of significance was also observed with pod width. A positive and highly significant correlation at 1% level was observed between grain weight of 10 pods and pod length, number of grains per pod and pod breadth. Primary branch number and flower number per peduncle were found to be non significantly and negatively associated with grain weight of 10 pods.

A positive and significant association was observed between a pair of characters which are as follows: days to first flower appearance, days to first green pod harvest and number of flowers per produncle with node number at which first flower appeared days to first flower appearance with days to first green pod harvest and number of flowers per peduncle; days to first green


Size and colour of pods

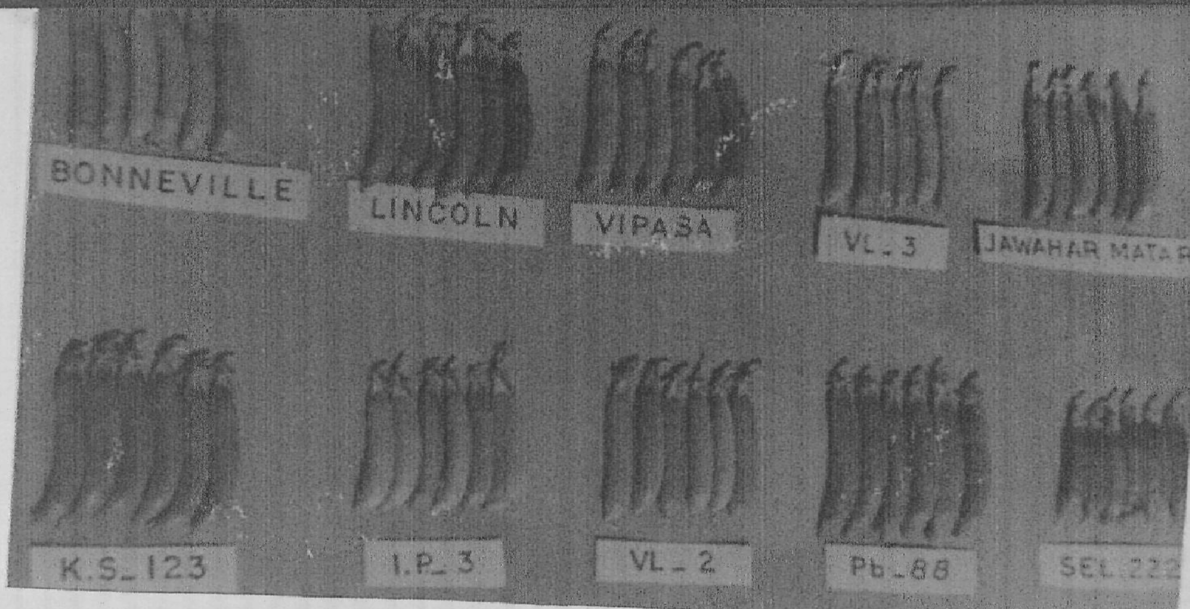



Pod filling

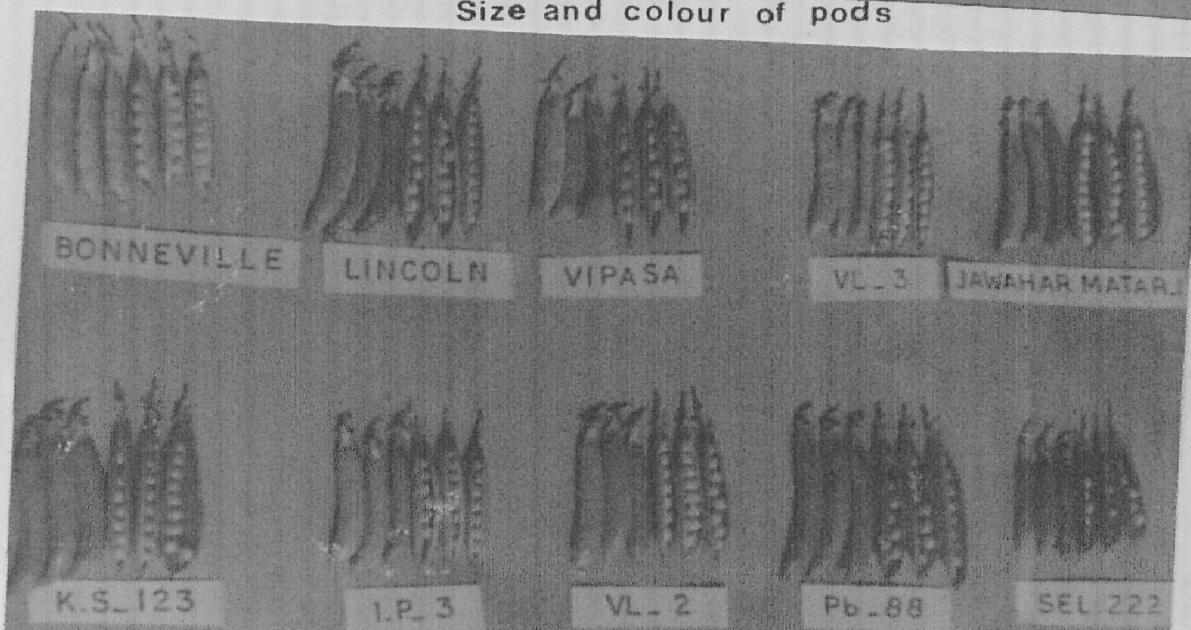



Green grains

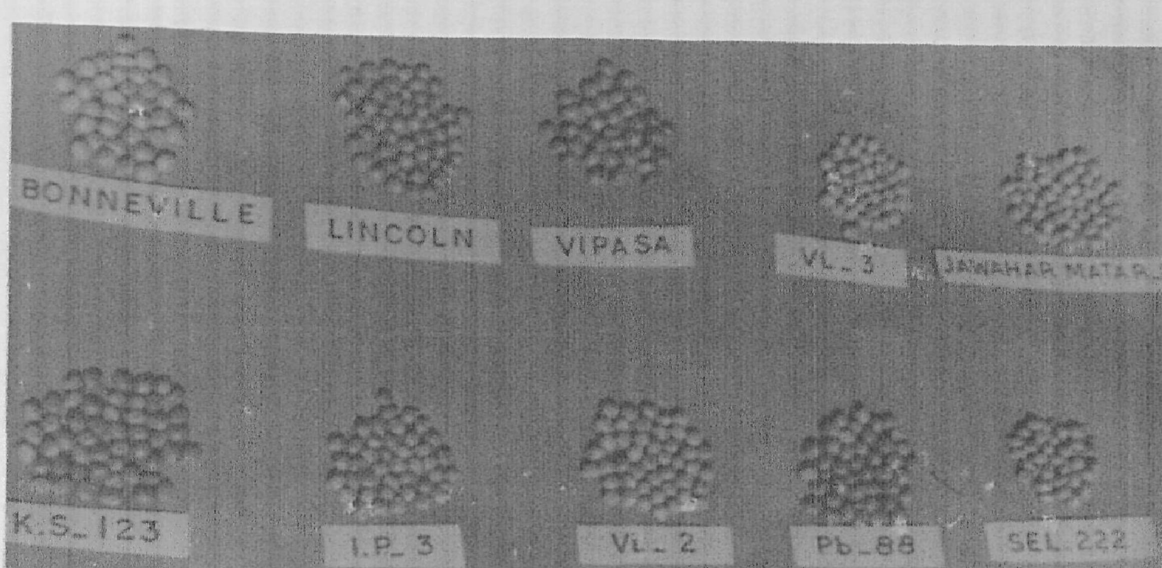
Pl.8 Showing ten early varieties




Size and colour of pods

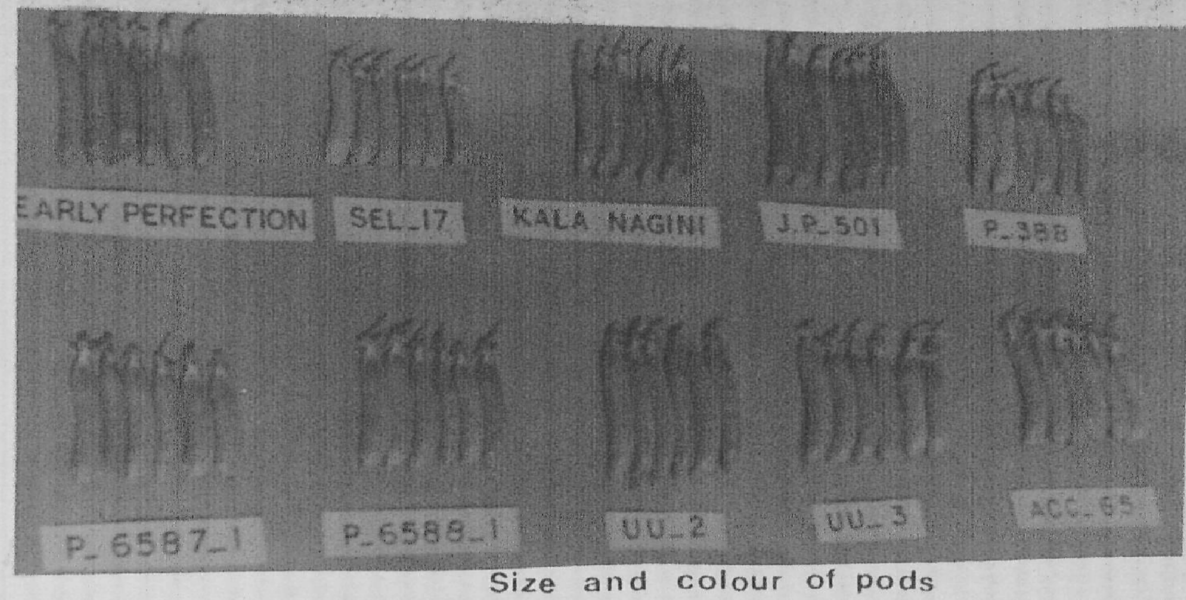



Pod filling

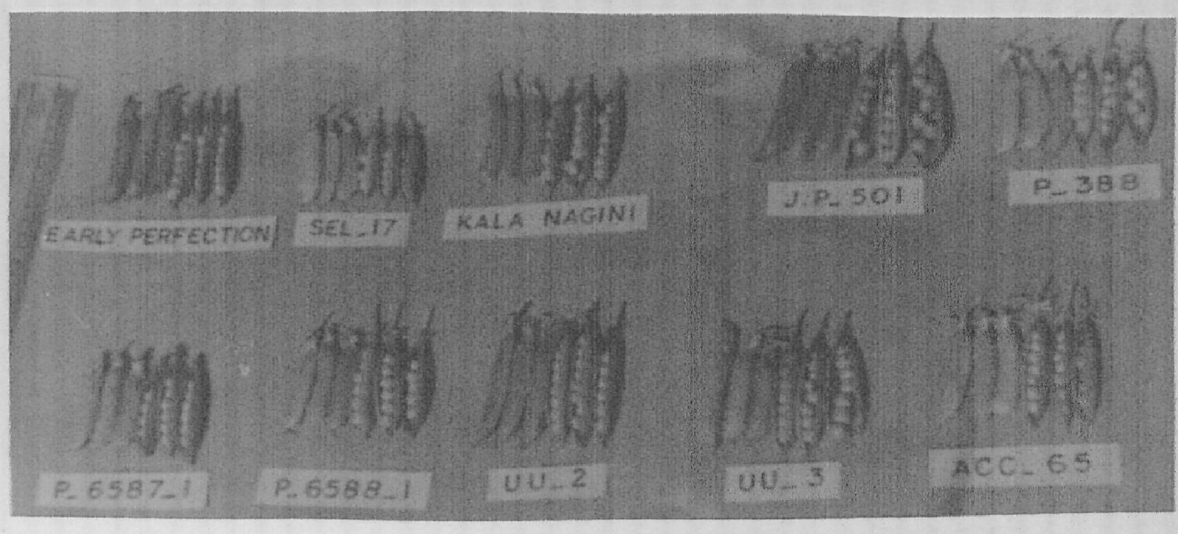



Green grains

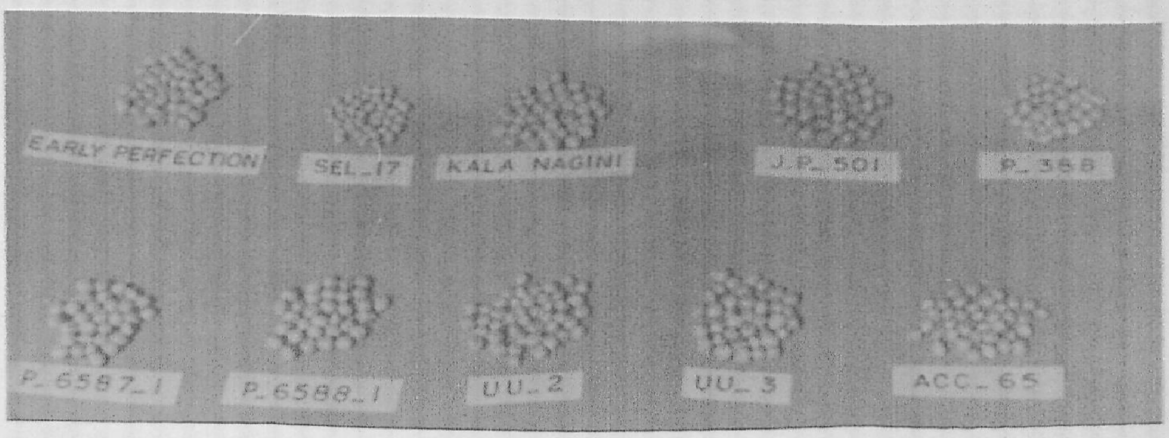
**Pl.9** Showing ten mid varieties




Size and colour of pods




Pod filling




Green grains

Pl.10 Showing ten late varieties

pod harvest with number of flowers per peduncle.

## Path Coefficient Analysis:

To identify a model morphological framework or to understand the plant architecture a study was made on path coefficient analysis besides the study of character association, utilizing a collection of 30 diverse cultivars. The estimate was worked out for 14 yield contributing characters. The study was conducted for two years that was in winter 1988-89 and winter 1989-90.

### Phenotypic path coefficient analysis (1988-89):

A phenotypic path analysis was dealt to sort out the direct as well as indirect effects of 14 yield contributing characters towards the dependent character, the average yield per plant (Table 28). The estimates revealed that the number of primary branches had the maximum direct effect upon yield which was followed by days to first flower appearance, number of pods per Kg weight, grain weight of 10 pods, node number at which fist flower appeared, number of flowers per peduncle, pod length, pod width, pod breadth and internodal length. The lowest direct effect value was noticed for days to first green pod harvest.

Looking into the indirect effects, days to first green pod harvest-showed the maximum indirect effect through days to first flower appearance followed by number of primary branches and node number at which first flower appeared. Also, a significant contribution of days to first green pod harvest was observed through pod width, pod breadth and grain weight of 10 pods, towards yield.

Node number at which first flower appeared found to contribute through days to first flower appearance, primary branch number and number of pods per Kg weight in order of magnitude, indirectly. Node number was also found to contribute remarkably through days to first flower appearance and number of flowers per peduncle.

Internode length helped to increase the average yield per plant through days to first flower appearance, number of pods per Kg weight and node number at which first flower appeared.

Plant height contributed indirectly through days to first flower appearance, number of pods per Kg weight and node number at which first flower appeared

IST YEAR

**Table No. 28 (A). GENOTYPIC PATH COEFFICIENT ANALYSIS IN 30 VARIETIES OF GARDEN PEAS**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | **0.1566** | 0.9930 | -0.8883 | 0.3153 | -0.2508 | 0.3229 | -0.0836 | -0.3041 | 0.3696 | 0.1515 | -0.3507 | -0.1420 | 0.3009 | -0.3967 |
| 2. | 0.1330 | **1.1690** | -0.9885 | 0.2889 | -0.2047 | 0.3517 | -0.0718 | -0.3175 | 0.3452 | 0.1607 | -0.3957 | -0.1528 | 0.2374 | -0.3333 |
| 3. | 0.1361 | 1.1304 | **-1.0222** | 0.2792 | -0.2052 | 0.3508 | -0.0659 | -0.3422 | 0.3474 | 0.1550 | -0.3376 | -0.1702 | 0.2786 | -0.3371 |
| 4. | 0.0919 | 0.6285 | -0.5310 | **0.5374** | -0.1801 | 0.1795 | -0.0164 | -0.1704 | 0.1774 | 0.0943 | -0.3022 | -0.0675 | 0.0456 | -0.2749 |
| 5. | 0.1303 | 0.7934 | -0.6955 | 0.3210 | **-0.3015** | 0.2702 | -0.1504 | -0.3448 | 0.3317 | 0.2482 | -0.4057 | -0.1385 | 0.4011 | -0.4472 |
| 6. | 0.0664 | 0.5402 | -0.4711 | 0.1268 | -0.1070 | **0.7612** | -0.0449 | -0.0908 | 0.1204 | 0.0251 | -0.3179 | -0.0804 | 0.2016 | -0.1683 |
| 7 | -0.371 | -0.2379 | 0.1909 | -0.0250 | 0.1285 | -0.0968 | **0.3528** | 0.2692 | -0.3586 | -0.3358 | 0.5767 | 0.1057 | -0.3594 | 0.3050 |
| 8. | -0.0922 | -0.7188 | 0.6774 | -0.1773 | 0.1429 | -0.1338 | 0.1839 | **0.5164** | -0.4789 | -0.1696 | 0.4205 | 0.1201 | -0.2927 | 0.2901 |
| 9. | -0.1067 | -0.7457 | 0.6563 | -0.1762 | 0.1848 | -0.1694 | 0.2338 | 0.4530 | **-0.5411** | -0.2085 | 0.5985 | 0.1198 | -0.3973 | 0.3580 |
| 10. | -0.0514 | -0.4069 | 03431 | -0.1097 | 0.1621 | -0.0414 | 0.2566 | 0.1897 | -0.2444 | **-0.4617** | 0.5029 | 0.1137 | -0.2935 | 0.3651 |
| 11. | -0.0661 | -0.5562 | 0.4150 | -0.1953 | 0.1471 | -0.2909 | 0.2446 | 0.2611 | -0.3895 | -0.2792 | **0.8316** | 0.0582 | -0.3463 | 0.3323 |
| 12. | 0.0904 | 0.7259 | -0.7068 | 0.1474 | -0.1696 | 0.2486 | -0.1515 | -0.2519 | 0.2633 | 0.2132 | -0.1966 | **-0.2462** | 0.2576 | -0.2966 |
| 13. | 0.0773 | 0.4549 | -0.4668 | 0.0402 | -0.1983 | 0.2516 | -0.2078 | -0.2478 | 0.3524 | 0.2221 | -0.4721 | -0.1040 | **0.6100** | -0.3066 |
| 14. | 0.1210 | 0.7585 | -0.6709 | 0.2876 | -0.2625 | 0.2493 | -0.2094 | -0.2916 | 0.3771 | 0.3282 | -0.5380 | -0.1421 | 0.3614 | **-0.5137** |

Residual 0.1469

**Tale No. 29 (B) PHENOTYPIC PATH COEFFICIENT ANALYSIS IN 30 VARIETIES OF GARDEN PEAS.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | **0.2729** | 0.7766 | -0.6279 | 0.1480 | 0.0369 | 0.2418 | -0.0461 | -0.1055 | -0.0513 | 0.0601 | -0.1688 | -0.1253 | 0.2076 | -0.4274 |
| 2. | 0.2303 | **0.9200** | -0.7019 | 0.1351 | 0.0302 | 0.2657 | -0.0399 | -0.1109 | -0.0483 | 0.0648 | -0.1939 | -0.1351 | 0.1645 | -0.3609 |
| 3. | 0.2358 | 0.8886 | **-0.7268** | 0.1309 | 0.0303 | 0.2654 | -0.0359 | -0.1195 | -0.0487 | 0.0624 | -0.1654 | -0.1505 | 0.1934 | -0.3652 |
| 4. | 0.1528 | 0.4702 | -0.601 | **0.2643** | 0.0255 | 0.1338 | -0.0061 | -0.0539 | -0.0246 | 0.0358 | -0.1399 | -0.0553 | 0.0320 | -0.2817 |
| 5. | 0.2232 | 0.6166 | -0.4886 | 0.1494 | **0.0451** | 0.1996 | -0.0787 | -0.850 | -0.0462 | 0.0995 | -0.1982 | -0.1211 | 0.2750 | -0.4793 |
| 6. | 0.1126 | 0.4172 | -0.3292 | 0.0603 | 0.0154 | **0.5859** | -0.0235 | -0.0291 | -0.0162 | 0.0101 | -0.1531 | -0.0703 | 0.1371 | -0.1788 |
| 7. | -0.0587 | -0.1714 | 0.1218 | -0.0075 | -0.0166 | -0.0648 | **0.2144** | 0.0885 | 0.0449 | -0.1291 | 0.2574 | 0.0837 | -0.2272 | 0.3011 |
| 8. | -0.1530 | -0.5423 | 0.4615 | -0.0757 | -0.0204 | -0.907 | 0.1008 | **8.1882** | 0.0663 | -0.0690 | 0.2018 | 0.1019 | -0.1961 | 0.3013 |
| 9. | -0.1743 | -0.5528 | 0.4404 | -0.0808 | -0.0260 | -0.1182 | 0.1198 | 0.1553 | **0.0804** | -0.0791 | 0.2729 | 0.1003 | -0.2590 | 0.3657 |
| 10. | -0.0852 | -0.3097 | 0.2358 | -0.0491 | -0.0233 | -0.308 | 0.1438 | 0.0675 | 0.0330 | **-0.1925** | 0.2419 | 0.0981 | -0.1980 | 0.3833 |
| 11. | -0.1116 | -0.4325 | 0.2914 | -0.0897 | -0.0217 | -0.2175 | 0.1338 | 0.0921 | 0.0532 | -0.1129 | **0.4125** | 0.0505 | -0.2391 | 0.3559 |
| 12. | 0.1562 | 0.5679 | -0.4996 | 0.0668 | 0.0250 | 0.1882 | -0.0820 | -0.0876 | -0.0368 | 0.0862 | -0.0951 | **-0.2189** | 0.1782 | -0.3201 |
| 13. | 0.1335 | 0.3567 | -0.3312 | 0.0199 | 0.0292 | 0.1893 | -0.1148 | -0.0869 | -0.0490 | 0.0898 | -0.2324 | -0.0919 | **0.4244** | -0.3316 |
| 14. | 0.2094 | 0.5963 | -0.4766 | 0.1337 | 0.0388 | 0.1882 | -0.1159 | -0.1018 | -0.0528 | 0.1325 | -0.2637 | -0.1258 | 0.2528 | **-0.5568** |

Residual 0.2468

in order of merit. It also helped in yield increase through number of grains per pod, grain weight of 10 pods, pod length and pod width, however, days to first green pod harvest showed the least contribution to plant height for yield improvement.

Shelling percentage was found to contribute maximum through days to first flower appearance followed by primary branch number and number of pods per Kg weight. The least contributor here was days to first green pod harvest.

Days to first flower appearance showed contribution through primary branch number followed by node number at which first flower appeared. It was also found to contribute maximum through days to first green pod harvest, number of flowers per peduncle, internode length, primary branch number, shelling percentage, number of pods per Kg weight and plant height.

Pod width and breadth were found to contribute moderately with days to first green pod harvest while pod length contributed through grain weight of 10 pods. The results obtained from correlations coefficient and path coefficient had similarity in their estimates.

## Phenotypic Path Coefficient Analysis (1989-90):

The experimental study was conducted for average yield in the year 1989-90 also with the objective of confirming the results of the previous years (Table No.29). The number of primary branches had maximum direct effect followed by days to first flower appearance, node number, number of pods per kg weight, grain weight of 10 pods, pod breadth, number of flowers per peduncle and pod length. The lowest value for direct effect noticed for days to first green pod harvest whereas other characters showed values between these two limits i.e. plant height, number of grains per pod, shelling percentage, internode length and pod width in increasing order of magnitude.

The results drawn out for indirect effect revealed that days to first green pod harvest was the maximum contributor towards yield through days to first flower appearance followed by node number and number of primary branches. It was also found to contribute maximum through pod width and pod breadth. Grain weight of 10 pods was also found to contribute days to first green pod harvest for yield.

Node number contribute maximum indirectly through days to first flower appearance followed by primary branch number and number of pods per kg weight.

**Table 29. A Genotypic Path Co-efficient analysis in 30 varieties of garden pea.**

**II ND YEAR**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | **0.9958** | 1.6409 | -1.9520 | 0.4046 | -0.7608 | 0.3629 | -0.0335 | 0.0040 | -0.1280 | 0.1280 | -0.3558 | -0.1279 | 0.4918 | -0.4970 |
| 2. | 0.8402 | **1.9446** | -2.1598 | 0.3510 | -0.6254 | 0.3885 | -0.0309 | 0.0038 | -0.1182 | 0.1881 | -0.3960 | -0.1396 | 0.3590 | -0.4259 |
| 3. | 0.8717 | 1.8836 | **-2.2298** | 0.3462 | -0.6249 | 0.3897 | -0.0274 | 0.0039 | -0.1207 | 0.1757 | -0.3444 | -0.1550 | 0.4253 | -0.4277 |
| 4. | 0.5961 | 1.0100 | -1.1422 | **0.6759** | -0.5746 | 0.1890 | -0.0004 | 0.0020 | -0.0617 | 0.0513 | -0.2853 | -0.0490 | 0.1026 | -0.3447 |
| 5. | 0.8233 | 1.3216 | -1.5143 | 0.4220 | **-0.9202** | 0.2850 | -0.0630 | 0.0039 | -0.1188 | 0.2815 | -0.4121 | -0.1311 | 0.6293 | -0.5637 |
| 6. | 0.4549 | 0.9509 | -1.0937 | 0.1607 | -0.3301 | **0.7945** | -0.0069 | 0.0012 | -0.0600 | -0.0156 | -0.3212 | -0.0709 | 0.3208 | -0.2518 |
| 7 | -0.1906 | -0.3437 | 0.3499 | -0.0015 | 0.3317 | -0.0315 | **0.1748** | -0.0041 | 0.0929 | -0.5453 | 0.6443 | 0.0954 | -0.4628 | 0.3585 |
| 8. | -0.6297 | -1.1717 | 1.3853 | -0.2197 | 0.5674 | -0.1486 | 0.1135 | **-0.0063** | 0.1550 | -0.3546 | 0.4729 | 0.1325 | -0.4939 | 0.3919 |
| 9. | -0.8040 | -1.4502 | 1.6972 | -0.2632 | 0.6894 | -0.3006 | 0.1025 | -0.0062 | **0.1585** | -0.3071 | 0.5947 | 0.1582 | -0.6061 | 0.5072 |
| 10. | -0.1745 | -0.5007 | 0.5364 | -0.0475 | 0.3545 | 0.0170 | 0.1305 | -0.0031 | 0.0666 | **-0.7305** | 0.5960 | 0.1038 | -0.3731 | 0.3748 |
| 11. | -0.3781 | -0.8217 | 0.8194 | -0.2058 | 0.4046 | -0.2723 | 0.1202 | -0.0032 | 0.1006 | -0.4646 | **0.9372** | 0.0514 | -0.5136 | 0.38885 |
| 12. | 0.5195 | 1.1073 | -1.4092 | 0.1350 | -0.4918 | 0.2297 | -0.0680 | 0.0034 | -0.1023 | 0.3093 | -0.1966 | **-0.2452** | 0.4307 | -0.3754 |
| 13. | 0.5206 | 0.7421 | -1.0082 | 0.0737 | -0.6156 | 0.2710 | -0.0860 | 0.0033 | -0.1022 | 0.2897 | -0.5117 | -0.1123 | **0.9406** | -0.3875 |
| 14. | 0.7609 | 1.2733 | -1.4662 | 0.3573 | -0.7975 | 0.3076 | -0.0963 | 0.0038 | -0.1236 | 0.4210 | -0.5598 | -0.1415 | 0.5604 | **-0.6505** |

Residulal = 0.1946

**Table 29. B Genotypic Path Co-efficient analysis in 30 varieties of garden pea.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | **0.6312** | 0.7367 | -8299 | 0.1698 | -0.1166 | 0.3027 | -0.0252 | 0.0184 | -0.2469 | 0.0553 | -0.1480 | -0.0793 | 0.2258 | -0.5229 |
| 2. | 0.5282 | **0.8803** | -0.9193 | 0.1485 | -0.0959 | 0.3271 | -0.0234 | 0.0171 | -0.2291 | 0.0814 | -0.1650 | -0.0877 | 0.1656 | -0.4485 |
| 3. | 0.5497 | 0.8493 | **-0.9529** | 0.1462 | -0.0964 | 0.3282 | -0.0208 | 0.0176 | -0.2338 | 0.0762 | -0.1443 | -0.0978 | 0.1964 | -0.3916 |
| 4. | 0.3624 | 0.4418 | -0.4708 | **0.2958** | -0.0861 | 0.1588 | 0.0004 | 0.0091 | -0.1103 | 0.0188 | -0.1183 | -0.0284 | 0.0406 | -0.3501 |
| 5. | 0.5075 | 0.5821 | -0.6335 | 0.1756 | **-0.1450** | 0.2369 | -0.0458 | 0.0160 | -0.2207 | 0.1201 | -0.1706 | -0.0818 | 0.2862 | -0.5839 |
| 6. | 0.2822 | 0.4252 | -0.4620 | 0.0694 | -0.0507 | **0.6771** | -0.0051 | 0.0051 | -0.1143 | -0.0031 | -0.1329 | -0.0446 | 0.1446 | -0.2632 |
| 7. | -0.1171 | -0.1519 | 0.1459 | 0.0008 | 0.0490 | 0.0253 | **0.1357** | -0.0181 | -0.1861 | -0.2312 | 0.2642 | 0.0598 | -0.2109 | 0.3716 |
| 8. | -0.3168 | -0.4090 | 0.4557 | -0.0730 | 0.0633 | -0.0938 | 0.0669 | **-0.0367** | 0.2380 | -0.1118 | 0.1564 | 0.0603 | -0.1698 | 0.3218 |
| 9. | -0.4683 | -0.6062 | 0.6697 | -0.0981 | 0.0962 | -0.2325 | 0.0759 | -0.0263 | **0.3327** | -0.1304 | 0.2288 | 0.0902 | -0.2719 | 0.4964 |
| 10. | -0.1053 | -0.2162 | 0.2191 | -0.0168 | 0.0526 | 0.0064 | 0.0947 | -0.0124 | 0.1310 | **-0.3313** | 0.2358 | 0.0630 | -0.1652 | 0.3797 |
| 11. | -0.2364 | -0.3675 | 0.3479 | -0.0885 | 0.0626 | -0.2277 | 0.0907 | -0.0145 | 0.1926 | -0.1977 | **0.3952** | 0.0327 | -0.21357 | 0.4083 |
| 12. | 0.3108 | 0.4792 | -0.5785 | 0.0521 | -0.0737 | 0.1874 | -0.0504 | 0.0137 | -0.1864 | 0.1297 | -0.0802 | **-0.1610** | 0.1908 | -0.3823 |
| 13. | 0.3204 | 0.3278 | -0.4208 | 0.0270 | -0.0933 | 0.2202 | -0.0644 | 0.0140 | -0.2034 | 0.1231 | -0.2094 | -0.0691 | **0.4448** | -0.4006 |
| 14. | 0.4800 | 0.5743 | -0.6260 | 0.1506 | -0.1232 | 0.2592 | -0.0733 | 0.0172 | -0.2402 | 0.1830 | -0.2347 | -0.0896 | 0.2591 | **-0.6875** |

Residual = 0.2960

Pl.11 Showing different stages of maturity and height among early, mid and late maturing varieties

It was also found that days to first green pod harvest contributed least to node number for yield.

The result revealed that the number of flowers per peduncle, inter node length and number of primary branches contributed very significantly towards yield through the character days to first flower appearance followed by node number, whereas days to first green pod harvest contributed least to all the characters mentioned above.

Pod length found to contribute through plant height followed by grain weight of 10 pods while the least contribution came through days to first flower appearance. Pod width and pod breadth contributed maximum through days to first green pod harvest while the least contribution was through days to first flower appearance.

Number of grains per pod was found to contribute much through plant height and grain weight of 10 pods but the least contribution was made through days to first flower appearance.

Grain weight of 10 pods contributed maximum through plant height followed by days to first green pod harvest. Shelling percentage contributed most through days to first flower appearance and least through days to first green pod harvest. Number of pods per kg weight and plant height contributed most through days to first flower appearance followed by node number but through days to first green pod harvest the contribution was least.

## STABILITY RESULTS

The stability of yield performance over varied conditions is one of the important aspects of crop production. The dynamic model stability analysis (Eberhart & Russell 1966) provides parametric approach to get an over all picture of crop response to varied environments created or subjected to it over years, locations, sowing time, fertilizer application or method of culture applications. Yield stability of crop plants, a complex genetic trait is ensured by the inherent ability of a genotype to perform well and be able to face fluctuating growing conditions.

In the present study an attempt has been made to investigate the stability of a set of 30 indigenous as well exotic garden pea cultivars, grouped into three maturity groups viz., early, mid and late, comprising 10 cultivars each, through the approach of regression analysis of Eberhart and Russell (1966).

The investigation and understanding of Genotype x environment interaction has been one of the most important advances in the biometrical techniques (Breese 1972). Though the importance of genotype x environment interaction has been recognized well and they are known to be heritable (Jinks and Mather 1955), still they have been termed instabilities (Spragus 1966), and regarded as intractable, and hence the main effort has been to reduce them and scale them out. The genotypic values are considered as fixed sets, for, if the error variance are homogenous for a fixed set of genotypic values, there will be no systematic bias in the normal estimates of regression coefficients (Hard Wick and Wood 1972 and Freeman, 1973).

Keeping the above conditions in mind the result of the stability analysis for 30 *Pisum sativum* sub sp. *hortense* cultivars/selection lines was carried out using the model of Eberhart & Russell (1966). The study was conducted in eight different rhizosphere microenvironments. A brief description of this is available in table 30. The yield obtained per cultivar per plant ranged from 85.32 g to 288.99 g. The general mean performance over environment ranged from 161.53 to 182.28 g with a population mean of 170.58 g. The highest mean performing environment (location number eight) comprises of rhizobial inoculation + pelleting combination. The lowest performer was location number one comprising of no cultural treatment. In the most favourable environment i.e. in location number eight the highest yielder was the cultivar Jawahar Matar 1,a mid maturing type, followed by an early maturing cultivar VP-8005 and then by a late maturing cultivar P-6588-1. Taking into consideration, the maturity group performance, it was found that the performance of the early maturing group ranged from 109.73 to 288.00 g, of mid season it was 94.857 to 299.99 g and the late performers stretched between 111.87 g and 252.53 g, respectively.

Table 32 gives the environmental index which has been worked out following Eberhard and Russell's Model (1966). This involves calculating an index for each environment, based on the mean performance of all populations under comparision, measured as deviation from general mean over the environments for the trait, here it is yield. The results showed that out of eight

**Table No. 30 ANOVA Table for Stability**

| SOURCE | DF | MEAN SUM OF SQ |
|---|---|---|
| VARIETIES | 29 | 23986.05* |
| ENVIRONMENTS | 7 | 2411.46* |
| VAR X ENVIRON | 203 | 3.95* |
| ENV. +(VAR. X ENV.) | 210 | 84.20 |
| ENVIRONMENT (LINEAR) | 1 | 16876.22* |
| VAR. X ENVIRON (LINEAR) | 29 | 23.36* |
| POOLED DEVIATION | 180 | 0.72 |
| POOLED ERROR | 464 | 0.63 |

**Table No. 31 Env. (Lin ) and Var X Env (Lin) Test Against Pooled Deviation**

| VAR | MEAN | REGRESSION COEFFICIENT (B) | S(DELTA) SQR |
|---|---|---|---|
| 1 | 151.91 | 0.97 | 7.66 |
| 2. | 135.93 | 1.00 | 1.37 |
| 3. | 95.35 | 1.19 | 1.43 |
| 4. | 170.20 | 0.83 | 0.48 |
| 5. | 198.67 | 0.96 | 4.96 |
| 6. | 100.55 | 0.97 | 0.31 |
| 7. | 223.71 | 1.63 | 3.20 |
| 8. | 105.74 | 1.11 | 2.75 |
| 9. | 99.70 | 1.53 | 27.81 |
| 10. | 276.16 | 1.08 | 6.61 |
| 11. | 222.97 | 1.16 | 10.39 |
| 12. | 178.02 | 1.19 | 0.94 |
| 13. | 136.90 | 1.05 | 0.81 |
| 14. | 205.53 | 1.14 | 8.51 |
| 15. | 288.99 | 0.89 | 0.77 |
| 16. | 188.51 | 1.13 | 1.71 |
| 17. | 146.45 | 0.97 | 3.49 |
| 18. | 194.38 | 0.97 | 2.16 |
| 19. | 237.89 | 0.85 | 6.89 |
| 20. | 85.32 | 0.76 | 8.37 |
| 21. | 195.07 | 0.83 | 4.56 |
| 22. | 113.38 | 0.97 | 2.28 |
| 23. | 138.57 | 0.89 | 3.17 |
| 24. | 145.49 | 0.92 | 10.85 |
| 25. | 214.73 | 0.83 | 1.60 |
| 26. | 176.55 | 0.74 | 1.14 |
| 27. | 243.41 | 0.85 | 1.63 |
| 28. | 192.80 | 0.83 | 0.77 |
| 29. | 153.25 | 0.83 | 2.80 |
| 30. | 101.35 | 0.92 | 0.37 |

POP MEAN = 170.58
S.E. MEAN = 0.32
MEAN OF B = 1.00
S.E. OF B = 0.03

environments studied four were positive environmental index and rest four were having negative index. The index was recorded positive in case of location eight followed by location four, location six and lastly location two. The most unfavourable location was environment one followed by environment five, three and seven, respectively.

An analysis of variance for stability parameters for yield is given in table 30. The differences between cultivars and environmental differences as well as the linear component due to genotypes environment interaction were significant. The differences between cultivars were observed to be significant when the mean square was tested over pooled deviations. The significance of variety x environment (linear) component suggested the existence of genetic differences in the stability of responses of the cultivars.

The estimated values of three parameters, namely, ui, (mean over locations for individual genotypes), bi (response slope of genotype over environmental index) and $S^2$ di (mean square deviation) were given in table 31. Based on the estimates of ui, bi and $S^2$ di , 30 genotypes could be classified into different groups adopted to different regions of stability. In figure (19) vertical lines are the two standard deviations, above and below the grand mean and the horizontal lines are the two regression lines above and below the most stable point, bi = 1. The figure indicated that the varieties Jawahar Matar-4, Bonneville, Lincoln, VL-3 and KS-123 (variety numbers 7,11,12,14 and 16) were adapted to good and favourable environment, the varieties;Hara Bona, Vp-8005 and VL-2 (Variety number-5,10,18) could be adapted to average environment and varieties Jawahar Matar-1,Pb-88, Early perfection, P-388, P-6588-1 and UU-2 (variety numbers; 15,19,21,25,26,27 and 28 respectively) could maintain their performance in poor environments. All the above mentioned cultivars were the good performers as their yield being greater than the population mean (170.58 g).

Based on the experimental findings it is concluded that the successive grwoth stages of the pea crop require a set of specifications to be adopted for a profitable cultivation. The first and foremost prerequiest iln this regard is the practice of seed inoculation with suitable bacterial strains followed by pelleting with Calcium Sulphate ensures successful establishment of *Rhizobiaum* even under unfavourable conditions of Rhizospheric -microenvironment. It is important

**Table No. 32 Environmental Index for Eight Environment**

(A) POSITIVE ENVIRONMENT

| ENVIRONMENTS | VALUES |
|---|---|
| I2 | 4.23 |
| I4 | 11.14 |
| I6 | 4.92 |
| I8 | 11.70 |
| | 31.99 |

(B) NEGATIVE ENVIROMENT

| ENVIRONMENT | VALUES |
|---|---|
| I1 | -9.05 |
| I3 | -7.08 |
| I5 | -8.85 |
| I7 | -7.01 |
| | -31.99 |

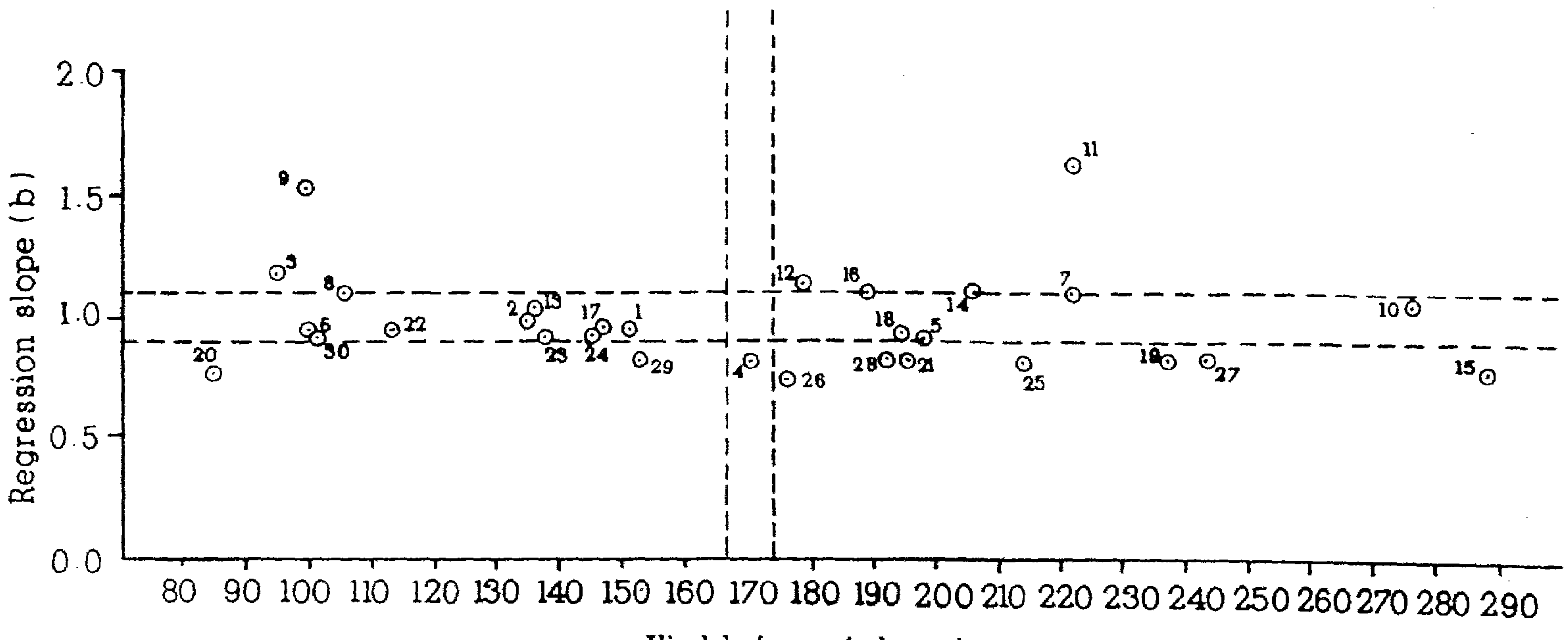



Fig. 19- Distribution of thirty cultivars for mean and response.

because healthy establishment by virtue of profuse nodulation guarantees better flowering and pod development which ultimately helps to increase grain/pod yield. A marked reduction in nodule count was observed as the plant progresses in successive growth stages. However, the most promising and responsive cultivars were observed to be VP-8005, Jawahar Matar-1 and P-6588-1 in early mid and late -maturing group respectively.

# DISCUSSION

Indian diet as predominantly being vegetarian depends heavily on cereals and pulses and of course on green vegetables, reason being that these are rich and comparatively cheaper source of vitamins and minerals which are the precursors of energy. Relative increase in such a qualitative character will bring an increase in the calories, available in the nutritive diet. The potential for increasing calorie production through the production improvement (of cereals, pulses and vegetables ) appears very fascinating but their performance potential , so far achieved is fairly inadequate in quality and quantity. The failures in management and system of production still needs elucidation. Several steps and planned efforts have been made to give effect to this objective. The research programmes directed for improvement of quality and quantity still needs to be endowed with operational simplicity and economy which are the reflections of advancement in technology.

Pea is a winter crop intensively cultivated in rabi season and warrants a large input of capital, labour and technology per unit area of land. Keeping the economic importance of peas in view, it is difficult to ascertain in light of its being utilized both as preferred vegetable as well as pulse. Its precise position in the diverse horticulture industry needs no justification due to its high nutritional values as a fresh vegetable. But being taken as a secondary crop in India hardly any attention is paid regarding its proper requirements , fertilizer application and nutrition. Further, the scarce and expensive chemical fertilizers always demand from producers a flexibility in the management of their system of production and from researcher an innovation for a shift to a cheaper alternative. In light of this the use of biofertilizers came into picture with much hope and promises to satisfy the nitrogen hunger of the legume crops. Use of various responsive bacterial strains and method of applications have since then been utilized by various workers on different crops to come out with the best results. This artificial inclusion of bacteria to the legume host is currently recouped as an important adjunct for maintenance of continuous and vital supply of nitrogen for a triggered economic production. An attempt has been made in the present investigation to examine the suitability of different inoculation methods to 30 garden pea (*Pisum sativum* L. sub.

Sp. *hortense* Asch. and Graebn.) cultivars for better nodulation and responsive increase in productivity. The importance of the crucial role that play the easy affordable bacterial culture for nitrogen fixation is adorned not only in poor developing countries but has a global consideration also.

Swaminathan (1973) and Borlaugh, (1973) have suggested that there is an urgent need to increase food legume production, because heavy dependence on cereals and pulses continues unabated. The easiest and the cheapest method to reach this objective is to exploit the symbiotic association, the leguminous crops established with the additive supply of bacterial inoculum to the rhizosphere . Climate, a fundamental force in environment shapes the configuration of the immediate temperature, moisture and light effects which the crop is going to face throughout its growth stretch. The physical environment of plant includes their action and interaction providing a suitability for growth. The pea crop requires higher temperature with long day condition for growth period and cool, frost free atmosphere at green pod setting. The results of the present investigation indicated in general that there was decrease in the growth and yield of pea crop during the year 1988-89 as compared to that of 1989-90. In the later year during Rabi 1989-90, pea crop received well distributed rain in the entire stretch of growing period which might be one of the probable factor responsible for higher yields. The field experiments were conducted under the agroclimatic conditions of Delhi in the experimental farm of Indian Agricultural Research Institute. The objective was to explore out the most handy easier and cheaper method of seed inoculation which will be easily affordable by common farmers with definite advantage over scarce fertilizers having formidable high costs.

Inoculation success in legumes, at field level, have been well documented from time to time. Failure to obtain the desired responses in crops under field conditions has generally been attributed to the fact that the soil may not have adequate population of efficient native Rhizobia capable of nodulating roots or that the applied strain, though effective, failed to displace the native ineffective strains. In fact, this ability to out compete or dislodge the native strains of Rhizobia by more effective strains has been the critical problem in soils when *Rhizobium* species (cowpea miscellany) predominate and promiscuously nodulate roots of many species of leguminous plants. This situation was demonstrated with reference to groundnut (*Arachis hypogea*) by Gaur *et al.*(1973).

Another most important limiting factor for nodule interaction and its establishment is soil pH. The pH of Delhi soil is 8.10 being almost normal or neutral. Bhardwaj, (1975) studied the survival and symbiotic characteristics of Rhizobium in saline-alkaline soil. They found that majority of bacteria did not survive at pH 10, but as the pH was lowered all the strains survived in the soil. Since rhizobia tolerate much higher salt concentrations than the agricultural plants do, selection for tolerance would be useful only to eliminate the odd sensitive strain (Richard, 1954, Lauter *et al.* 1981). Kumar and Garg, (1980) also found that at pH 10 (saline-alkaline condition) the pea variety, Bonneville, had a complete failure of nodulation. Siddiqui *et al.*(1985) found similar effect of salinity/alkalinity on pea (*Pisum sativum* L.). It was also found that nitrogenase activity was more adversely affected by salt treatments than nodule fresh weight (Siddiqui *et al.* 1986). However, it was pointed out that soil reactions at its extreme end frequently reduce the nodule formation. Rhizobia flourishing well at slight acidic (6.5 pH) and neutral soil reaction. The Delhi soil pH ( 8.10) falls within this favoured category so was ideal for conducting the experiment.

Temperature is the other most important limiting factor for establishment of the bacterial population. Nutman (1956) found that $24^0$ C was the optimum temperature for the growth of pea, soybean, red clover and alfalfa, while it was also reported $20^0$ c to be optimum for pea. Mes (1959) found that rise in the soil temperature from 18,19 or $21^0$C to 25 to $27^0$ C generally decreased the activity of nodule bacteria of *Vicia sativum, Lupius lutens* and *Pisum sativum*. In both the experimental years the entire growth period of the crop had the same required range of temperature (Maximum in the month of October-$33.1^0$ C and $34.3^0$ C in first and second year respectively and minimum in the month of January $6.1^0$ C in the first year and in the month of December $7.5^0$ C in the second year.)

A well distributed rain during Rabi 1989-90 was attributed to comparative better grain yield than the previous year. Though artificial irrigation was applied to the crop but still it had the impact on favoured nodulation. Roughly and Vincent (1967) had reported that moisture content less than 30% or more than 60% was harmful for the survival of Rhizobia. Goyal *et al.* (1984) reported water stress to adversely affect the optimum pH, temperature and thermostability of the enzyme phosphates.

Before sowing the seeds and the field was well prepared and pulverized for easy aeration required for the aerobic *Rhizobium* essential for in successful growth and functioning. In nodule the *Rhizobium* resides in reduced oxygen tension but its reproduction in soil and survival were greatly increased by supplying free air (Fried *et al.* 1932). Legume seed inoculation involves introduction of the rhizobia into an environment to which it is not immediately adaptable and therefore must compete with the existing established microbial complex until more favourable rhizosphere zone of the legume seedling is available. A delay in germination accentuates this situation resulting in high mortality of the inoculated rhizobia. From the point of operational simplicity and economic advantage, inoculating legume seeds is the most preferred technique for increase in production. In the present study, three different methods of providing artificial microenvironment were applied to the 30 elite cultivars of garden pea. The methods include conventional inoculation, pelleting without inoculation and combined application of inoculant and pelletant. The pelletant used for the experiment was Gypsum ($CaSO_4$) which was found to be most suitable as the soil pH was 8.10 of the experimental plots.

Significant differences were obtained in the performance of varieties as a whole and in the performance of treatments irrespective of variety. The combination effect of joint application of inoculant and pelletant was found to be invariably and significantly superior to all other treatments irrespective of the differential varietal capability of symbiotic establishment. The conventionally inoculated method was found to perform next best followed by pelleting without inoculation which performed fairly better than control which was devoid of any seed treatment.

For ensuring a prompt and effective nodulation the need for high number of rhizobia (a minimum of 100,000) on seeds has been emphasized. The present study includes the carrier based inoculum prepared on Gum arabic slurry . It has been suggested that carrier based inoculant provides high numbers and prolonged survival of Rhizobia on seed and a slurry of this inoculant in the 45% Gum ababic solution provides Rhizobia a protection from dehydration and physical separation from toxic seed exudates (Vincent *et al.*

(1962). Iswaran *et al.* (1972) also reported Gum arabic as the best adhesive for uniform coating. Date, (1968a) found gum arabic to be the best adhesive material for better survival of all *Rhizobium* and firmness of pellet. However, the survival was poor when inoculant slurry in plain water was used. In conventional inoculation , the pelletant was not added to the inoculated seeds.

In the present investigation Gypsum ($CaSO_4$) was used as a pelletant for seed coating. Pelleting was done in two different lots of seeds in two different ways. To the first lot of seeds, the pelletant was applied without inoculating the seeds, that is, the seeds after being wetted by gum arabic slurry were directly coated with pelletants. The bacterial culture was not applied to it. In the second lot, first the seeds were inoculated as was done under conventional method and then were pelleted with $CaSO_4$ (Gypsum). The result obtained indicated that the pelleted seeds substantially performed superior than uninoculated and unpelleted controls, though as compared to conventionally inoculated they were found to be poor in expression. The best response observed with respect to all the characters studied was of inoculated pelleted treatment. The performance superiority of pelleted seeds over control may be attributed to the fact that pellets might have helped for avoiding early dehydration and thus enhancing moisture absorption and protection from other pathogenic attacks and adverse soil reactions that would have posed hindrance in efficient germination and thus providing sufficiently favourable rizosphere micro environment. This encouraged the native microflora to establish sufficiently in absence of the survival competitiveness of the introduced inoculum that otherwise would have out competed the native inhabitants. There had been many claims that pelletting of seeds with different materials improved the nodulation and the productivity of leguminous crops under adverse soil conditions (Chhonkar *et al.* 1971; Jain, 1972, Bhatnagar *et al.* 1981, Jauhri *et al.* 1981) which supported the present findings.

The inoculated but unpelleted lot was also studied separately and it was found that the performance was superior to the pelleted but uninoculated test study. The reason might be attributed to the increased inoculum load on the seed surface which increases the probability of nodulation with the desired strain in the soil with high naturalized population (Wade *et al.* 1972; Weaver and Frederick, 1972). The survival was related to the size of inoculum for the first two weeks.

The effect of inoculum level was also noted in adverse soil conditions with higher number giving better nodulation (Rice, 1975).

The biological activity of an organism in an ecosystem depends primarily on its survival and ability to compete with the authochthonous flora and establish itself, besides the inter play of climatic and edaphic factors. When artificial inoculation of the seeds with specific bacteria is contemplated, the reaction of the seed coat with which the organism comes in contact first, assumes particular importance. The evidence of inhibitory effect of seeds of leguminous crops on their respective *Rhizobium* were rather indirect. Requirement of high dose of inoculum of Rhizobia on the seeds for better nodulation (Thornton *et al.* 1957) led to the view that probably legume seed exerted some inhibitory effect on the respective *Rhizobium* which could only be overcome by providing a high population of efficient *Rhizobium* on the seed surface.

The inoculated pelleted treatments were found to be significantly better over all other seed treatment methods as the result indicated by the responsive performance of all the 30 varieties studied. To ensure the successful performance due to inoculation inspite of unfavorable conditions of nodulation, a technique of coating the inoculated seed with lime was followed in the present study. Gympsum ($CaSO_4$) was used for the purpose . A remarkable increase in yield along with other vital plant expressions were observed in case of inoculated pelleted test study over ordinary inoculated, just pelleted and uninoculated control. The result may be attributed to increased competing inoculum load on the seed coat and the protection of Rhizobia from adverse soil conditions. viz; low pH Bergersen et al. 1958) microbial antagonism (Hely, Bergersen and Brockwell, 1957) and phosphorus toxicity ( CassSmith, 1959). A comparative high nodulation in inoculated pelleted treatment in the present study suggested a diffuse increased number of rhizobia on seed surface with potential out competing ability to the native flora. It was also found that low number of rhizobia on seed caused excessive delay in nodule interaction, consequent retardation of nodule size and even the failure of the plant growth. Thus it can be said that the present findings are very well in accordance with the earlier findings. It was also suggested that Calcium Sulphate showed a significant increase in grain yield when pelleted with, in *Phaseolus aureous* seeds. While studying the pelleting effect of Calcium Carbonate, rock phosphate and Calcium Sulphate on soybean seeds, Koshy and Jauhri (1984) concluded that superiority of the materials are conducive for growth and multiplication of Rhizobia seeds, this idea is also in accordance with the present findings.

Considering all the thirty varieties together which include each of the ten early, mid and late maturing cultivars, it was interesting to note that the nodule number was invariably more in counting as long as the crop remained in vegetative phase that is in preflowering phase. As the crop matured entering into the reproductive phase, the nodule count was markedly reduced and after entering into the pod maturing stage the count was found drastically lowered. So was the case with nodule weight measured as dry weight per plant. Mal, and Yadav, (1972) supported the idea with their results in Guar that maximum nodulation was at preflowering stage which began to degenerate with the onset of flowering. Pate (1958) observed the same pattern in *Pisum arvense* L. saying peak values in total nodule number falling at 7 leaf stage and a regular decline in nodule number keeping pace with the nodule size increase and fixation efficiency as was found in the present investigation. Maximum nodule number was observed at 30 days after sowing and it was remarkable to note that nodulation kept pace with plant growth until flowering starts. This finding is at par with the above mentioned finding of Pale, (1958). Das,(1982) also reported the same result studying *Vigna radiata.*

The reasons for maximum nodule number at preflowering stage may be attributed to the fact that maximum nitrogenase activity and the accumulation of photosynthates take place at this very growth stage but as the crop enters into the reproductive phase the nutritional demand of the reproductive processes strains the nodules of assimilates necessary to support optimum levels of nitrogenase activity and thus a decline in nodule count. Pate (1958) found similar results in *Vicia sativa* roots. After the on set of flowering , the nodule started degenerating which is probably due to diversion of the nitrogen accumulated in the root nodules to the sites of the flower bud formation and Pod inititation (Mal and Yadav, 1972). It was also a point of debate that nodule reduction with the onset of reproductive phase may be because during the period from flowering to fruiting, nitrogenase activity and accumulation of $^{14}C$ photosynthates in the nodule decline by 60% where as the photosynthesis of the plant gets doubled, (Lawrie and wheelar, 1974). So these may be the supporting arguments on the findings of the present investigation with respect to the pattern of nodulation in general, in all the 30 pea test cultivars. It was tacitly assumed that fixed nitrogen was stored in nodules and later released in host digestion.

A well defined pigment change was also observed in nodule population with the age advancement. The young developing nodules at 1-3 leaf stage were generally white in colour. The haemoglobin formation was found rapid in all nodules and the nodules on primary roots were the first to be pigmented . Maximum total red nodules were obtained at 6-8 leaf stage. The haemoglobin concentration found to reach its peak at mid vegetative phase. The subsequent active life of red nodules varied from 8-80 days. Then the destruction of haemoglobin starts with the maturing of plants resulting in green nodules. At pod maturing stage the plants were found almost devoid of nodules.

Size of the nodule was found to be dependent on plant age, site of nodule formation and effectiveness of Rhizobium strain. In this study, nodules on the tap root were bigger than those on the root branches. Bigger nodules were found at pre-flowering stage of growth than those produced at later stages. The effective and large nodules were found at the upper portion of root system. Similar results were reported by Baired (1956) in *Vicia faba*. It was also noticed that the nodule density was higher on primary roots and on the bases of the root branches and rootlets. Distal ends were devoid of nodules or with few nodules. The nodule density may be attributed to Nutman (1956) finding that nodule density is related with the number of preformed foci and the formation of these foci is determined by genetic factors controlling meristematic sites in the roots.

Now coming to the individual varietal responses that were observed through the selected characters studied with regard to different methods of seed treatments, it was worth mentioning that the response differed significantly from variety to variety and from treatment to treatment inspite of uniform application of the same strain of inoculam and the same pelletant (Sahoo *et al.* 1984). This led to the idea that differential interaction established between a particular variety and the treatment method may be responsible for the differential availability of micro environmental expression obtained. The quantification of actual increase suggests the approximate estimate to which magnitude of the factors studied contributed.

In the early maturing group the cultivar Hara Bona was found consistent in performance with highest nodule number per plant in all the three growth stages studied namely pre-flowering, flowering and post-flowering stage. The pooled analysis also suggested Hara Bona to give the highest nodule number. This gave the idea that Hara Bona was the best responder irrespective of the growth stages of the plant and hence may be recommended for cultural treatments satisfactorily. Also, the cultivar VP-8005, Little Marvel and JP-829 were found next to Hara Bona in nodule count in pre-flowering, flowering and post-flowering stages, respectively. However, the pooled effect revealed VP-8005 to be a good treatment responder irrespective of growth stages. Hara Bona along with VP-8005 also showed the high nodule dry weight . This lead to a quite remarkable idea that all the factors which affected nodule number in the present study might had similar effects on nodule weight also, hence the nodule weight per plant increased proportionately with the nodule count in the present study. However, they did not respond well with regard to the plant fresh weight and dry weight which was found remarkable in Meteor and Early Badger. Plant height was found to be expressed fairly well by VP-8005 along with Early Badger(highest) and Little Marvel. The nodule count and dry weight were also fairly good in VP-8005 which led to the conclusion that increase in nodule number and nodule weight significantly increased the plant height (Pahwa and Patil , 1983). The increase in nodule number and thus nodule weight led to an increase in plant fresh and dry weight of the cultivar Hara Bona in the later stages of the plant growth and ultimately up the production level to a remarkable extent. This gave the idea that plant dry weight had significant effect on grain yield. The cultivars Jawahar Matar-4, Little Marvel and Arkel also showed a considerably higher yield per plant though they did not do well with regard to nodule number and nodule dry weight which suffice the idea that there may not be significant correlation between yield and number of nodules or dry weight of nodules (Rai and Singh, 1979). However, VP-8005 was found to be the highest yielder because a relatively increased nodule number and dry weight triggered a relative higher plant height supporting more node numbers to bear more numbers of pods and thus more yield.

The discrepancies in relation to lower number of nodules and higher crop yield in the present study may be attributed to the effectiveness of the nodules rather than total number of nodules (Date, 1970). The inoculated and pelleted results also projected the cultivar VP-8005 and Hara Bona for nodule count and dry weight, however, the cultivars Meteor and Arkel were found responding best with regard to the dry matter which pushed up their production level to a remarkable extent. With regard to yield per plant the maximum relative increase was observed in Hara Bona which may be attributed to its all round excellence in all the factors studied viz., nodule number, nodule dry weight and plant dry weight which are the yield contributing attributes. It was remarkable to note that the cultivar VP-7839 performed well with regard to nodule number and dry weight in pre-flowering stage but did not figure worthy in production ranking. This may lead to the idea that nodulation and nitrogenase fixation did not appear to be correlated with seed yield (Rao *et al.* 1986). Pelleted seeds were found inferior to the inoculated seeds led to the idea that a relative low number of rhizobia on seed may have caused excessive delay in nodule initiation and consequent relation in nodule size and thus failure of proper plant growth (Date, 1970). However, the pelleted seeds found to be superior to control may be attributed to their neutralizing and buffering action which might have resulted in a favourable micro environment. The pelletant application remarkably increased the height in Jawahar Matar-1 thus considerably triggering its yield potential. The pooled analysis for post-flowering results were in accordance with it in most of the cases. Thus it can be concluded that the cultivars VP-8005, Jawahar Matar-4, Hara Bona and Little Marvel were the best responder. Hara Bona responded most positively when inoculant and pelletant were applied together but when the two were applied separately cultivar VP-8005 responded best.

In the mid maturing cultivars Jawahar Matar-1, VL-2 and VL-3 figured out for more nodule number but when the corresponding nodule dry weight was studied the cultivar Vipasa along with the above mentioned cultivars showed high nodule dry weight. The same trend of observations were found when the treatment effect of inoculant and pelletant was studied jointly, the number was shown highest by Vipasa whereas the nodule weight was shown highest by Bonneville along with Vipasa. In the study when inoculant and pelletant were applied separately and singly, the highest nodule number was again depicted by

Vipasa but as we said the dry weight in the corresponding treatments the cultivars VL-2 and Jawahar Matar-1 figured out to be the highest. The similar discrepancy was observed in the late cultivars showing highest nodule number in ACC -65 and Early Perfection but the corresponding highest nodule weight was shown by Early Perfection, Kala Nagini and P-388 . When the treatment effects were scrutinized Kala Nagini, Early Perfection and ACC-65 were found with high nodule number but when dry weight was studied the cultivar P-388 also figured out which did not show any superiority when nodule number were studied. The above finding may be attributed to the fact that there did not exist any relation between nodule number and nodule dry weight (Kumar *et a l.* 1965). The nodule dry weight was found high in Jawahar Matar -1 among mid season cultivars and JP-501, Set-17, P-388 and Kala Nagini in late cultivars KS-123, Pb-88,VL-2 and IP-3 treatment effects were studied. In mid maturing cultivars corresponding yield study was also found to be in accordance with the cultivars mentioned above, depicting Jawahar Matar-1, Pb-88, KS-123 to give high figures. The cultivars Bonneville and VL-2 were also found to perform well mainly because a remarkable increase was observed in their case. Vipasa was found to do fairly well just because of its profuse nodulation. The late cultivars projected P-6588-1 to give highest yield followed by P-388 and Early Perfection. Kala Nagini was found to respond best in case of inoculation in combination with pellets whereas Sel.-17 was the best when only inoculants were applied. The pelletants depicted P-6588- 1 to respond highest remarkably increasing the plant height. In sorting out the cultivars as best responders with regard to yield, the dry weight of plant was taken into consideration because it is most closely related to yield as compared to nodule number so can be used as selection criterion (Khurana *et al.* 1984). So it can be concluded that among mid maturing cultivars Jawahar Matar-1, Pb-88 and KS-123 were the best responders with regard to yield though Vipasa was found to respond remarkably with high nodule count and nodule dry weight with a fairly high production level. In the late cultivars, P-6588-1, P-388 and Early Perfection may be recommended as best yielders but Kala Nagini was remarkable with a very high response towards nodule count and dry weight with a fairly good yield potential. Yield is a complex character with a number of components and the concept of optimal geometry for a green environment has been an important objective to find out the responsiveness pattern of all the character under study. A knowledge of inter relationship between two or more characters help in selection for simultaneous improvement of these characters . Much of the information available on association of plant characters with grain yield has been obtained in a limited number of genetic backgrounds and does not go beyond suggesting that number of pods/plant and seeds/pod showed strong association with yield (Ramanujam, 1975). The chances of building up ideal genotypes for different agricultural situations would depend to some extent on the relationship between various yield attributing parameters. This has been attempted in the present study by working out combination between yield and other traits. Such an information will give an insight to attributes of desirable ideotype. The results obtained keeping in view of the above are discussed below.

It is worth noting that high performance in respect of seed yield per plant was significant and positively associated with number of primary branches and pod length (Tomar *et al.* 1982 and Singh 1982). The association behaviour of primary branches and plant yield was very high and positive (Kumar Yatendra *et al.* 1965; Singh and Singh 1970; Narsinghani *et al.* 1978; and Singh *et al.*1978). The association of pod length with yield was though less stronger than primary branch but was remarkably significant (Kumar Yatendra *et al.* 1965; Singh and Pratap 1968 and Teotia *et al.*1983). All other characters were found to associate positively but non significantly with grain yield. Primary branch was also found to be associated positively and significantly with node number at which first flower appeared , days to first flower appearance and days to first green pod harvest. While pod length was found to be associated significantly but negatively with internodal length. However, pod width, pod breadth, number of grains per pod, grain weight of 10 pods and average yield per plant were found to be positively and significantly correlated with pod length. The association of number of pod per Kg weight, and plant height and shelling percentage with pod length was though significant but negative. These results thus conclusively demonstrated that the number of primary branches and the pod length were the most suitable characters for selection for yield in garden peas. However, the association of number of grains per pod with yield was also found positive and sufficiently high which was also found to be correlated significantly and positively with pod length, pod width and pod breadth. So this may also be considered while going for a selection because response to number of grains per pod directly leads to the response to pods per plant and thus yield. Gupta (1971) and Ramanujam and Gupta (1973) had suggested the incorporation of small seededness for greater response to yield because in their study the responsiveness for yield was associated with non responsiveness for seed size, but Mehra (1974) reported that bold seededness could be compatible with greater response to yield. It was also remarkable to observe that the genotypic correlation coefficients were higher than the phenotypic correlation coefficients. This indicated that inspite of strong inherent association between various traits studied, the phenotypic expression of 14 characters were less used under the influence of environment. Various other workers indicated the similar trend (Johnson *et al.* 1955; Singh and Singh, 1970).

To gain further understanding of the relationship of yield and its various components in the present material, a very intricate system of path analysis was considered. For a clearer picture, the direct and indirect contributions of the yield components were separated out. The indirect contribution that was made through its relationship with other attributes was also taken into consideration to avoid misleading impressions.

The study of path analysis revealed that number of primary branches had the highest positive maximum direct effect upon average yield per plant (Singh *et al.* 1978) followed by days to first flower appearance, number of pod per kg weight, grain weight of 10 pods, node number at which first flower appeared, number of flowers per peduncle, pod length, pod width, pod breadth and internodal length. The second year study also revealed the same result with a slight position reshuffling. However the maximum indirect contribution was observed of days to first green pod harvest through days to first flower appearance, number of primary branches and node number at which first flower appeared. Internodal length was also found to contribute indirectly through days to first flower appearance, number of pods per Kg weight and node number at which first flower appeared. Plant height and shelling percentage were also found to contribute indirectly and significantly through days to first flower appearance.

In the present study the positive but non-significant correlation of shelling percentage with plant yield was mainly contributed by indirect effect via days to first flower appearance and number of primary branches but it was counteracted by a considerable negative indirect effect via days to first green pod harvest, plant height and grain weight of 10 pods to result into a lower correlation magnitude between shelling percentage and yield per plant. Similar results has also been reported with regard to harvest index in chickpea by Bahl *et al.* (1976) and Bahl (1979).

From path analysis, it could be concluded that greater emphasis would have to be placed on number of primary branches, days to first flower appearance, number of pods per Kg weight and grain weight of 10 pods, while selecting for higher yielding genotypes and at the same time seed size would have to be kept maximum to increase the remarkable shelling percentage because productivity could be improved by super imposing the plant structure to improved harvest index (Murty , 1975).

The stability of yield in different environments is of great interest to the breeders and a measure of stability is provided by deviation from regression as a measure of stability (Sd). In this analysis mainly three parameters are estimated, namely $\mu$(mean value), b (measure of responsiveness) and $S^{-2}d$ (deviation from regression i.e. measure of stability. According to Finlay and Wilkinson (1963) an ideal genotype is the one with maximum yield potential in most favourable environment along with certain regression slope (s) as a stability parameter. Eberhart and Russell (1966) advocated, besides regression slope of the genotype (b), deviation for regression as another stability parameter ($S^{-2}d$). It has since come to be recognized that the slope (regression) actually measures the response of a variety to changes in the environment and would perhaps better be referred to as responsiveness while stability should be used to refer to absence or low deviation from the regression which measures the responsiveness of the variety in different environments (Breese, 1969). Such a concept of stability has been supported and extensively used by various workers in different crops (Paroda and Hays, 1971; Ramanujam and Gupta, 1973; Langer *et al.* 1979; Singh and Mehra,1980).

In this study, an attempt has been made to investigate the stability of a set of 30 genotypes of garden pea developed in different agroecological regions, through an analysis of genotype x environment interaction adopting the approach of regression analysis of Eberhart and Russell (1966). A fairly varied sample of eight environments has been used for this investigation. Of the three stability parameters, estimates of regression (b) are relatively unaffected even if the sample of environments available is biased. The mean value ($\mu$) on the other hand, depend directly on the specified set of environments . To obtain reliable estimate of $S^2d$, several unbiased environments with minimum number of replication (not less than 2) per environment are required.

The most important practical aspect appear to be in existence is of g x e interaction, and the quantum of this interaction which is linear when there is no g x e interaction or where such g x e interaction as is non-linear, the behaviour of genotypes is predictable across environments. Such prediction becomes impossible if the non linear components of g x e interaction is predominant.

As Eberhart and Russell (1966) point out that the conventional concept, of a stable variety is one that gives the same performance under all conditions even in poor environments. Such a variety would of course be relatively low performing but be desirable under conditions where there is not much of a surplus production. In terms of the present analysis such varieties will be characterized by average ($\mu$) or below average ( $b < 1$). In the present finding the cultivars VP-8005, Hara Bona and VL-2 showed the high stability with a very high yield potential while the cultivars Arkel, IP-3 , JP 501, Kala Nagini, Vipasa and Meteor also showed a good stability but their production performance was below average mark in an average environment. The performance responsiveness and stability levels appeared to be specific for individual genotypes. So the cultivars VP-8005 may be recommended for high yield and stable performance. Also the cultivars VL-2 and Arkel was a bit below average. It has, therefore, could be suggested on the basis of the findings of the investigation that satisfactory success can be achieved in lifting yield ceiling in garden pea by adopting the suggestive measures extracted from the study for optimum plant type needed.

Based on the experimental findings it is concluded that the successive grwoth stages of the pea crop require a set of specifications to be adopted for a profitable cultivation. The first and foremost prerequisite in this regard is the practice of seed inoculation with suitable bacterial strains followed by pelleting with Calcium Sulphate ensures successful establishment of *Rhizobiaum* even under unfavourable conditions of Rhizospheric -microenvironment. It is important because healthy establishment by virtue of profuse nodulation guarantees better flowering and pod development which ultimately helps to increase grain/pod yield. A marked reduction in nodule count was observed as the plant progresses in successive growth stages. However, the most promising and responsive cultivars were observed to be VP-8005, Jawahar Matar-1 and P-6588-1 in early mid and late -maturing group respectively.

# SUMMARY

The present study deals with one of the most popularly demanded winter vegetables, the garden pea (*Pisum sativum* L. Sub Sp. *hortense* Asch. and Graebn.), with the objectives to collect maximum information regarding the yield benefits which can be derived from different methods of seed inoculation and thus to identify the most responsive genotype; to understand the nature and extent of character associations that contribute towards yield and thus to postulate the ideal ideotype; to know the direct and indirect bearing and contributions of the characters towards yield; and to assess the magnitude of the genotype x environment (g x e) interaction and thus stability for yield. The experiment was conducted during the year 1988-89 and 1989-90 in Rabi season, in the experimental farm of the division of Vegetable Crops, Indian Agricultural Research Institute, New Delhi, with 30 diverse test genotypes, consisting 10 each of early, mid and late maturing group.

To identify and compare the inoculation responsiveness of individual genotype, the treatment methods followed were; conventionally inoculated, pelleted and the joint application of inoculant and pelletant to the equally divided seed lots of individual genotype. All these treatment methods were compared against each one's control to measure the relative responsiveness to know the actual increase. So, all the 30 varieties were treated with the above mentioned methods and compared with control. To know the exact pattern of responsiveness three stage readings of six parameters were taken into consideration. The parameters were; number of nodules per plant, dry weight of nodules per plant, plant fresh weight, plant dry weight, plant height and finally the yield. The three stage readings mean that the observation on all the above mentioned parameters were taken for all the 30 Genotypes at three different stages viz; pre-flowering, flowering and post flowering stages. After going through keenly the respective varietal responses in all the treatment methods applied in all the three stages in each case, the individual varietal responses were rated. The individual treatment effect was also taken into account ignoring the varietal performances. Then the interaction (variety x treatment) study was made to know the exact trend with respect to each treatment applied to individual cultivar. A pooled analysis taken over the three growth stages was also studied, to identify the degree of responsiveness. In case

of yield, the pooled analysis study was made to examine the performance sustainability. A thorough observation finally gave the conclusion that varietal responses with regard to nodule count and dry weight were maximum, invariably, at pre-flowering stage and as the plant entered into flowering and subsequent post-flowering stage a remarkable reduction in both the parameters was observed. But for characters like plant fresh weight, plant dry weight and plant height, the response was reverse showing pre-flowering stage to give minimum response, flowering stage to intermediate and post-flowering stage to give highest values. The individual treatment effect and the interaction study revealed that the combined application of inoculant and pelletant gave the best result followed by conventionally inoculated and then by pelleted over control. Thus the final conclusion drawn out from the study was on the basis of the yield and the nodulating expression. In the early group, the cultivars VP-8005 and Hara Bona; in mid group, Jawahar Matar -1 and Vipasa and among late cultivars, P-6588-1 and Kala Nagini responded the best.

Once the respective responsiveness with regard to culture application of the individual cultivar/selection line was derived, it was the need to find out the character association of different yield attributing plant parameters. This aided to the selection criteria for screening the best variety. For this a set of 15 plant characters were taken, namely node number at which first flower appeared, days to first flower appearance, days to first green pod harvest, number of flowers per peduncle, internode length, number of primary branches, pod length, pod width, pod breadth, number of grains per pod, grain weight of ten pods, shelling percentage, number of pods per Kg weight, average yield per plant and plant height. The results indicated that the characters, namely number of primary branches and pod length were positively and significantly associated to contribute towards yield of a particular genotype. It was remarkable to note that in general, the genotypic coefficient of correlation was higher in magnitude than phenotype correlation coefficient for different pairs of characters studied. While studying the direct and indirect bearing of all these above mentioned characters (Path analysis), again, the character primary branch number was found with the highest direct effect on yield.

After the most responsive genotypes were identified with respect to *Rhizobium* and Pellet treatments and the parameters screened out which contributed towards yield, it becomes indispensable to go for the yield stability test. This was studied from Genotype x Environment interaction. A sum total of eight micro environments of the soil root rhizosphere interface was studied. Environmental index revealed that the environment number 8 (inoculated-pelleted, 1989-90) was the most favorable environment for the character expression followed by environment number 4 (inoculated-pelleted, 1988-89). Environments 1,3,5 and 7 had the negative index. The population mean was found to be 170.58 g. The most stable as well as high yielding varieties recommended for good and favourable environment were Jawahar Matar-4, Bonneville, Lincoln, VL-3 and KS-123. For average environment, Hara Bona, VP-8005 and VL-2 were recommended. Under poor environmental conditions the cultivars, namely Jawahar Matar-1, Pb-88, Early Perfection, P-388, P-6587-1, P-6588-1 and UU-2 were found to yield more with required stability.

The objective of the study was to identify the best responsive genotypes in response to *Rhizobium* inoculation in early, mid and late maturing 30 test cultivars attributed with yield stability. So it can be suggested on the basis of inferences drawn that the cultivars VP-8005 , Jawahar Matar-4 and Hara Bona in early maturing group, Jawahar Matar-1 Pb-88 and KS-123 in mid maturing group and P-6588-1, P-388 and Early Perfection in the late maturing group could be recommended for stable high yield. Also, for an ideal ideotype, the characters those should be taken into most prominence for selection criteria should be increased number of primary branch with increased pod length to accommodate more number of bold seeds per pod so as to enhance the yield potential per plant sufficiently. Other characters to supplement the effect could be days to first flower appearance, node number at which first flower appeared,grain weight of ten pods, number of flowers per peduncle, pod length, pod width and pod breadth.

Hence, it can be concluded that a quantum of yield enhancement is possible with definite results by *Rhizobium* inoculation in garden pea (*Pisum sativum* L Sub Sp *hortense* Asch. and Graebn.). The much cheaper biofertilizer ( *Rhizobium* culture) is certain to out compete the high priced N-fertilizers which are less affordable to the subsistence farmers. Crucial in this regard is to breed and select out the cultivars with the best responses on the basis of characters suggested and fill up the gap with comprehensive understanding and additional information between innovation and actual implementation .

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