STUDIES ON GROWTH, REPRODUCTION AND QUALITY OF SEED PRODUCTION IN FRENCH BEAN (*Phaseolus vulgaris* L.) cv. CONTENDER UNDER VARYING STRESSES

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled 'Studies on growth, reproduction and quality of seed production in French bean (*Phaseolus vulgaris* L.) cv. Contender under varying stresses' submitted by Mr. Sumon Mukhopadhyay for the award of the Degree of Doctor of Philosophy in Horticulture of Bidhan Chandra Krishi Viswavidyalaya is the faithful and bonafide research work carried out under my supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of investigation have been duly acknowledged.

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Sumon Mukhopadhyay.

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CHAPTER I

INTRODUCTION

INTRODUCTION

The value of vegetables as an important article for daily human diet has been recognised all over the world. Several important constituents needed by human being for proper growth, reproduction and maintenance of health can be obtained from vegetables. In India, where vegetarianism has been a way of life since the early days of recorded history, vegetables have gained much importance as they vitally contribute to the general well-being to a considerable extent.

At present, India produces above 40 million tonnes of vegetables in about 4 million hactares of land and ranks second in vegetable production in the world. While the international standard of consumption of vegetables stands at 300 g per head per day, India is capable of producing only 120 g per head per day which is much below the required level. According to the dieticians an average requirement of calories for an adult in India is 2400 and to serve this requirement, one should consume at least 115 g each of leafy and other vegetables and 70 g of root vegetables per day that makes a balanced diet.

Green revolution, in the late sixties, in India stressed much on cereals and as an obvious consequence area under cultivation of other crops including vegetables narrowed down. However, the demand for vegetables in the post revolution era has increased many folds. This has been much more evident in a country like ours where majority of the population are vegetarians.

It is estimated that by 2000 A.D., the annual demand for vegetables in India may reach 83 million tonnes. Increased productivity is, therefore,

the only visible solution to meet this demand. Optimisation of different production resources may lead to increased vegetable production through adoption of improved production technology, use of seeds of improved varieties and other improved management practices. Thus an added output of vegetables, besides meeting the dietary habit of the bulk population of the country, can also help maintain proper health through additional supply of many protective ingredients like vitamins, minerals etc. in addition to carbohydrates, proteins and fats for a balanced diet.

French bean (*Phaseolus vulgaris* L.), also known as Kidney bean, Haricot bean, Snap bean, Navy bean, Common bean or Rajma is no doubt one of the most nutritive and highly relished vegetable internationally, because of its good cooking quality and flavour. While its tender, delicate green pods and tender seeds are used as vegetables, dried seeds are consumed as pulses in India. In India, traditionally it is cultivated in the hilly tracts of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and parts of Maharastra on about 85000 hactares of land as a rainy season crop, where as its adoption as a winter crop in the plains has gained much importance. Being leguminous, it is proteinecious and short duration, deep rooted and suitable for rainfed areas. They are less sensitive to water stresses than shallow rooted crops. It has been a delicacy of high value vegetable and slowly gaining ground among the Indians, especially in the vicinites of metropolitan cities.

Southern Mexico and Central America are considered to be the primary centre of origin of this crop, while Peruvian-Ecuadorian-Bolivian area to be its secondary centre of origin. It is now generally agreed that genous *Phaseolus* originated in the new world and that old world species,

previously included in genera *Phaseolus* were assigned to genera *Vigna.* Four cultivated species, now found in the new world are *Phaseolus vulgaris, Phaseolus coccineus, Phaseolus lunatus* and *Phaseolus acutifolius* var. *latifolius.*

French bean ranks high as chief source of nourishing food amongst these species. It is rich in protein, calcium, iron and vitamins and can help supplement protein deficiency in diet which is a chronic problem in all developing countries. The nutrient status per 100 g of edible portion of French-bean, according to Aykroyd (1963) is as follows :

Moisture	91.4 g	Minerals	0.5 g	Potassium	129 mg
Protein	1.70 g	Vitamin A	221 I.U.	Sulphar	37 mg
Fat	0.1 g	Thiamine	0.08 mg	Sodium	4.3 mg
Carbohydrate	4.5 g	Riboflavin	0.06 mg	Copper	0.21 mg.
Fibre	1.8 g	Iron	1.7 mg		

French bean is chiefly grown as a winter crop in West Bengal. As a result of intensive and systemic efforts by the Directorate of Pulses, Kanpur and at the All India Co-ordinated Pulses Improvement Projects (I.C.A.R.) operating at different sub-centres, some new short duration dwarf and photoinsensitive varieties have been evolved which can, however, be tried twice a year in the mild warm climate condition, provided other environmental factors are conducive. The optimum sowing time of those cultivars are October while a second sowing during January is also possible. However, the crop is characterised by susceptibility to both low and high temperature (Singh and Prasad, 1967).

Production of biomass in the root nodules of French bean plants, is chiefly attributed by the bacteria belonging to *Rhizobium* sp., which has an inherent capacity to trap atmospheric nitrogen. But being a shy nodulator, it is essential that the soil or the seeds be inoculated with appropriate strain for successful growth particularly in places where they are grown for the first time. A small quantity of nitrogenous fertilizer also needs to be applied as a booster dose to facilitate better build up of bacterial colony in the vicinity of root nodules.

Selection of Rhizobial strain is one of the most important prerequisite for successful inoculation. Saono *et al.* (1976) reported that out of 90 strains tested, only 33 enhanced growth of the whole plant. The effect was greater on aerial growth than on underground growth. Regarding the availability of nitrogen through root nodule bacteria, Graham and Rosas (1977) observed that 20 cultivars of *Phaseolus vulgaris* differed in their growth habit when inoculated with efficient strains of *Rhizobium phaseoli*. Nitrogen gain was estimated to be 20-30 kg per ha per growing cycle.

Like other leguminous crops, *Phaseolus vulgaris* does not readily nodulate with native rhizobium. Consequently, basal application of a proper dose of nitrogen through inorganic or organic sources becomes essential for exploiting early vegetative growth and ultimate yield potential of the crop. Studies conducted at Kanpur (D.P.R.) and Varanasi (A.I.R.P.I.P.) have shown that the crop responds favorably to nitrogen fertilizers. Besides, balanced and timely application of phosphate and potassic fertilizers are also essential.

Foliar feeding of the crop with different growth regulators have been found to increase yield of legumes when sprayed at seedling (true-leaf) stage or at the time of flowering. Morgan (1977), Naito *et al.* (1978) and Wraight *et al.* (1978) are some workers who opine from the experiments on French-bean that appropriate growth regulators, with their proper concentrations, if applied at right stage of plant growth, can effectively influence the enzymatic activities to modify different quantitative and qualitative plant characters, which in turn may be contributory to higher yield or quality.

Though French bean has gained some recognition in the states of Maharastra, Mysore, Andhra Pradesh and Punjab, it is yet to become popular enough among the farmers particularly in the West Bengal plains, despite its number of attributed qualities. In West Bengal, though different local cultivars are abundantly grown in the home gardens of Northern Hill districts, its cultivation is still restricted due to poor average yield of the crop in the plains of West Bengal. Risk growing of the crop on marginal or submarginal land, non-availability of viable seeds of good quality, limited use of improved varieties, lack of information on the crop among the farmers with respect to use of organic or inorganic manures or fertilizers, plant protection measures etc. are some of the visible limitations which render the crop nontraditional in the crop calendar. Information based on scientific investigations carried out on this crop, particularly on the background of Gangetic alluvial region are also meagre. Keeping this in view, the present experiment has been taken up to study the effect of Rhizobium inoculation, fertilizer application and spraying of different growth regulators in the phyllosphere as a package of practice to increase productivity, seed yield and quality of this short duration leguminous

vegetable under available climatic condition in the plains of West Bengal. Furthermore, interrelationship among different input factors are also supposed to be observed keeping in view the necessity to lunch a pragmatic approach to counter-act the production constraints and thereby popularising the crop among the farmers.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Effective utilisation of agro-ecological conditions has always played a key role for successful cultivation of any crop. French bean, at its different centres of production tends to produce distinctive types and this may well be due to variation in soil, climate and cultural (management) practices. Crop improvement, therefore, lies on the technique of optimisation of these different production resources (genetic and environmental). Time of planting is known to influence the performance of genotypes of crop-plants due to weather conditions those prevail during the different periods of growth (Chatterjee and Som, 1990) and sequential planting have, therefore, been taken up by many scientists to determine the relationship between environmental factors and their response to plant growth.

Scientific observations of a legume crop like French bean have raised certain quaries regarding its manurial requirements, rhizobial inoculation and use of growth promoting substances. Necessity of nitrogen, phosphorus and potassium along with some other mineral nutrients have been suggested by many workers outside and inside the country.

Inoculation with suitable rhizobial strain is an essential pre-requisite for the shy nodulator French bean, which is capable of fixing atmospheric nitrogen through symbiotic association with the bacteria.

Modification of growth habit with an eye to improve yield and quality have been attempted by many workers in India and aborad.

Successful employment of different growth regulators have proved beneficial in this purpose.

Literature on doses and time of fertilizer application, inoculation with Rhizobium and use of growth regulators on the growth, yield and quality of seeds produced in French bean are reviewed and presented below.

2.1 NUTRITION

Balanced and proportionate use of different plant nutrients in available forms is essential for successful growth and reproduction of crop plants. French bean also responds to different inorganic and organic nutrients. Vigour of Snap bean was found to increase by 27 percent over control under nitrogen and phosphorus respectively, when each was applied at the rate of 25 lbs per acre. Addition of potash in the nutrient management also improved vigour of the plant (Smith, 1975). An optimum dose of nitrogen and phosphorus of 125.6 kg and 143 kg per hactare respectively for improvement of growth of French bean was reported by Srinivas and Naik (1990). Hine and Sprent (1988) opined that with variation in nitrogen sources (nitrate, ammonia and urea) the distribution of growth between the plant parts varied. Fertilization in the form of ammonium sulphate efficiently influenced growth of the crop in an experiment by El-leboudi *et al.* (1976).

Increase in yield of Snap bean under nitrogen and phosphorus applications @ 25 lbs per acre was noticed by Smith (1975). Regarding sources of nitrogen fertilizers, Lima bean was reported to give highest yield in association with CAN when applied @ 30 kg per hactare

(Thimmegowda and Krishnamurthy, 1975). Rubes (1976) on the other hand observed that ammonium sulphate was a better source of nitrogen than calcium nitrate when applied @ 30-150 kg per hactare for higher bean yield. An yield increase by 10- 40% with one or two foliar treatment with NPK solution was obtained by Neumann and Giskin (1979) in pot grown *Phaseolus vulgaris*.. However, Singh and Rajput (1985) obtained good results with respect to different yield components in Cluster bean with a basal application of nitrogen @ 20 kg and phosphate @ 60 kg per hactare followed by application of 20 kg nitrogen as top dressing 20 days after sowing. Srinivas and Naik (1988) suggested that nutrient management with application of nitrogen @ 160 kg and phosphate @ 80 kg per hactare, where half of the nitrogen dose was required to be applied before sowing and the remaining half 25 days later, phosphorus attributed to increases in a number of yield components. Singh *et al.* (1989) reported that application of phosphorus @ 100 kg per hactare brought tremendous improvement with regard to pod yield in French bean. Srinivas and Naik (1990) applied a further higher dose and reported that an optimum nitrogen and phosphorus dose of 125.6 kg and 143 kg respectively were ideal for green pod yield of French bean.

Newton and Robertson (1982) recommended application of nitrogen at sowing which stepped up seed yield from 249 to 324 g per square meter and application of nitrogen solution during pod development raised the grain yield from 258 to 316 g per square meter. Vargas *et al.*(1983) obtained highest seed yield with 100 kg nitrogen in association with 200 kg phosphate, 10 kg potash, 19 kg of a mixture of trace elements per hactare.

Fertilization was proved to influence nutrient status of the crop. Higher rates of fertilization tended to improve nitrogen content in bush Snap bean (Mack, 1983) and leaves were found to be the chief source-sink to accumulate most (about 50%) of the total accumulated nitrogen regardless of nitrogen source (Timpo and Neyra, 1983). Though fertilization in the form of ammonium sulphate influenced nutrient status of Snap bean (El-leboudi *et al.* 1976), Singh *et al.*(1989) suggested better efficiency of urea than ammonia or nitrate fertilizers with regard to its contribution towards fixed nitrogen in Cowpea. But obviously, this was true with moderate dose applied fertilizer @ 20 kg per ha (Ssali and Keya, 1980) and higher dose of applied nitrogen reduced nitrogen fixation in legume plants. Ruschel et al. (1982) also supported this view. Improvement in nutrient status in French bean with optimum N and P_2O_5 fertilization (125.6 kg and 143 kg per ha, respectively) was reported by Srinivas and Naik (1990). Dombovary (1977) also obtained increased amount of fixed nitrogen as a result of phosphorus fertilization in soil. Improvement in total protein content of seeds with supply of nitrogen and phosphorus @ 40 kg and 60 kg per ha respectively was obtained in Cluster bean (Singh and Rajpoot, 1985). Oliker *et al.* (1978) opined that nitrogen content of seeds is independent of that of pods and nitrogen accumulation in seeds started only after it stopped in pods.

2.2 RHIZOBIAL INOCULATION

There are several reports suggesting that increase in nodulation leads to increased dry matter production and yield of legumes, but as yield is a very complex character, it is not always possible to establish a direct relationship between nodulation and crop yield. However, it is known that

the yields of pulse crops can be stepped up substantially by the use of rhizobial cultures as shown by extensive studies in different parts of the country under the All India Co-ordinated Pulse Improvement Research Programme. Significant influence on crop yield through effective inoculation of seeds or through soil application of appropriate inoculants have been observed by scientists in many legumes including French bean. Beneficial effects of rhizobial culture have been tested in farmers' fields also. The beneficial effects of bacterial culture on growth and production of leguminous crops are presented below.

Effect of rhizobial inoculation on the growth of Lima bean was studied by Saono *et al.* (1976) and it was found that out of 90 strains employed only 33 could influence or modify growth of the crop. Findings of Iruthyathas and Ulassak (1982) also revealed that among different bacterial strains, starian NGR - 258 was highly effective in forming good amount of nodule tissue, total nodule mass and fixing an ample amount of nitrogen than the strains SRI - I and MAR 655 in Winged bean.

Augmented nitrogen content with addition of nitrogen on Rhizobial inoculation was observed in *Phaseolus vulgaris* (Ruschel and Ruschel, 1975). Graham and Rosas (1977) estimated that plants of *Phaseolus vulgaris* when inoculated with efficient strain of *Rhizobium phaseoli,* increased fixed nitrogen to a substantial extent. Such augmented nitrogen content reached its maximum 3 weeks after inoculation as observed by Saito and Cardoso (1977); however, Sundstrom *et al.* (1982) opined such peak 35 days after sowing in bean cultivars.

2.3 FOLIAR APPLICATION OF GROWTH REGULATORS

Growth regulators of different kinds and nature have been found to be associated with crop yield in may ways. Foliar feeding with growth regulators with appropriate doses normally increases yield when sprayed at 2-3 true leaf stage or at the time of flowering. Out of a number of growth regulators applied so far on different legumes including French bean, with a view to modifying growth habits leading to increased crop yield and better quality, some have consistantly proved beneficial effects. Information in these regards are reviewed as follows.

Germination and radical length were influenced by spraying growth regulators like GA_3, IAA or Kinetin. However, the influence could be modified by variation in incubation temperature (Sanchez-Calle, 1989). Regarding doses of growth regulators, El-fouly *et al.* (1988) found that GA_3 concentration ranging between 25-100 ppm influenced stem height and diameter in Kidney bean whereas B-9 or CCC generally had opposite effects to those of GA_3 . High level of endogenous IAA is thought to be correlated with inhibited lateral shoot growth of intact and decapitated *Phaseolus vulgaris* seedlings. Low levels of endogenous IAA however did not inhibit growth (Hoof, 1986). No significant increase in plant growth of French bean was obtained by Ries *et al.* (1978) by seed or soil application of I-Triacontanol. However, foliar application of 0.01-10 mg Triacontanol per litre at 2-3 true-leaf stage increased biomass under glass house condition. Ethrel @ 0.25 ai per hactare when sprayed during 2-true leaf stage checked apical dominance, induced branching and produced higher biomass in French bean (Wraight and Rogers, 1978). Naito *et al.* (1978) observed that growth of bean leaves were also influenced positively

when leaves were regularly painted with BA from an early stage. In non-leguminous plants like Marigold and China ester, Shyamal *et al*(1990) observed that GA_3 at 200 ppm increased plant height however, application of MH at 400 ppm was found to supress vegetative growth.

Morgan (1977) presumed that Abscisic acid (ABA) might have participated in flower bud differentiation in *Phaseolus vulgaris* and opined that ABA concentration varied depending on variation in day length. Endogenous growth substances were investigated by Goto (1978) in 2 varieties of dwarf *Phaseolus vulgaris*, 5 GA like activities and 6 growth inhibiting activities were detected with almost identical levels in both varieties. In the both, external GA_3 treatments caused two inhibitory activities to decrease, one of which was thought to involve ABA. Alvino *et al.* (1988) reported that use of foliar spray of BNOA twice at 1% concentration on Kidney bean confirmed its positive effect on growth. Shyamal *et al.* (1990) as stated earlier, indicated that GA_3 (200 ppm) induced growth in Marigold and China aster, whereas MH (400 ppm) suppressed both vegetative growth and flowering.

Different yield components of Soybean plants were found to be influenced by application of growth regulators like NAA, Chlormequat and Maleic hydrazide when applied at 6-8 trifoliate leaf stage @ 375 gm per hactare depending on determinate or indeterminate growth habit of plants (Arthur and Myers, 1974). No significant increase in yield of French bean was obtained by Ries *et al.* (1978) by seed or soil application of l-Triacontanol. Neumann and Giskin (1979) reported that though nutrient solution of NPK increased yield of French bean when sprayed during seed filling stage, incorporation of Cytokinin into the nutrient solution had no

effect on yield. Rafique-uddin (1984) reported that 2-4 foliar application of growth retardant like Cycocel (Chlormequat) at 400 ppm to *Phaseolus vulgaris* significantly increased seed yield by 15%. But its concentration of 200 or 800 ppm was less effective and at 1000 ppm concentration it rather caused decrease in yield. Singh and Rajput (1985) reported that different yield components of Cluster bean were influenced positively when CCC was applied at 500 ppm concentration 25 days after sowing in combination with suitable nutrient management practices. Both lower and higher concentration of CCC proved less effective. Alvino *et al.* (1988) reported that use of foliar spray of BNOA at 1% had its positive effect on yield and yield components of French bean. Leprince (1989) found that Alar 85 (Daminozide) or Banronet (Triapenthenol) applied @ 750 g per hactare in the beginning of flowering increased yields of *Phaseolus vulgaris* by an average of 6 and 8 percent respectively over two seasons. Berelex (Gibberellicacid) either decreased yields or had no effects. Shyamal *et al.* (1990) studied the effect of GA_3 on seed yield of Marigold and China aster and it was observed that GA_3 200 ppm increased seed yield.

Chemical composition of bean leaves were influenced positively when attached leaves were painted regularly with BA preparation from an early stage (Naito *et al.*, 1978). Application of CCC @ 500 ppm 25 days after sowing was found to influence chemical composition of pods in Cluster bean by Singh and Rajput, (1985.) Bentazon induced reduction in the quantity of fixed nitrogen in *Phaseolus vulgaris* plants was reported by Bethlenfalvay *et al.* (1979) which caused as a result of limiting availability of photosynthates to support root nodule activity.

2.4 GROWTH AND REPRODUCTION

Factors contributing to variation in plant growth may be due to nutritional differences (Challou *et al.*, 1986; Srinivas and Naik, 1990; Pereira and Bliss, 1987) differences in growing season (Scarascio and Losavio, 1979), ecological factors like temperature (Wendt, 1978), influence of internal or external growth promoting substances (Goto, 1978; Naito, Tsugi and Hatakeyama, 1978; Carmi, 1986), genotypes (Srivastava and Singh, 1989) etc. Findings of some scientific investigations in this regard are presented as follows

2.4.1 Seed germination

Symbiotic association of bacteria through inoculation improved the process of germination of seeds (Wendhaus, 1980) in leguminous crop French bean which was attributed to better sharing of metabolites after synthesis. In the light of above observations, the findings of Wendhaus (1980) indicating the time of application of nutrition with respect to nitrogen is important. He pointed out that application of nitrogen at later stage of plant growth was better than that of basal application which interfered with the germination process. Mineral nutrition of mother plant had a bearing on the germination process of the seeds but higher nutrition of mother plants adversely affected the germination of seeds (Nowosielska, 1982). Ambient temperature also affected the germination of seeds as Chatterjee and Som (1990) reported that sowing dates from Mid September to Mid December had influenced germination percentage of French bean seeds in field condition where germination decreased from 86.5 to 81.5 percent with delay in sowing. Subsequently, the phenomenon was confirmed by Som *et al.* (1991) in Pea seeds. Highest germination

percentage of Pea seed was associated with October sowing whereas least seed germination was obtained from November and December sowing. Effect of seed size and specific gravity on germination and stand establishment studied by Hoy and Gamble (1981) in Soybean indicated that lower germination, emergence and final stand were associated with small and intermediate sized seeds having lower specific gravity.

2.4.2 Height of the plant

Smith (1975) reported increased height in bean plants when soil was supplemented with nitrogen and phosphorus each at the rate of 25 lbs per acre. Addition of potash had also an accelerating effect. A report by Palaniyandi and Smith (1979) revealed that nitrogen and phosphorus treatment increased height of Snap bean regardless of the source of the nutrients although they observed slightly less vigorous plants resulting from nitrate than ammonical fertilizer application. This supports the earlier findings of El-leboudi *et al.* (1976) where ammonium sulphate positively influenced the height of Snap bean plants. Ludwig and Wilcox (1980) obtained higher plant height (21.5 inches) after application of nutrient solution containing potassium nitrate, phosphoric acid and ammonium nitrate (25 : 10 : 25) where both the forms of nitrate and ammonical nitrogen were present. Subsequent study of Westermann *et al.* (1981) suggested that early increase in plant height could be ascertained in French bean only by application of lower rate of nitrate nitrogen.

Symbiotic assimilation of nitrogen through rhizobial inoculation influenced plant height in Snap bean. (El-leboudi *et al.*, 1976). Venkateswamy and Peerally (1981) further confirmed the observation by in-vitro in French bean where the plant height increased within pH range

from 5.8 to 8.7 after inoculation. However, the extent of influence varied with the strain and Rhizobium strain 127-E-14 emerged significantly superior over stain 127-E-15 in inducing tallness of Limabean (Triplett *et al.*, 1981). Nitrogen starvation owing to unfertilization and uninoculation resulted in severe reduction of height in *Phaseolus vulgaris* seedlings (Sundstrom *et al.*,1982). Growth retardants also imposed limit to plant height. Significant decrease in the height of *Phaseolus vulgaris* plants was obtained with application of 2-4 foliar sprays of 400 ppm Cycocel (Chlormequat) by Rafique-uddin (1984). Increased stem length was seen to be associated with reduced stem diameter when Kidney bean plants were subjected to foliar application of GA_3 @ 25-100 ppm one month after sowing (El-fouly *et al.*, 1988).

2.4.3 Lateral branches and spread of the plant

A fertilizer mixture comprising nitrogen and phosphorus at a ratio of 28 : 28 was noted to increase the total number of branches (Smith, 1977) in *Phaseolus vulgaris.* On the other hand, cultural solution containing ammonium nitrogen exclusively not only reduced the spread of the Bush bean (cv. Improved Tendergreen) but also caused ammonium toxicity. Palaniyandi and Smith (1979) used three different nitrogen sources where they found that the treated plants were vigorous and yielded more compared to control. The response of phosphate was investigated by Araujo *et al.* (1982) where they reported that a combined fertilizer treatment (cowmanure 15t, soluble phosphate 100 kg and rock phosphate 300 kg per hactare) when mixed up with *Rhizobium phaseoli* increased number of branches in bean plants. Development of canopy or bearing surface due to increased branching, an important aspect to increase the

yield was studied by Saono *et al.* (1976). He reported that nodulation due to inoculation had a positive influence on the branching of Lima bean. This phenomenon is probably also true in other leguminous plants as Rennie and Kemp (1981) observed that lower nodulation in Pea and bean cultivars adversely affected the lateral branching of the plants under observation. Not withstanding the above findings the levels of endogenous IAA had been reported to determine the extent of lateral and apical growth vis-a-vis branching and height (Hoof, 1986) and high levels of endogenous IAA and inhibition of lateral shoot growth in *Phaseolus vulgaris* had been found to have a correlation by the author.

2.4.4 Dry matter content

The rate of dry matter accumulation could be modified with the supply of nutrients as Mc Elhanon and Mills (1978) observed that leaf dry weight of Lima bean was higher when nitrate constituted 75% or more of the supplied nitrogen. Gradual increase in leaf and shoot dry weight with age and supplied nitrogen (Leidi and Gomez, 1980) further confirmed the findings of Mc Elhanon and Mills. Although the above findings were true for aerial parts, yet these did not reflect any effect on the subaerial parts. In this context, the findings of Rosas (1984) transpired that higher nitrogen rates and high temperature decreased dry weight of the subacrial plant part. Sundstrom *et al.* (1982) observed increased nodule dry weight with moderate (@ 25 kg per ha) N dose, however its higher dose decreased nodule dry weight in *Phaseolus vulgaris.*

However, specificity of bacterial strain cannot be overruled as Chui and Nadar (1984) reported that Rhizobium strain NU-439 when inoculated to *Phaseolus vulgaris,* produced highest dry weight of shoot as well as

total dry weight at maturity. Foliar application of 0.01 - 10 mg Triacontanol per litre at 2-3 true leaf stage also increased biomass (Ries *et al.*, 1978). The dry weight could be continued to increase upto a potential limit in bean plants when the leaves were painted on a regular basis with BA preparation from an early age (Naito *et al.*, 1978).

2.4.5 Flowering

Nodulation due to inoculation with appropriate strain fixed greatest amount of nitrogen in *Phaseolus vulgaris* which led to significant increase in starch content and subsequent enhancement of flowering (Graham and Rosas, 1977). Possible participation of day length and Abscisic acid (ABA) in regulation of flower bud differentiation in *Phaseolus vulgaris* was reported by Morgan (1977). Severe inhibition to flower bud formation occurred at higher concentrations of ABA and it was found associated with day length. Lower photoperiodic exposure helped build up lower ABA concentration and normal bud development. Pookpakdi (1979) observed that shorter photoperiod and higher temperature gave smaller plants with fewer flowers in Soybeans and earlier flowering with delay in sowing date (Scarascio and Losavio, 1979) confirmed the observation. Exogenous foliar application of 1% BNOA solution twice on Kidney bean induced flowering probably by suppression of endogenous ABA, further confirmed the above findings.

2.4.6 Number, length and weight of pods

Lugo-Lopez *et al.* (1977) observed an increase in number and weight of pods of Lima bean under nutritional treatment of 80 kg nitrogen per hactare compared to higher or lower nitrogen rate. Higher dose of nitrogen was applied by Scarisbrick *et al.* (1982) where they suggested

application of 100 kg nitrogen per hactare for more number of pods per square meter. On the other hand, Araujo *et al.* (1982) recorded increased pod length and pod weight with application of cowdung manure at 15t per hactare in bean plants. Tau *et al.* (1984) compared the effect of a combined nutrition treatment (60 kg nitrogen, 160 kg phosphorus and 100 kg potash per hactare) with a peat based inoculant (containing greater than 10^{10} *Rhizobium phaseoli* F-45 cells per gram). It was found that the nutritional treatment yielded increased number of pods with higher pod weights in *Phaseolus vulgaris* . Foliar spray of BNOA1% on Kidney bean however failed to influence pod number (Alvino *et al.*, 1988). Tayo (1986) pointed out that 2nd and 3rd node produced 50% of the pods that retained upto maturity in French bean. Variation in pod number with pod bearing habit in Soybean as a result of change in sowing dates was reportd by Scarascio and Losavio (1979).

2.4.7 Harvest

Time of pod maturity and harvesting varied with variety as Mangual-crespo (1977) reported that harvesting of Snap bean cv. Wade, Contender and Tendergreen gave optimum yields of 5560, 5672 and 3991 kg per hactare when once over harvested at 55 days, 47 days and 49 days after planting, respectively. Pookpakdi (1971) observed that Soybean pods matured faster and could be harvested earlier if exposed under shorter photoperiod in combination with higher temperature. Physiological maturity was also influenced by sowing date in beans (Iglesias *et al.*, 1984).

2.4.8 Pod yield

Combined application of nitrogen and phosphate each at 25 lbs per acre was found to increase pod yield but addition of potash failed to influence it (Smith, 1975). MauroChagas and Viera (1975) indicated that varying doses of fertilizer mixture of NPK from 20:60:10 to 40:120:20 kg per hactare increased yield of beans. Maximum yield of dry beans (1051 to 1180 kg per hactare) was also obtained by Rodriquez (1976) with application of 225 kg phosphate, 40 kg potash, 2t per hactare dolomite and some minor nutrients but without any nitrogen. Marketable yield of Snap bean was found to increase with nitrogen application (Doss *et al.*,(1977). Smith (1977) in subsequent publication reported the doses of nitrogen and phosphate treatment required to be 28:28 kg per hactare for highest yield. Duranti and Carone (1978) obtained higher average yield from a single dressing of 200 kg nitrogen, 400 kg phosphate and 100 kg potash per hactare in dwarf beans. Neumann *et al.*(1979) obtained increased yield in *Phaseolus vulgaris* by foliar nutritional treatment of NPK at seed filling stage. Further NPK sprays became less effective. In Winged bean increased yield was obtained as a result of application of lime + 60 kg phosphate + 30 kg nitrogen per hactare (Pagaduan, 1980). Nitrogen emerged to be the most effective nutrient by Thimmegowda and Krishnamurthy (1975) where they advised application of 32 kg CAN per hactare. But application of nitrogen at 80-100 kg per hactare was advocated by Chuna *et al.* (1980) to have higher yield. Inoculation and 40 kg nitrogen applied at flowering was reported to produce highest yield in *Phaseolus vulgaris* by Wendhaus (1980). But Hoy *et al.* (1981) could not get higher yield due to inoculation and fertilization in Soybean where nitrogen was applied at the rate between 40-80 kg per hactare. On the

other hand, Singh *et al.* (1989) reported that green pod yield improved due to Rhizobium inoculation and application of phosphorus at 100 kg per hactare in Cowpea.

Although about 6.81% yield increase in *Phaseolus vulgaris* over two seasons were obtained by application of Alar 85 (Daminozide)& Baronet (Triapenthenol) @ 750 gm per hactare at the beginning of flowring by Leprince (1989), yet the application of long chain growth regulator Triacontanol failed to increase yield significantly in French bean either with seed or with soil treatment. Wendt (1978) obtained highest yield of dwarf beans at a soil temperature of 25^0 - 30^0C.

2.4.9 Seed yield

Levels of plant nutrients including NPK had no marked effect on seed yield grown on average fertile soil (Nowosielska, 1982), rather excessive nutrition reduced the seed yield. An inconsistant effects of various nitrogen sources on seed yield of Common bean was observed by Rosas (1984). Posypanov *et al.*(1978) reported a greater influence of phosphorus and potash as basal dressing and nitrogen nutrition on bean seed yield. Higher seed yield in inoculated bean plants was reported by Samtsevich *et al.*(1980).

Rafique-uddin (1984) reported that 2-4 foliar sprays with 400 ppm Cycocel (Chlormequat) increased seed yield of *Phaseolus vulgaris* by 15% Chlormequat 200 or 800 ppm proved less effective and at 1000 ppm concentration it rather lowered seed yield considerably. But El-fouly (1988) found that application of Chlormequat at 100, 250 and 500 ppm, one month after sowing increased seed yield of Kidney bean. He also

found that seed yield was increased by 100 and 250 ppm B-9 (Daminozide) foliar sprays.

Iglesias *et al.* (1984) observed highest seed yield (2.59 and 1.9 t per hactare, respectively) in bean cultivars to be associated with the dates of sowing of seeds during October and November. May sown crop gave the lowest seed yield of 0.12 t per hactare. Chatterjee and Som (1990) observed that out of the three sowing at monthly interval from 15th September to 15th December resulted in progressive reduction in seed yield in French bean. In a field trial on Snap bean in Maharastra, French bean cultivars sown on 15th October, 30th October and 14th November gave seed yield of 1.14, 1.23 and 0.95 t per hactare, respectively (Vyas *et al.*, 1990). Som *et al.* (1991) studied the effect of sowing date on seed production of Pea and opined that out of the 4 sowing dates from September to December, October sown crop produced maximum seed yield.

Smittle (1986) observed that seed yield of Lima bean could be increased under temperature variation with the plants growing larger to produce larger bearing surface before flowering.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

Two sets of experiments were conducted on French bean entitled " Studies on germination and subsequent growth of seeds under varying levels of fertilizers and bacterial inoculation during two different seasons " (Expt. 1) and "Studies on growth and reproduction of French bean under different treatment of growth regulators and time of nitrogen applications with or without bacterial inoculation during two different seasons" (Expt. 2) from 1992-1994 in the Department of Horticulture, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. The details of materials used and the methods adapted are presented in the following pages under separate sub-headings.

3.1 Experimental site

The experiment was conducted in the 'C' Block of the Kalyani Seed Farm of Bidhan Chandra Krishi Viswavidyalaya. The farm is situated on the 23.5^0 North and 89^0 East latitude and longitude respectively and is located on the western side of the Kalyani township at about a kilometer away on the eastern bank of the river Ganges. The altitude of the farm is 9.75 m above the mean sea level (MSL).

3.2 Experimental soil

The station of experiment belongs to alluvial zone of West Bengal. Soil of the experimental plot was found sandy loam in texture, neutral in reaction with low nitrogen and potash and medium phosphorus content. Result of soil analysis is summarised as follows :

Table 3.1 : Physico-chemical property of the soil of the experimental plot

Soil character	Components	Methods followed
Textural class	Sandy loam	International Pipette method (Piper, 1966)
Sand(%)	37	
Silt(%)	20.9	
Clay(%)	17.8	
Total nitrogen(%)	0.07	Modified Kjeldahl method (Jackson, 1967)
Organic C (%)	0.59	Walkley & Black method (Piper, 1966)
Available P (kg/ha)	34	Olsen's method (Jackson, 1967)
Available K (kg/ha)	112	Flame Photometer method (Jackson, 1967)
Soil pH	7.1	Backman's pH meter in 1:2.5 soil water suspension (Jackson, 1967).

3.3 Climatic condition

Kalyani has a subtropical humid climate and it is situated just north of Tropic of Cancer. Here the crop seasons are broadly classified as I) *Kharif* or rainy (Warm and rainy within July to October) ii) *Rabi* or Winter (Cool and dry within November to February) and iii) *Zaid* or Summer (Hot & humid within March to June). The long term average rainfall is 1457.1 mm but the bulk of it, is received from last week of June

to the end of September and relative humidity remains higher during this period. Details of climatic conditions pertaining to the period of experiment as recorded from the meteorological observatory of the nearby Haringhata Dairy Farm are indicated below :

Table 3.2 Meteorological observation during the period of Experiment

		Temperature (°C)		RH (%)		Rainfall (mm)
		Max.	Min.	Max.	Min.	
1992	October	32.06	23.08	89.93	65.45	47.40
	November	29.52	18.14	85.90	47.10	5.2
	December	24.31	11.64	81.87	44.90	0.0
1993	January	24.40	11.72	89.09	41.03	0.0
	February	28.97	16.27	85.71	52.32	0.0
	March	34.30	18.56	80.74	36.87	76.6
	April	34.41	23.42	83.86	49.0	45.6
	May	33.66	24.64	83.96	59.90	148.5
	June	32.23	26.38	89.40	72.0	341.0
	July	31.57	25.76	91.58	76.22	344.8
	August	31.86	25.70	92.63	78.41	312.0
	September	30.30	23.93	90.03	74.40	354.2
	October	31.99	23.13	90.83	68.77	92.80
	November	29.04	17.92	89.43	57.93	6.0
	December	23.99	12.60	90.19	48.06	0.0
1994	January	23.38	11.45	86.16	38.70	13.4
	February	24.10	14.59	89.67	50.0	45.8
	March	32.89	20.38	87.80	42.70	6.8
	April	33.36	22.65	84.80	51.30	116.8
	May	35.06	26.39	86.61	54.54	133.8
	June	31.81	26.14	91.16	76.13	316.8
	July	30.42	26.12	90.74	79.12	292.2
	August	30.06	25.50	91.77	79.67	374.4
	September	27.63	24.84	89.96	64.96	129.8
	October	29.55	23.67	88.50	58.0	63.2
	November	26.02	19.62	88.25	48.0	3.2
	December	27.18	12.48	88.8	37.0	0.0

3.4 Experiment 1 : Studies on Germination and subsequent growth of seeds under varying levels of fertilizers and bacterial inoculation during two different seasons.

3.4.1. Layout

Design	:	Randomised Block Design
Replication	:	3
Number of treatments	:	7
Total Number of plots	:	21
Net plot size	:	1.5 m x 2.25 m
Width of irrigation channel	:	90 cm
Spacing -		
Plant to plant	:	15 cm
row to row	:	45 cm

3.4.2 Treatment factors

Factor I. Combined fertilizer treatments

Symbols used	Doses in Kilogram per hactare		
	N	P	K
P_1	80	40	40
P_2	40	20	20
P_3	20	10	10

Factor II. Bacterial inoculation

R_1 = Seeds inoculated with *Rhizobium phaseoli*

R_0 = Seeds without any inoculation treatment

3.4.3 Factor combinations (Treatments)

T_1 = P_1 ($N_{80}P_{40}K_{40}$) x R_o

T_2 = P_1 ($N_{80}P_{40}K_{40}$) x R_1

T_3 = P_2 ($N_{40}P_{20}K_{20}$) x R_o

T_4 = P_2 ($N_{40}P_{20}K_{20}$) x R_1

T_5 = P_3 ($N_{20}P_{10}K_{10}$) x R_o

T_6 = P_3 ($N_{20}P_{10}K_{10}$) x R_1

T_7 = Control (Without fertilizer and bacterial treatment)

3.5 Experiment 2 : Studies on growth and reproduction of French bean under different treatment of growth regulators and time of nitrogen applications with or without bacterial inoculation during two different seasons.

3.5.1 Layout

Design	:	Split Split Plot Design
Replication	:	3
Number of treatments	:	30
Number of sub sub plots	:	90
Net sub sub plot size	:	2 m x 3 m
Width of irrigation channel	:	90 cm
Spacing -		
plant to plant	:	20 cm
row to row	:	60 cm

3.5.2 Basal fertilizers application

Phosphatic fertilizer (single super phosphate) : @ 40 kg/ha

Potassic fertilizer (Muriate of potash) : @ 40 kg/ha

P-1) Panoromic view of the Experimental plot (replicate - 1, Expt. 2)

3.5.3 Treatment factors

Factor I : Spraying with growth regulators at pre-flowering stage (Main plot factor)

A_0 : No growth regulator spray

A_1 : Spraying with BNOA 25 ppm

A_2 : Spraying with GA_3 100 ppm

A_3 : Spraying with 2,4-D 2 ppm

A_4 : Spraying with MH 500 ppm

Factor II : Time of application of nitrogenous fertilizer (Sub plot factor)

B_1 = Basal application of full dose (80 kg/ha)

B_2 = 50% basal + 50% top dressing 20 DAS

B_3 = 50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS

Factor III : Inoculation (Sub sub plot factor)

C_0 = No inoculation

C_1 = Seed inoculation with *Rhizobium phaseoli*

3. 5 4. Factor combinations (Treatments)

T_1	=	$B_1C_0A_0$	T_{16}	=	$B_2C_1A_2$
T_2	=	$B_1C_1A_0$	T_{17}	=	$B_2C_0A_3$
T_3	=	$B_1C_0A_1$	T_{18}	=	$B_2C_1A_3$
T_4	=	$B_1C_1A_1$	T_{19}	=	$B_2C_0A_4$
T_5	=	$B_1C_0A_2$	T_{20}	=	$B_2C_1A_4$
T_6	=	$B_1C_1A_2$	T_{21}	=	$B_3C_0A_0$
T_7	=	$B_1C_0A_3$	T_{22}	=	$B_3C_1A_0$
T_8	=	$B_1C_1A_3$	T_{23}	=	$B_3C_0A_1$
T_9	=	$B_1C_0A_4$	T_{24}	=	$B_3C_1A_1$
T_{10}	=	$B_1C_1A_4$	T_{25}	=	$B_3C_0A_2$
T_{11}	=	$B_2C_0A_0$	T_{26}	=	$B_3C_1A_2$
T_{12}	=	$B_2C_1A_0$	T_{27}	=	$B_3C_0A_3$
T_{13}	=	$B_2C_0A_1$	T_{28}	=	$B_3C_1A_3$
T_{14}	=	$B_2C_1A_1$	T_{29}	=	$B_3C_0A_4$
T_{15}	=	$B_2C_0A_2$	T_{30}	=	$B_3C_1A_4$

3.6 Input components

3.6.1 Seed material and variety

Experimental seed material was cv. 'Contender' of bushy type French bean and was collected from National Seed Corporation Limited, Calcutta.

3.6.2 Inoculum

A mixture of different strains of *Rhizobium phaseoli* was used as seed inoculum and was collected from the Officer-in-Charge of the 'Project on Survey, Selection & Mass production of nodule bacteria', B.C.K.V.V., Mohanpur, Nadia.

3.6.3. Fertilizers

Urea (Oswal Chem. and Fert. Ltd), Single super phosphate (Joyshree Chem. and Fert.) and Muriate of potash (Indo-gulf Fert. and Chem. Ltd.) were used as chief source of plant nutrients.

3.6.4 Growth regulators

GA_3 (Gibberelic acid) (Loba Chemie Pvt. Ltd.), 2,4-D (2,4 Dichlorophenoxy acetic acid) (Loba Chemic. Pvt. Ltd.), BNOA (Beta napthoxy acetic acid) (Sigma Chem. Company) and MH (Maleic hydrazide) (Sisco Res. Lab. Pvt. Ltd.) at different levels of concentrations were used as growth regulating chemicals.

3.7 Details of Management Practices

3.7.1. Land preparation

For the field experiments, land was prepared to a fine tilth with one deep ploughing by tractor followed by two ploughings with power-tiller and subsequent laddering for levelling of land. Individual plots were separately laid out with channels to facilitate irrigation and drainage and bunds to restrict the overflow of water and admixture of treatments.

3.7.2. Application of manures and fertilizers

Thoroughly decomposed farm-yard manure was added at the rate of 10 t per ha. during final land preparation and each of phosphorus and potash as basal dose (Expt. 1 & 2). Nitrogenous fertilizer was applied to the individual plot (Expt. 1) / sub sub plot (Expt. 2) as single basal dose

or through split doses as implied in the treatments and was thoroughly mixed up with soil.

3.7.3 Fungicidal seed treatment

Seeds were dressed with chemical fungicide Thiram @ 3 g per Kg of seeds seven days before their sowing in the final field.

3.7.4 Seed inoculation with rhizobium strain

Required quantity of seed was inoculated with the mixture of strains of *Rhizobium phaseoli* following suitable seed inoculation method. For this purpose each 1 kg of seed was soaked for five minutes in water. Water was then drained out and 33g rhizobium culture was thoroughly mixed up with seed and kept under shed for 15-20 minutes for drying and penetration inside before they were sown in the final field.

3.7.5 Sowing of Seed

Sowing was done twice in each occasion for raising the Spring and Summer crop, respectively. First sowing during 1992 was done in the first fortnight of October (12/10/92) and the experiment was repeated in the next year i.e. 1993 and the seeds were sown on 8/10/93 to get the Spring season crop and the second sowing during 1993 was done during first fortnight of January,'93 (13/01/93) and the experiment was repeated during 1994 where sowing was done on 17/01/94 for obtaining Summer crop. On each occasion sowing operation was taken up during the afternoon with placement of two seeds per heel arranged in lines. The seeds were sown at a depth of 3-4 cm inside and covered with loose soil.

3.7.6. Interculture operation

Shallow hoeing along the interspace between the rows during the early stage of crop growth was done for preventing weeds to compete with the crop. Altogether three hoeing was done during the entire growing season as per need in different growth stages. Weeds germinating close to the experimental plants were uprooted manually.

3.7.7 Irrigation

For the purpose of keeping the soil sufficiently moist restricted irrigation was provided to the plots/sub sub plots through irrigation channel/sub channels. Precaution was taken so that applied fertilizer may not flow with irrigation water from one plot to the adjacent one. Watering was done after application of each split dose of nitrogenous fertilizer and also during moisture stress condition of the experimental soil.

3.7.8 Plant protection measures

Spraying with malathion @ 0.1% at regular interval (15 days interval) was done to prevent white flies as were observed during both the growing seasons at early crop growth stage starting from true-leaf stage of the crop. Sporadic emergence of bacterial blight was observed and antibiotic preparation Streptomycin (100 mg per litre of water) was used as foliar spray for its control.

3.8 Observational methods :

3.8.A Observation on physical parameters : (Expt - 1 & 2)

3.8.A.1 Germination percentage of seeds

Germination count was recorded as percent taking into account number of normal germinated seedlings under each treatment replication when germination process was ceased.

3.8.A.2 Emergence rate of seedlings (E. R.)

Emergence rate of seedlings per treatment replication was computed using the formula as follows :

$$ER = \frac{1}{2}\left[\frac{\text{Number of seedlings emerged after 5 days}}{5} + \frac{\text{Number of seedlings emerged after 8 days}}{8}\right]$$

This was taken as a basis of comparison of germination speed of seedlings.

3.8.A.3 Root length of seedlings

Mean length of root of the seedlings (from the root tip of the main root to the colar junction at the base of the soil) was recorded in centimeter scale 15 days after sowing (DAS) after uprooting of representative seedlings and taking the mean value into account.

3.8.A.4 Shoot length of seedlings

Shoot length of the seedlings (from the base of the soil to the point of emergence of true-leaf) was also measured in centimeter scale 15 DAS

and the mean value from ten representative seedlings was recorded replication wise.

3.8.A.5 Fresh weight of seedlings

Mean fresh weight per seedling was recorded in gram 15 DAS from the tagged plants in each treatment replication.

3.8.A.6 Dry weight of seedlings

Mean dry weight per seedling in each replication was recorded in gram from the sampled plants collected for estimating fresh weight after oven drying the samples at 76°C temperature for 48 hours.

3.8.A.7 Height of the plant

Final height (after onset of flowering) from the tagged plants per treatment replication was measured from the ground level upto the top-most leaf of normal field grown plant in centimeter and the mean value was recorded.

3.8.A.8 Number of primary branches

Total number of primary branches emerging from the main axis were recorded from the tagged plants in each replication of the treratments and the mean value was recored for analysis.

3.8.A.9 Dry matter accumulation

Mean data was recorded in gram per plant from the whole plant (leaf, root and shoot) after the representative tagged plants under each

treatment-replication were uprooted cleaned and kept in drier for 48 hours at a constant temperature of 76 ^{0}C.

3.8.A.10 Flower initiation period

Duration in days taken from the date of sowing upto the stage of appearing first bloom in the flower cluster was recorded from the mean data from the tagged plants under each treatment-replication.

3.8.A.11 Node to give first flower

Position of the node from the base of plants wherefrom the first flower emerged was taken into account and mean data from the representative plants per treatment under each replication was recorded for analysis.

3.8.A.12 Pod number

Pod numbers were counted upto the second picking and the mean number of edible pods per plant was recorded from the representative tagged plants under each treatment-replication.

3.8.A.13 Length of pod

Five edible and mature pods from each of the representative tagged plants were taken and the mean pod length was recorded in centimeter replication wise from each treatment.

3.8.A.14 Pod yield

Fresh pod yield per plant was recorded considering the cumulative weights of both marketable and non-marketable pods from each harvest from tagged plants in each replication under the treatments. Total yield from individual treatments was averaged per plant replication wise and computed for analysis.

3.8.A.15 Seed-pod number

After two consecutive picking for fresh edible pods, plants were allowed to set seed pods. Mature seed pods were obtained for collection of seeds. Mean data on average number of seed pods per plant was recorded from the representative tagged plants under each treatment replication when they were about to shatter.

3.8.A.16 Number of seeds per pod

Fully mature pods, at the pre-shattering stage were picked from each replication under the treatments and opened to count the number of seeds. These were subsequently averaged to get the number of seeds per pod and recorded for statistical analysis.

3.8.A.17 Seed yield

Mature seeds from over ripe seed-pods of the representative tagged plants under each treatment-replication were weighed to get mean seed yield per plant and was recorded in gram replication wise for analysis.

3.8.A.18 Germinability of offspring seeds (seeds produced)

Germinability of the offspring seeds (seeds produced) was measured by rolled towel test in the laboratory during the following season. 100 randomly chosen seeds produced under each treatment replication were placed within moist towels, rolled from right to left and kept in ambient condition. Germination count was recorded 10 days after as percent taking into account the sprouted seeds with normal radical and plumule growth.

3.8.A.19 Length of offspring seeds (seeds produced)

Screw gauge with verneer scale attachment was used for measuring length of seeds produced (offspring seeds). Mean data from 15 randomly chosen seeds per treatment-replication was recorded in milimeter.

3.8.A.20 Breadth of offspring seeds (seeds produced)

Seed breadth was also measured in milimeter scale using screw-gauge as before. Breadth of 15 randomly chosen seeds per treatment replication atleast from two positions breadth wise was recorded to get the mean value.

3.8.A.21 Specific gravity of offspring seeds (seeds produced)

Specific gravity of offspring seeds (seeds produced) was recorded by water dispersion method in graduated cylinder and treatmentwise mean data were recorded taking the average of 15 seeds per replication.

3.8.A.22 Weight of offspring seeds (seeds produced)

Weight of offspring seeds was taken in gram and mean data was recorded taking the average of 20 seeds per replicate :

3.8.B Assay of bio-chemical constituents

3.8.B.1 Estimation of chlorophyll content of cotyledonary leaf of seedlings (chlorophyll a, chlorophyll b & total chlorophyll) [Mahadevan & Sridhar, 1982]

Procedure : chlorophyll content of cotyledonary leaf was determined by colorimetric method. For the purpose, 500 mg chopped leaf sample per treatment-replication was put into a test tube and chlorophyll was extracted in 80% acetone. The tube was then covered with black papers fitted with a cork to avoid losses of acetone and kept for three days in refrigeration. After three days the chopped tissues appeared completely devoid of chlorophyll. The extract was finally made to 20 ml with acetone and the aliquot was separated from the leaf tissues by centrifuge. An aliquot of 5 ml of this extract was taken for spectophotometric reading and chlorophyll content was determined by the following formula

$$\text{Chlorophyll a (mg/100 g)} = \frac{12.7\, A_{663} - 2.69\, A_{645} V}{a \times 1000 \times w \times 100}$$

$$\text{Chlorophyll b (mg/100 g)} = \frac{22.9\, A_{645} - 4.68\, A_{663} V}{a \times 1000 \times w \times 100}$$

$$\text{Total chlorophyll (mg/100gm)} = \frac{2.78\, A_{552}\, V}{a \times 1000 \times W \times 100}$$

Where a = length of path light in the cell, (taken as 1 cm)

V = Volume of extract in ml, W = Fresh weight of the sample in gram,

A = Wave length of light.

3.8.B.2 Estimation of total Nitrogen content of plant material

Plant material (whole plant i.e. leaf, root and shoot) for estimation of total nitrogen content was collected after onset of flowering and the test was carried out from dried powdered materials (drying at 70^0C temperature for 2 days) stored in a desiccator following modified Microkjeldahl method (Jackson 1967).

a) Reagents used

i) Diacid Mixture - H_2SO_4 + Salicylic acid (20:1)
ii) Sodium thiosulphate ($Na_2S_2O_3$, 5 H_2O)
iii) Potassium sulphate (K_2SO_4)
iv) Ferrus sulphate ($FeSO_4$)
v) Copper sulphate ($CuSO_4$, $5H_2O$)
vi) Sodium hydroxide (NaOH)
vii) Boric acid (H_3BO_3)

b) Procedure

Digestion

0.1 g dried and powdered sample was taken and 10 ml di-acid mixture and 1 g $Na_2S_2O_3$, $5H_2O$ were added to it and kept for half an hour with occasional shaking. Then it was digested in a Digestion flask adding 3 g of digestion mixture (K_2SO_4 : $FeSO_4$: $CuSO_4$, : $5H_2O$ = 10 : 1: 0.5) until it became colourless.

Distillation

The colourless mixture was cooled and poured in distillation flask. To it 10-15 ml water and 80 ml of 40% NaOH solution was added and

immediately connected with distillation set. Then the distillate upto 200 ml over 25 ml of 4% H_3BO_3 (blue colour) was collected.

Titration

Titration of the distillate was done with N/10 H_2SO_4 until brown colour just appeared, total nitrogen was then calculated from the following formula

$$N\% = NT \times S \times 14/10^3 \times 100/g$$

where, S = Strength of acid = N/10

g = Sample weight in gram

NT= Net titre value = x-y

where, x = Titre value,

y = Blank

3.8.B.3 Estimation of total Protein content of seeds produced (offspring seeds)

Protein was estimated by the colorimetric method of Lowry *et al.* (1951).

a) Reagents used

1) Borate buffer pH -10

2) 20% Trichloro acetic acid solution

3) 0.1 (N) NaOH solution.

4) Solution A- 2gm of Na-K-tartarate and 100 g of Na_2CO_3 were dissolved in 500 ml of 1(N) NaOH solution and dlituted with water to one litre.

5) Solution B - 2gm of Na-K tartarate and 1 g of $CuSO_4$. 5 H_2O were dissolved in 90 ml water and 10 ml 1 (N) NaOH was added to it.

6) Solution C - 1 volume of Folin - ciocalteu reagent was diluted with 15 volume of H_20.

b) Extraction

50 mg of the dried ground sample was homoginized with 5 ml borate buffer of pH 10. The homogenate was transferred into a 15 ml centrifuge tube. The process was repeated twice with 3 ml of borate buffer. The volume of the combined homogenate was made to 10 ml and then centrifuged for 2 minutes at 6000 rpm. The supernatant was carefully collected. Protein extracted by this buffer was total soluble protein. The supernatant was immediately used for protein estimation.

c) Estimation

1 ml solution of protein was taken in a test tube and treated with 0.9 ml of solution A. The tube was placed on a water-bath at 50°C for 10 minutes, cooled at room temperature and treated with 0.1 ml of solution B. Then the solution was left at room temperature, for exactly 10 minutes and 3 ml of solution C was forced rapidly to ensure good mixing. The tube was again heated at 50^0C for 10 minutess and cooled to room temperature. A blank was also run along with this estimation. Absorbance of this solution was read at 750 nm. Amount of protein was determined from a standard curve of protein solution.

d) Preparation of standard curve of protein

40, 60, 80, 100, 120. 140, and 160 µg/ml of Bovine serum albumin solutions were taken for preparation of standard curve of protein. Lowry method was applied for colour development.

3.9 Soil sample analysis

For chemical analysis of soil, soil sample was collected before final land preparation and composited following suitable method of sampling from a depth of about 6″, dried under shade, ground to pass through 80 mesh-sieve and then stored in clean polythene bags for analysis. Result of analysis was obtained from the Research laboratory, Dept. of Soil Science, B.C.K.V.

3.10 Statistical analysis

Observation-data of different parameters were subjected to different statistical analysis by analysis of variance method (Gomez & Gomez, 1984) and the significance of different source of variations were tested by Error Mean Square of Fisher and Snedecor's 'F' test of probability at 0.05% level. For determination of critical difference of significance at 5% level, Fisher's and Yates' tables were consulted. The standard Error of Mean (S.Em) and the value of critical difference (C.D.) were thus determined to compare the differences between means.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Data of different field and laboratory experiments recorded during the course of investigation are analysed and results are interpretated and presented as follows :

4.1 Experiment 1 : Studies on Germination and subsequent growth of seeds under varying levels of fertilizers and bacterial inoculation during two different seasons.

4.1.1. Germination percentage of seeds

Seed germination was effected significantly under different treatments under both October and January sowing conditions of the crop. However, treatment differences were more distinct in later season. Higher percentage of germination was recorded during October sowing of the crop compared to that during the month of January and an increasing trend of percentage of seed germination with decreasing rate of basal fertilization was noticed during both the seasons, although the values did not always differ critically. No visible effect of seed inoculation on germination was observed. Highest values of germination percentage were 64.56(T_6) and 70.72 (T_6) during January and October sowing and the corresponding lowest values were 56.08 (T_1) and 60.88 (T_1) against values of 60.00 and 63.51, respectively for the treatment controls (Table 4.1). Earlier worker like Wendhaus (1980) on contrary to the present finding, obtained higher germination of inoculated seeds. However, he also reported better germination with lower dose of basal nitrogen fertilization. [Table 4.1 & Fig. 4.1]

Table-4.1: Germination Percentage of seeds under different treatments during October and January sowing conditions

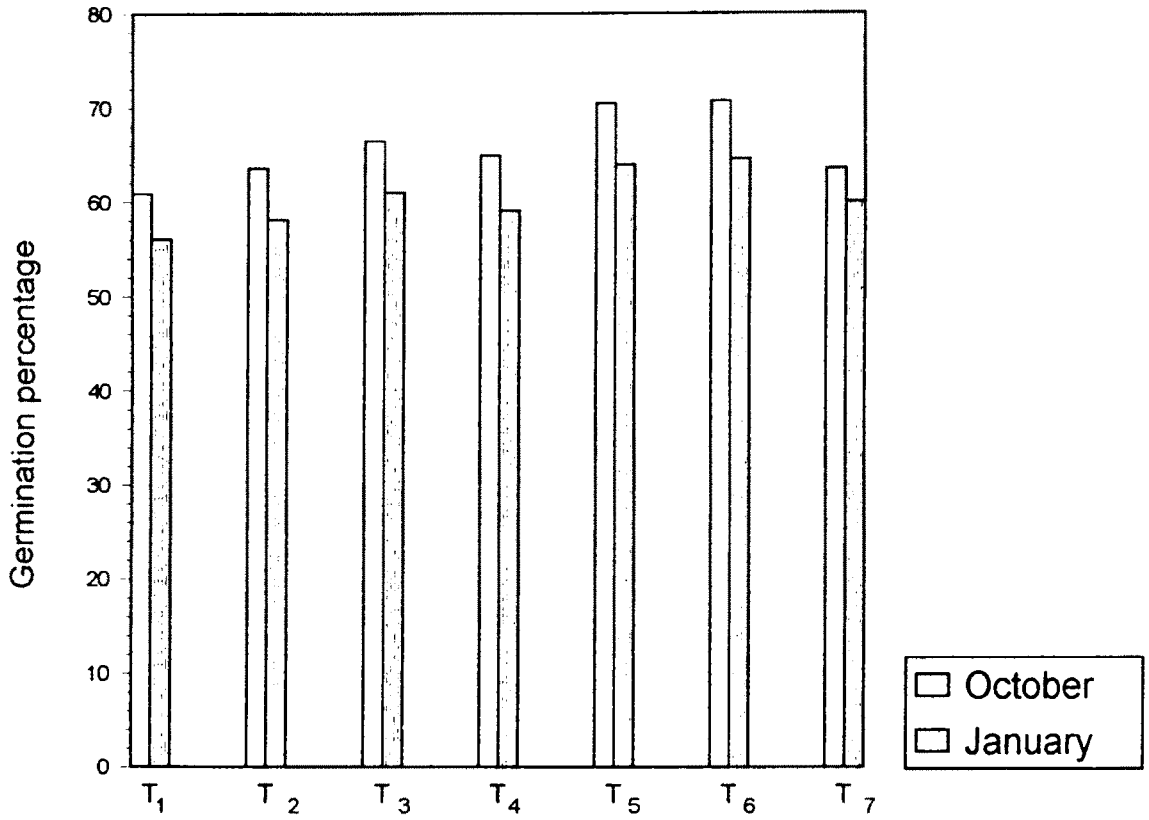
Treatments	October sowing	January sowing
T_1 (P_1R_0)	60.88 (76.30) *	56.08 (68.90)
T_2 (P_1R_1)	63.60 (80.20)	58.12 (72.10)
T_3 (P_2R_0)	66.46 (84.10)	61.00 (76.50)
T_4 (P_2R_1)	64.92 (82.00)	59.06 (73.60)
T_5 (P_3R_0)	70.50 (88.90)	63.93 (80.70)
T_6 (P_3R_1)	70.72 (89.10)	64.56 (81.50)
Control (P_0R_0)	63.51 (80.10)	60.00 (75.00)
S.Em (±)	0.816	0.75
C.D. at 5%	2.83	2.59

* Figures in parenthesis indicate actual values before arc-sine transformation.
P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation. R_1 = Seed inoculation with *Rhizobium* sp.

Table-4.2 : Emergence rate of seedlings under different treatments during October and January sowing conditions

Treatments	October sowing	January sowing
T_1 (P_1R_0)	8.24	7.20
T_2 (P_1R_1)	8.66	7.55
T_3 (P_2R_0)	8.68	7.75
T_4 (P_2R_1)	9.22	8.07
T_5 (P_3R_0)	9.47	8.15
T_6 (P_3R_1)	9.72	8.73
Control (P_0R_0)	9.03	8.28
S.Em (±)	0.069	0.08
C.D. at 5%	0.23	0.29

P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation. R_1 = Seed inoculation with *Rhizobium* sp.



$T_1 = P_1(N_{80}P_{40}K_{40}) \times R_0$, $T_2 = P_1(N_{80}P_{40}K_{40}) \times R_1$, $T_3 = P_2(N_{40}P_{20}K_{20}) \times R_0$,

$T_4 = P_2(N_{40}P_{20}K_{20}) \times R_1$, $T_5 = P_3(N_{20}P_{10}K_{10}) \times R_0$ $T_6 = P_3(N_{20}P_{10}K_{10}) \times R_1$

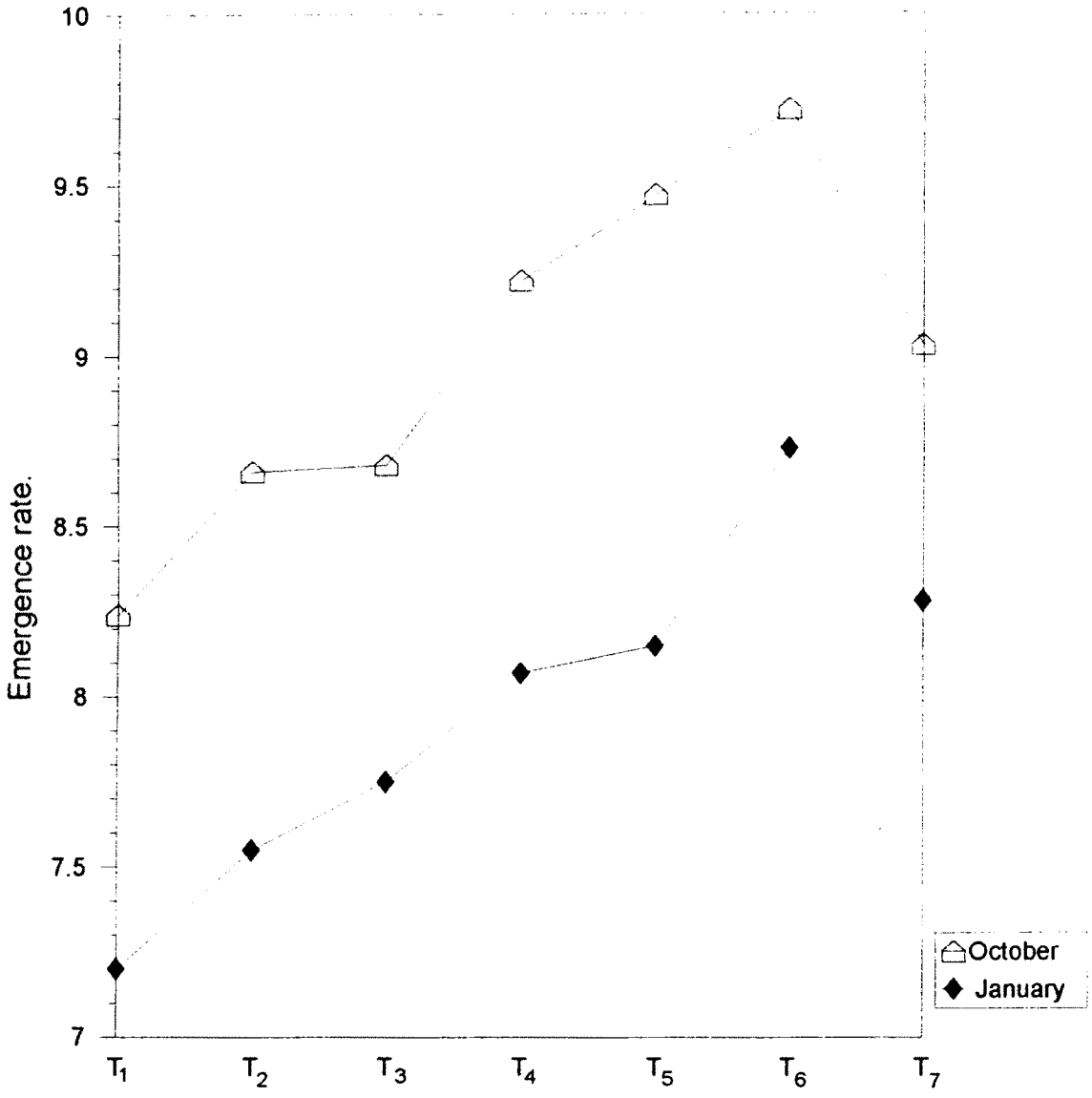
$T_7 = P_0(N_0P_0K_0) \times R_0$

P = Nutrient combination (N P K) in kg/ha.

R_1 = Seed inoculation with *Rhizobium sp.*

R_0 = No inoculation.

Fig. - 4.1 : Effect of different rates of NPK fertilization and rhizobial inoculation on seed germination 15 DAS under October and January sown conditions.



T_1 = $P_1(N_{80}P_{40}K_{40})$ x R_0, T_2 = $P_1(N_{80}P_{40}K_{40})$ x R_1, T_3 = $P_2(N_{40}P_{20}K_{20})$ x R_0,

T_4 = $P_2(N_{40}P_{20}K_{20})$ x R_1, T_5 = $P_3(N_{20}P_{10}K_{10})$ x R_0 T_6 = $P_3(N_{20}P_{10}K_{10})$ x R_1

T_7 = $P_0(N_0P_0K_0)$ x R_0

P = Nutrient combination (N P K) in kg/ha.

R_1 = Seed inoculation with *Rhizobium sp.*

R_0 = No inoculation.

Fig. - 4.2 : Effect of different rates of NPK fertilization and rhizobial seed inoculation on emergence rate of seedlings under October and January sown conditions.

4.1.2. Emergence rate of seedlings

Quicker emergence of seedlings were observed under October sown condition compared to that during January sowing. Treatment effects were significant and here also higher emergence rate was found associated with lower dose of basal fertilizer application and rhizobium inoculation of seeds during both the seasons of experiment. Highest emergence rates were 8.73 per day (T_6) and 9.72 per day (T_6) during January and October sowing when the lowest rates recorded were 7.20 per day (T_1) and 8.24 per day (T_1) respectively against corresponding control values of 8.28 and 9.03, respectively (Table 4.2 Fig 4.2).

4.1.3. Root length of seedlings

Treatment effects were significant with apparently progressive increase in root length with declining rate of basal fertilization with or without rhizobium inoculation. Highest mean root length was 4.25 cm (T_6) and 5.34 (T_6) respectively during January and October sowing condition and corresponding lowest values were 3.71 (T_1) and 4.52 cm(T_1). Control plots yielded mean root length of 3.79 cm. and 4.64 cm respectively under January and October sowing condition (Table 4.3 & Fig 4.3).

4.1.4. Shoot length of seedlings

Significant treatment difference was observed with respect to average length of shoots during both the seasons of experiment. Here also higher length of shoot was found associated with lower dose of basal fertilization though the difference in mean height of shoot under different treatments did not always differ critically between them. Observed data

Table-4.3 : Root length (cm) of seedlings under different treatments during October and January sowing conditions

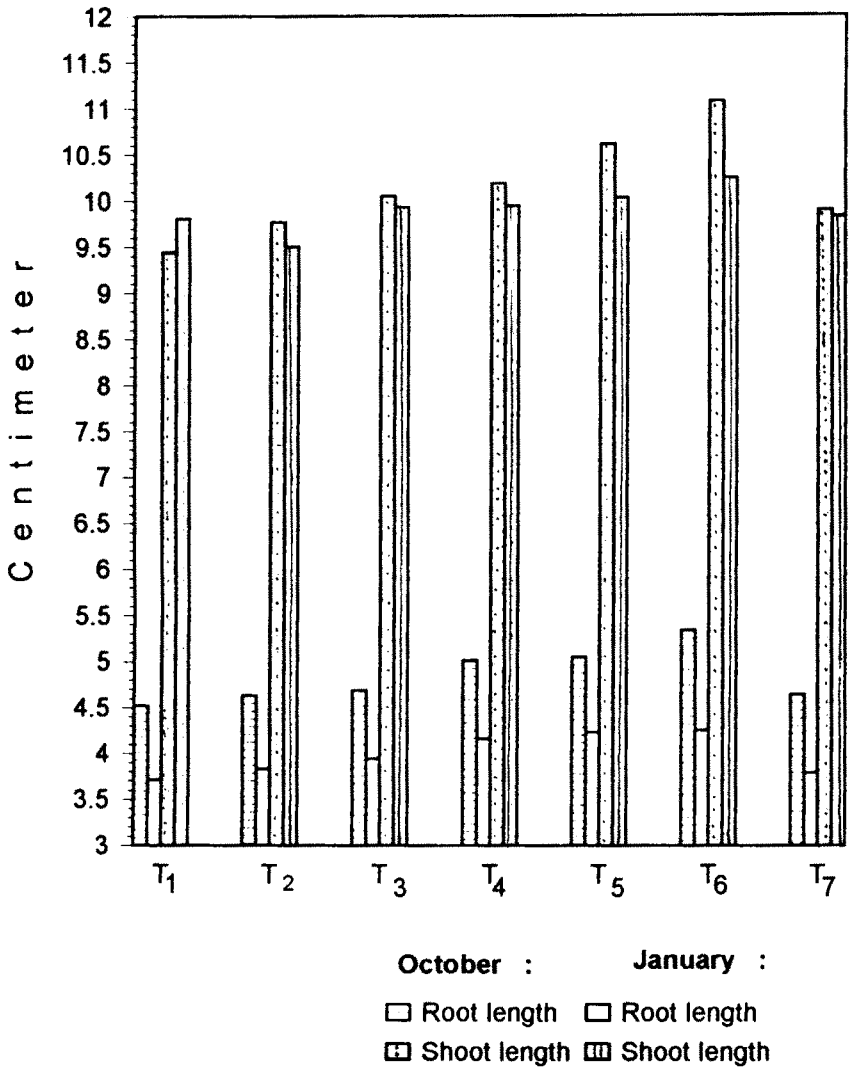
Treatments	October sowing	January sowing
T_1 (P_1R_0)	4.52	3.71
T_2 (P_1R_1)	4.63	3.83
T_3 (P_2R_0)	4.69	3.94
T_4 (P_2R_1)	5.01	4.16
T_5 (P_3R_0)	5.05	4.23
T_6 (P_3R_1)	5.34	4.25
Control (P_0R_0)	4.64	3.79
S.Em (±)	0.107	0.086
C.D. at 5%	0.37	0.299

P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation, R_1 = Seed inoculation with *Rhizobium* sp.

Table-4.4 : Shoot length (cm) of seedlings under different treatments during October and January sowing conditions

Treatments	October sowing	January sowing
T_1 (P_1R_0)	9.44	9.80
T_2 (P_1R_1)	9.77	9.50
T_3 (P_2R_0)	10.05	9.93
T_4 (P_2R_1)	10.18	9.94
T_5 (P_3R_0)	10.61	10.03
T_6 (P_3R_1)	11.08	10.24
Control (P_0R_0)	9.89	9.82
S.Em (±)	0.17	0.12
C.D. at 5%	0.56	0.40

P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation, R_1 = Seed inoculation with *Rhizobium* sp.



$T_1 = P_1(N_{80}P_{40}K_{40}) \times R_0$, $T_2 = P_1(N_{80}P_{40}K_{40}) \times R_1$, $T_3 = P_2(N_{40}P_{20}K_{20}) \times R_0$,

$T_4 = P_2(N_{40}P_{20}K_{20}) \times R_1$, $T_5 = P_3(N_{20}P_{10}K_{10}) \times R_0$ $T_6 = P_3(N_{20}P_{10}K_{10}) \times R_1$

$T_7 = P_0(N_0P_0K_0) \times R_0$

P = Nutrient combination (N P K) in kg/ha,

R_1 = Seed inoculation with *Rhizobium sp.*

R_0 = No inoculation.

Fig. - 4.3 : Effect of different rates of NPK fertilization and rhizobial seed inoculation on root length and shoot length of seedlings 15 DAS under October and January sown condition.

indicated slight superiority under October sowing in most of the treatments in comparison to those during January sowing for the character. Highest mean shoot length was 10.24(T_6) and 11.08 cm (T_6) under January and October sowing respectively and lowest values during the corresponding periods were 9.5 cm (T_2) and 9.44 cm (T_1) which were lower than the respective control values of 9.82 cm and 9.89 cm . Effect of seed inoculation, if any, could not be assessed distinctly as no interaction effect was studied and only the combined effects were taken into account. Lower nitrogen fertilization for early increase in plant height was reported earlier by Westermann *et al.* (1981) [Table 4.4 & Fig 4.3].

4.1.5. Fresh weight of seedlings

Fresh weight of seedlings was also found to be influenced significantly by different treatments during both October and January sowing of the crop. Greater values of fresh weights (with or without rhizobium inoculation) were observed with relatively higher dose of basal fertilization. Highest mean values for fresh weight were 3.35 g (T_2) and 3.87 (T_1) during January and October sowing when the corresponding lowest values were 2.50 g(T_6) and 2.61 g (T_5). Percentage increase of fresh weight over control was found to range between 6.8 to 43.8% during January and 5.7 to 57% during October sowing of the crop under different treatments provided (Table 4.5 & Fig. 4.4).

4.1.6. Dry weight of seedlings

Significant influence of different treatments over seedling dry weight was observed under both October and January sowing condition of the crop. Seedlings raised during the month of October produced higher dry

Table-4.5 : Fresh weight (g/plant) of seedlings under different treatments during October and January sowing conditions

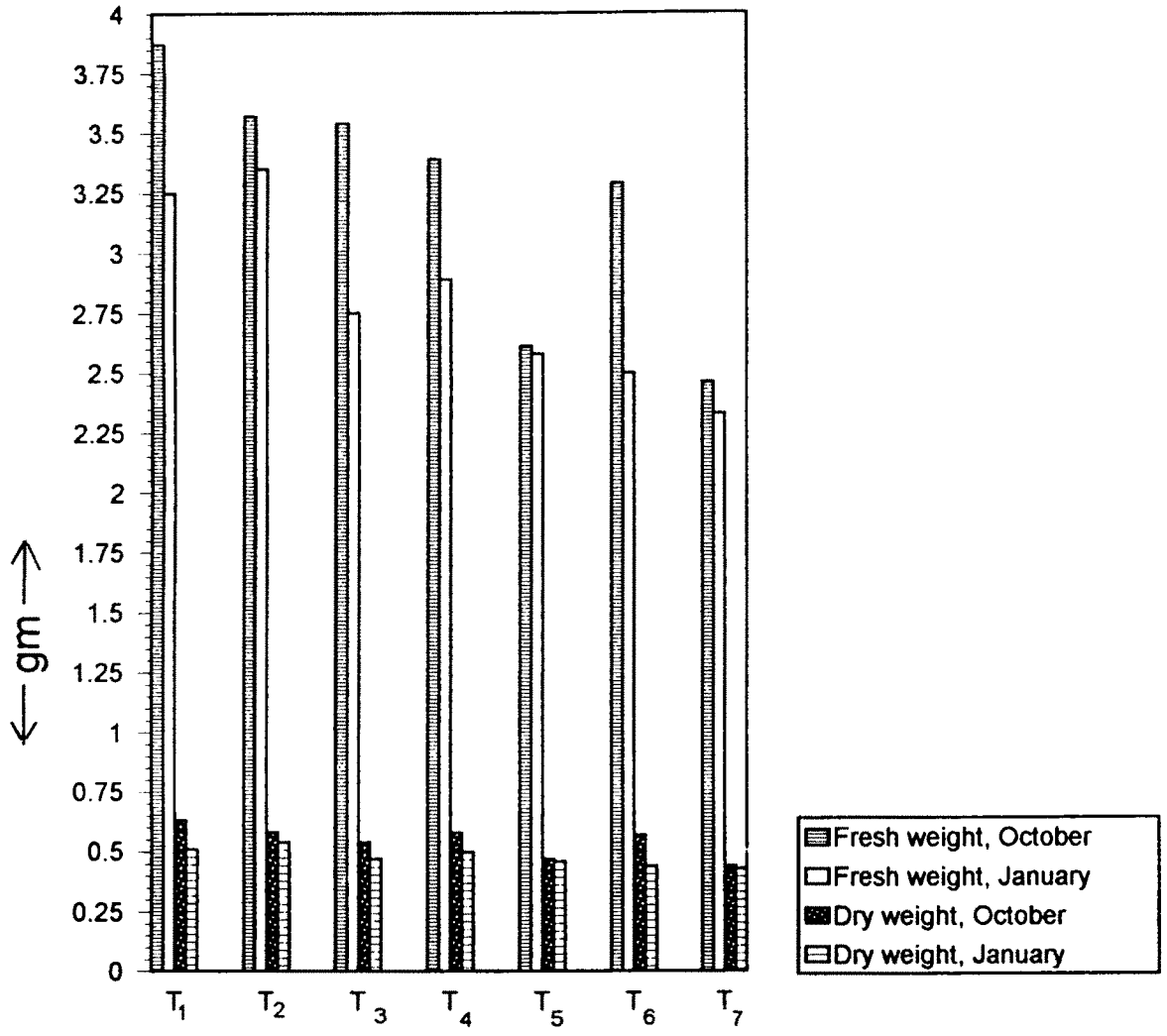
Treatments	October sowing	January sowing
T_1 (P_1R_0)	3.87	3.25
T_2 (P_1R_1)	3.57	3.35
T_3 (P_2R_0)	3.54	2.75
T_4 (P_2R_1)	3.39	2.89
T_5 (P_3R_0)	2.61	2.58
T_6 (P_3R_1)	3.29	2.50
Control (P_0R_0)	2.46	2.33
S.Em (±)	0.26	0.044
C.D. at 5%	0.84	0.152

P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation, R_1 = Seed inoculation with *Rhizobium* sp.

Table-4.6: Dry weight (g/plant) of seedlings under different treatments during October and January sowing conditions

Treatments	October sowing	January sowing
T_1 (P_1R_0)	0.63	0.51
T_2 (P_1R_1)	0.58	0.54
T_3 (P_2R_0)	0.54	0.47
T_4 (P_2R_1)	0.58	0.50
T_5 (P_3R_0)	0.47	0.46
T_6 (P_3R_1)	0.57	0.44
Control (P_0R_0)	0.44	0.43
S.Em (±)	0.032	0.009
C.D. at 5%	0.102	0.03

P_0 = No fertilization
P_1 = basal fertilization with N.P.K. @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with N.P.K. @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with N.P.K. @ 20 : 10 : 10 kg per ha.
R_0 = No inoculation, R_1 = Seed inoculation with *Rhizobium* sp.



$T_1 = P_1(N_{80}P_{40}K_{40}) \times R_0$, $T_2 = P_1(N_{80}P_{40}K_{40}) \times R_1$, $T_3 = P_2(N_{40}P_{20}K_{20}) \times R_0$,

$T_4 = P_2(N_{40}P_{20}K_{20}) \times R_1$, $T_5 = P_3(N_{20}P_{10}K_{10}) \times R_0$ $T_6 = P_3(N_{20}P_{10}K_{10}) \times R_1$

$T_7 = P_0(N_0P_0K_0) \times R_0$

P = Nutrient combination (N P K) in kg/ha,

R_1 = Seed inoculation with *Rhizobium sp.*

R_0 = No inoculation.

Fig. - 4.4 : Effect of different rates of NPK fertilization and rhizobial seed inoculation on fresh and dry weight (gm) of seedlings 15 DAS under October and January sown conditions.

matter compared to those raised during January under different treatments. Basal application with heavier dose of N. P. K. (@ 80 : 40 : 40 kg per ha) (with or without rhizobial inoculation) yielded higher seedling dry weights compared to those obtained with relatively lower dose of applied fertilizers. Maximum accumulation of dry matter was observed under T_2 (0.54 g) and T_1 (0.63g) under January and October sowing of the crop which were 25.5% and 43.18% over control during the respective seasons (Table 4.6 & Fig 4.4). Increased dry weight with higher fertilization was reported in French bean earlier by Srinivas and Naik (1988). Chandra *et al.* (1987) reported higher dry weight with rhizobium inoculation in lentil.

4.1.7. Chlorophyll content of cotyledonary leaf of seedlings

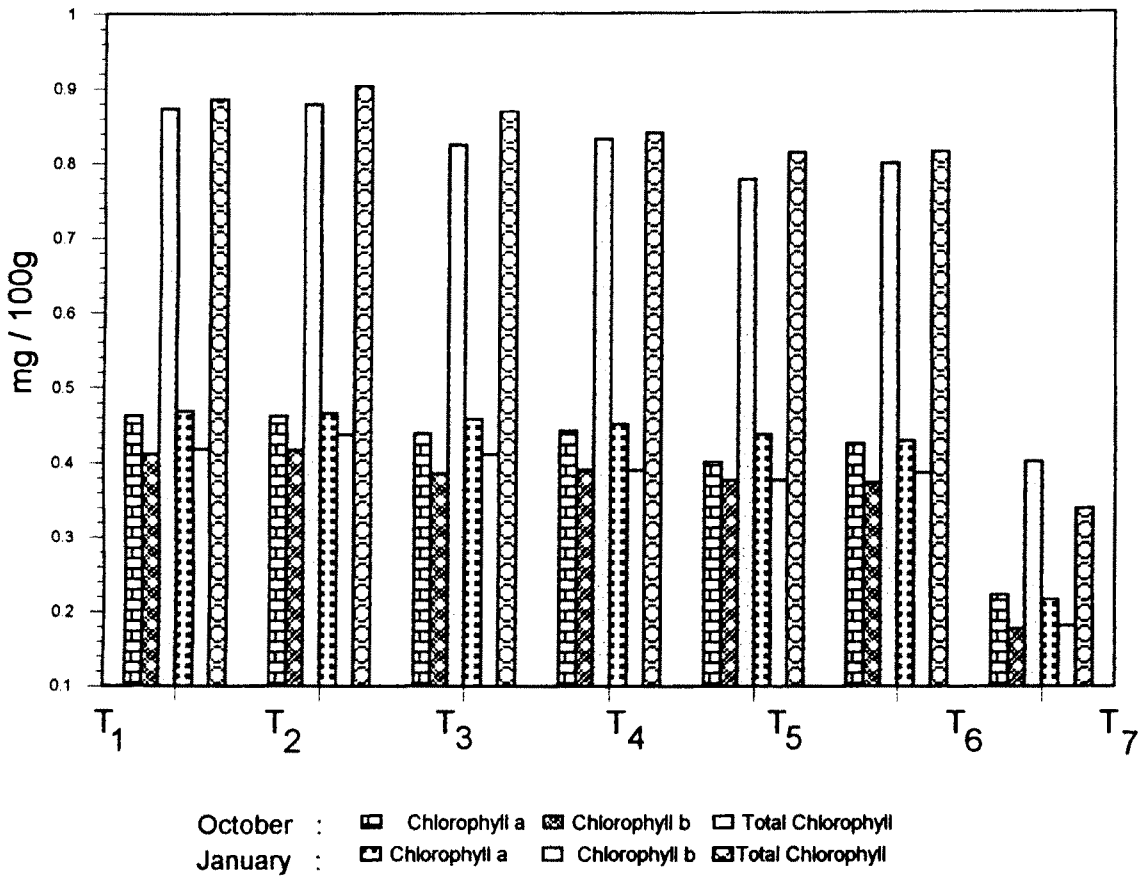
The data exhibited significant treatment difference for chlorophyll a, chlorophyll b and also for total chlorophyll content of cotyledonary leaf of the seedlings during both the seasons (October and January) of experiment. Highest values for chlorophyll a, chlorophyll b and total chlorophyll under January sowing condition were 0.468, 0.437 and 0.903 and those under October sowing were 0.462, 0.417 and 0.879. Respective control values stood on 0.218, 0.184 and 0.402 during January and 0.221, 0.178 and 0.339 during October sowing. An increasing trend towards higher chlorophyll content of cotyledonary leaf of seedling (with or without rhizobial inoculation) could be noticed with increasing dose of basal fertilization though values did not differ significantly (Table 4.7 & Fig. 4.5). Increased chlorophyll content with fertilization at higher dose was reported earlier by Srinivas and Naik (1990) in French bean which confirms the present finding.

Table - 4.7 : Chlorophyll content of cotyledonary leaf (mg/100g) of seedlings under different treatments during October and January sowing conditions

Treatments	Chlorophyll a		Chlorophyll b		Total chlorophyll	
	October sowing	January sowing	October sowing	January sowing	October sowing	January sowing
T_1 (P_1R_0)	0.462	0.468	0.411	0.418	0.873	0.886
T_2 (P_1R_1)	0.462	0.466	0.417	0.437	0.879	0.903
T_3 (P_2R_0)	0.439	0.458	0.385	0.411	0.824	0.869
T_4 (P_2R_1)	0.442	0.451	0.390	0.389	0.832	0.840
T_5 (P_3R_0	0.401	0.437	0.376	0.376	0.777	0.813
T_6 (P_3R_1)	0.425	0.428	0.373	0.386	0.798	0.814
Control (P_0R_0)	0.221	0.218	0.178	0.184	0.399	0.402
S.Em (±)	0.018	0.020	0.017	0.019	0.035	0.027
C.D. at 5%	0.062	0.069	0.058	0.066	0.121	0.093

P_0 = No fertilization
P_1 = basal fertilization with NPK @ 80 : 40 : 40 kg per ha.
P_2 = basal fertilization with NPK @ 40 : 20 : 20 kg per ha.
P_3 = basal fertilization with NPK @ 20 : 10 : 10 kg per ha.

R_0 = No inoculation
R_1 = Seed inoculation with *Rhizobium sp.*



$T_1 = P_1(N_{80}P_{40}K_{40}) \times R_0$, $T_2 = P_1(N_{80}P_{40}K_{40}) \times R_1$, $T_3 = P_2(N_{40}P_{20}K_{20}) \times R_0$,

$T_4 = P_2(N_{40}P_{20}K_{20}) \times R_1$, $T_5 = P_3(N_{20}P_{10}K_{10}) \times R_0$ $T_6 = P_3(N_{20}P_{10}K_{10}) \times R_1$

$T_7 = P_0(N_0P_0K_0) \times R_0$

P = Nutrient combination (N P K) in kg/ha,

R_1 = Seed inoculation with *Rhizobium sp.*

R_0 = No inoculation.

Fig. 4.5 : Effect of different rate of NPK fertilization and rhizobial seed inoculation on chlorophyll content (chlorophyll a, chlorophyll b and total chlorophyll) of cotyledonary leaf of seedling under October and January sown condition

4.2 Experiment 2 : Studies on growth and reproduction of French bean under different treatment of growth regulators and time of nitrogen applications with or without bacterial inoculation during two different seasons.

4.2.1. Height of the plant

Significant influence over final height of the plant was detected when sprayed with different growth regulators at pre-flowering stage. Varying time of nitrogen fertilization also influenced plant height significantly under both October and January sowing condition of the crop. However, seed inoculation with rhizobium strain failed to exert any significant influence on plant height during both the seasons of experiment. Significant interaction effects of some treatment factors could also be identified.

Among the different growth regulators tried though GA_3 (100 ppm) most effectively contributed to increased plant height (50.71% and 61.75% over control respectively, during the two seasons), the limiting factor however, was that the plants became lanky in many occasions and fell on the ground. On the contrary, significant reduction in height (15.89% and 8.8% below control) was obtained under MH (500 ppm) spray during October and January sowing of the crop respectively. BNOA (25 ppm) or 2,4-D (2 ppm) exhibited no superiority over control and their effects lay statistically at per with one another. Split application of nitrogen fertilizer with three split doses (one basal + two top dressing) proved more effective in influencing plant height compared to single or double dose of nitrogen fertilization.

Table - 4.8 a : Height of the plant (cm) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean (B)
B_1	34.40	35.30	53.26	34.06	29.50	35.60	34.45	54.10	33.87	30.15	37.47
B_2	36.90	38.33	55.16	37.13	32.00	36.19	37.17	56.22	38.06	33.46	40.16
B_3	38.20	37.33	57.45	38.75	33.35	39.60	38.00	56.30	39.80	32.12	41.09

Mean (A) $\overline{A_0} = 36.81$ $\overline{A_1} = 36.76$ $\overline{A_2} = 55.48$ $\overline{A_3} = 36.94$ $\overline{A_4} = 31.76$

Mean (C) $\overline{C_0} = 39.40$ $\overline{C_1} = 39.67$

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.58	0.16	0.14	0.36	0.18	0.22	0.50
C.D. at 5%	1.34	0.33	NS	0.725	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3 (2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.8 b : Height of the plant (cm) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	28.30	28.10	42.50	28.43	26.33	29.15	27.53	41.22	27.60	27.50	30.66
B_2	29.36	29.33	47.00	29.48	26.49	28.00	31.30	46.27	30.33	25.58	32.31
B_3	30.08	30.89	51.50	30.78	27.63	28.63	31.63	52.17	31.30	26.03	34.09
Mean (A)		$\overline{A_0}$ = 28.92		$\overline{A_1}$ =29.80			$\overline{A_2}$ = 46.78		$\overline{A_3}$ = 29.65		$\overline{A_4}$ = 26.59
Mean (C)		$\overline{C_0}$ = 32.41							$\overline{C_1}$ = 32.28		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.92	0.15	0.13	0.33	0.19	0.26	0.47
C.D. at 5%	2.12	0.303	NS	0.66	NS	NS	0.95

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS,
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Increased plant height with rhizobium inoculation in Lima bean was reported earlier by Saono *et al.* (1976) which stands in contrary to the present outcome. However, Chandra *et al.* (1987) in French bean obtained insignificant effect of rhizobium inoculation on plant height. Significant increment in height of non-legume Marigold and China aster as a result of GA_3 spray was reported earlier by Shyamal *et al.* (1990). Effectiveness of MH in suppression of plant height was also reported by him. Increased plant height with GA_3 application might be due to increase in cell division in apical meristem and elongation of individual cells. On the contrary, MH induced depression in height might have resulted from suppression of cell division in apical meristem (Table 4.8a & 4.8b).

4.2.2. Number of primary branches

Spraying with different growth regulators and varied time of nitrogen fertilization were found efficacious in modifying number of primary branches significantly. Rhizobial seed inoculation on the other hand, had no significant influence over number of branches and proved ineffective. Some significant interaction effects of the treatment factors were observed during both the seasons. Mean number of primary branches was highest under foliar spray of the plant with MH 500 ppm (Mean 27.96 and 21.59) followed by GA_3 100 ppm (Mean 19.01 and 14.15), BNOA 25 ppm (Mean 15.11 and 11.46), 2,4-D 2 ppm (Mean 14.82 and 10.15) and control (Mean 13.97 and 9.39) under both October and January sowing conditions of the crop, respectively. Three split applications (one basal + two top dressings) of nitrogen fertilizers compared to one or two could more effectively increase the number of primary branches (Table 4.9 a & 4.9 b).

P-2) A fully grown plant of French bean in bearing.

Table - 4.9 a : Number of primary branches per plant under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	11.45	13.00	16.20	1328	26.10	10.29	13.95	16.78	14.16	25.23	16.04
B_2	14.70	14.30	19.83	14.51	29.05	15.62	14.91	20.39	14.61	28.12	18.60
B_3	15.96	16.65	19.90	15.90	30.40	15.78	17.86	20.97	16.50	28.90	19.88
Mean (A)	$\overline{A_0}$ = 13.97			$\overline{A_1}$ =15.11		$\overline{A_2}$ = 19.01			$\overline{A_3}$ = 14.82		$\overline{A_4}$ =27.96
Mean (C)	$\overline{C_0}$ = 18.08								$\overline{C_1}$ = 18.27		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.413	0.284	0.148	0.401	0.331	0.408	0.898
C.D. at 5%	0.95	0.574	NS	NS	NS	0.82	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_2 (2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.9 b : Number of primary branches per plant under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	7.55	9.90	12.0	9.00	19.42	6.29	10.03	11.51	8.77	20.08	11.65
B_2	9.80	12.40	15.00	10.20	21.36	10.99	12.28	15.06	9.24	20.89	12.62
B_3	11.50	12.25	15.35	11.58	24.53	10.23	12.93	16.00	12.10	23.30	14.97

Mean (A) $\overline{A_0}$ =9.39 $\overline{A_1}$ =11.46 $\overline{A_2}$ = 14.15 $\overline{A_3}$ = 10.15 $\overline{A_4}$ =21.59

Mean (C) $\overline{C_0}$ = 13.46 $\overline{C_1}$ = 13.25

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.390	0.246	0.240	0.550	0.053	0.348	0.770
C.D. at 5%	0.712	0.497	NS	NS	0.118	0.703	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3 (2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

P-3) Effect of different growth regulators on branching habit of French bean.

Earlier worker like Chandra *et al.* (1987) reported insignificant effect of rhizobium inoculation over number of branches per plant which lies in confirmation with the present finding. However, Baird *et al.* (1983) reported positive effect of seed inoculation with *Rhizobium sp.* on number of lateral branches in *Phaseolus vulgaris*. Increased number of primary branches with MH treatments may be explained in the light of the theory of apical dominance and due to suppression in height.

4.2.3. Dry matter accumulation

Dry matter accumulation by plant was found to be significantly influenced by all three treatment factors and their all possible interactions effects during both the seasons of experiment. Plants could be able to produce more dry matter when sown during the month of October than during January sowing of the crop. All the four growth regulators tried contributed towards increased dry matter production compared to control. Out of them contribution of GA_3 (100 ppm) and MH 500 ppm were much higher than those of BNOA (25 ppm) or 2,4-D (2 ppm). Highest mean dry matter, obtained with application of GA_3 (100 ppm) was found 48.55% and 45.63% over control during October and January sowing of the crop respectively. Split fertilization of nitrogenous fertilizer also yielded significantly higher dry matter compared to single basal application during both the seasons of experiment (Table 4.10 a , 4.10 b & Fig 4.6).

Increase in dry matter accumulation with higher nitrogen fertilization was obtained earlier in French bean by Srinivas and Naik (1988).

Table - 4.10 a : Dry matter accumulation (g/plant) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	21.21	22.56	33.25	22.83	28.36	23.0	23.28	35.76	23.96	29.31	26.35
B_2	22.80	23.74	34.36	23.80	29.59	24.43	24.42	36.62	24.64	31.09	27.54
B_3	25.08	24.93	34.91	25.27	30.56	26.34	25.74	37.36	26.59	31.98	28.87

Mean (A) $\overline{A_0}$ =23.81 $\overline{A_1}$ =24.11 $\overline{A_2}$ = 35.37 $\overline{A_3}$ = 24.51 $\overline{A_4}$ =30.14

Mean (C) $\overline{C_0}$ = 26.88 $\overline{C_1}$ = 28.30

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.098	0.049	0.053	0.19	0.132	0.144	0.164
C.D. at 5%	0.226	0.099	0.118	0.291	0.294	0.383	0.331

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.10 b : Dry matter accumulation (g/plant) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	18.25	20.46	27.02	19.26	24.42	18.56	21.12	28.14	20.19	24.49	22.19
B_2	20.13	20.86	28.0	19.85	25.05	19.68	21.49	28.76	20.07	26.39	23.02
B_3	19.95	21.58	28.87	20.27	25.87	20.22	21.97	29.29	21.52	26.79	23.63

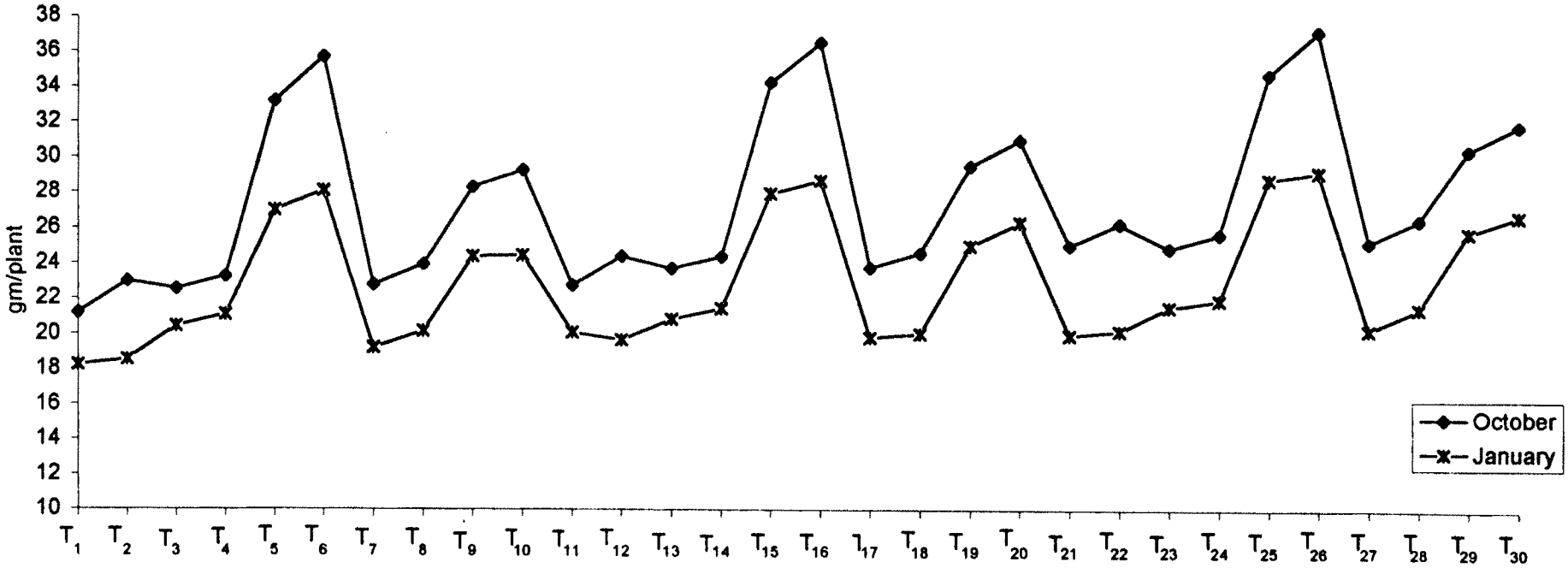
Mean (A) $\overline{A_0}$ =19.46 $\overline{A_1}$ =21.24 $\overline{A_2}$ = 28.34 $\overline{A_3}$ = 20.19 $\overline{A_4}$ =25.50

Mean (C) $\overline{C_0}$ = 22.65 $\overline{C_1}$ = 23.24

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.103	0.062	0.07	0.14	0.156	0.08	0.198
C.D. at 5%	0.238	0.127	0.155	0.283	0.347	0.179	0.400

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Fig - 4.6 : Effect of different growth regulators spray, time of nitrogen fertilization and rhizobial seed inoculation on dry matter accumulation by plants (before flowering) under October and January sown conditions



$T_1=B_1C_0A_0$,	$T_2=B_1C_1A_0$,	$T_3=B_1C_0A_1$,	$T_4=B_1C_1A_1$,
$T_5=B_1C_0A_2$,	$T_6=B_1C_1A_2$,	$T_7=B_1C_0A_3$,	$T_8=B_1C_1A_3$,
$T_9=B_1C_0A_4$,	$T_{10}=B_1C_1A_4$,	$T_{11}=B_2C_0A_0$,	$T_{12}=B_2C_1A_0$,
$T_{13}=B_2C_0A_1$,	$T_{14}=B_2C_1A_1$,	$T_{15}=B_2C_0A_2$,	$T_{16}=B_2C_1A_2$,
$T_{17}=B_2C_0A_3$,	$T_{18}=B_2C_1A_3$,	$T_{19}=B_2C_0A_4$,	$T_{20}=B_2C_1A_4$,
$T_{21}=B_3C_0A_0$,	$T_{22}=B_3C_1A_0$,	$T_{23}=B_3C_0A_1$,	$T_{24}=B_3C_1A_1$,
$T_{25}=B_3C_0A_2$,	$T_{26}=B_3C_1A_2$,	$T_{27}=B_3C_0A_3$,	$T_{28}=B_3C_1A_3$,
$T_{29}=B_3C_0A_4$,	$T_{30}=B_3C_1A_4$		

A - Growth regulator spray

A_0 = No growth regulator spray
A_1 = Spray with BNOA 25 ppm
A_2 = Spray with GA_3 100 ppm
A_3 = Spray with 2,4 -D 2 ppm
A_4 = Spray with MH 500 ppm

B- Time of Nitrogen fertilization

B_1= Basal application of full dose(80 kg /ha)
B_2 = 50 % basal + 50% top dressing 20DAS
B_3 = 50 % basal + 25% top dressing 20DAS+ 25 % top dressing 30 DAS

C - Inoculation

C_0 = No inoculation, C_1= Seed inoculation with *Rhizobium sp.*

4.2.4. Flower initiation period

Plants flowered earlier when sown during the month of January than during October sowing of the crop. While GA_3 100 ppm enhanced flower initiation period, MH 500 ppm delayed it with respect to control during both the seasons of experiment. BNOA 25 ppm and 2, 4-D 2 ppm failed to exert any significant deviation compared to control.

Plants resulting from seed inoculation with rhizobium culture also did not show any marked difference with uninoculated control with respect to the required time span for first flowering. Effect of nitrogen fertilization as single basal application was found better (early flowering) and significantly higher over single or double top dressing of the crop under both October and January sowing condition of the crop. Interaction effects of some of the treatment factors could also be detected (Table 4.11 a & 4.11 b).

Early flowering with increase in temperature was reported earlier in Soybean by Pookpakdi (1979). Suppression in flowering as a result of MH spray was obtained by Shyamal *et al.*, (1990) in China aster. Variation in flowering period might have resulted from variation in atmospheric temperature and photoperiodic exposure or variation in the strength in endogenous growth substances and C/N ratio.

4.2.5. Position of the first flowering node

Position of the node giving emergence of the first flower remained almost unaltered and no one of the treatment factors eg. growth regulators, seed inoculation with rhizobial strain or time of nitrogen fertilization could exert any significant influence in modifying this position during both the seasons of experiment. Observed data under all the treatments fluctuated

Table - 4.11 a : Flower initiation period (DAS) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	39.63	37.71	35.23	38.87	42.08	39.97	38.02	35.27	38.04	42.27	38.61
B_2	40.04	41.02	38.08	40.83	46.03	40.31	41.42	37.94	41.16	45.62	41.24
B_3	40.76	42.37	39.33	42.12	47.10	40.62	42.39	39.93	41.79	47.26	42.36

Mean (A)	$\overline{A_0}$ =40.22	$\overline{A_1}$ =40.48	$\overline{A_2}$ = 37.63	$\overline{A_3}$ = 40.30	$\overline{A_4}$ =45.06
Mean (C)	$\overline{C_0}$ = 40.68			$\overline{C_1}$ = 40.80	

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.189	0.084	0.076	0.179	0.132	0.141	0.231
C.D. at 5%	0.436	0.169	NS	0.284	0.294	0.361	0.467

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.11 b : Flower initiation period (DAS) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	34.82	35.18	32.04	34.52	39.28	35.06	35.53	32.63	34.70	38.99	35.34
B_2	36.57	37.29	34.75	37.90	42.10	36.42	37.13	34.53	37.48	41.81	37.40
B_3	36.70	37.46	35.07	38.19	42.23	36.93	38.20	35.33	38.08	42.63	38.18

Mean (A) $\overline{A_0}$ =36.08 $\overline{A_1}$ =36.80 $\overline{A_2}$ = 34.06 $\overline{A_3}$ = 36.81 $\overline{A_4}$ =41.17

Mean (C) $\overline{C_0}$ = 36.94 $\overline{C_1}$ = 37.03

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.323	0.121	0.107	0.171	0.241	0.271	0.384
C.D. at 5%	0.745	0.245	NS	NS	NS	0.548	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3 (2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*
	N. S. - Not significant.

Table - 4.12 a : Position of the first flowering node (from the base of the plant) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	3.37	3.30	3.0	3.17	3.27	3.23	3.17	3.20	3.20	3.10	3.20
B_2	3.27	3.17	3.23	3.17	3.27	3.17	3.23	3.10	3.53	3.27	3.24
B_3	3.28	3.20	3.30	3.67	3.20	3.23	3.27	3.0	3.27	3.27	3.27
Mean (A)		$\overline{A_0}$ =3.26		$\overline{A_1}$ =3.22		$\overline{A_2}$ = 3.13		$\overline{A_3}$ = 3.33		$\overline{A_4}$ =3.23	
Mean (C)		$\overline{C_0}$ = 3.26						$\overline{C_1}$ =3.21			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.07	0.04	0.03	0.08	0.08	0.05	0.11
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS)
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.12 b : Position of the first flowering node (from the base of the plant) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	3.17	3.20	3.13	3.23	3.26	3.20	3.10	3.13	3.30	3.18	3.18
B_2	3.20	3.20	3.37	3.36	3.16	3.37	3.14	3.10	3.20	3.00	3.21
B_3	3.43	3.27	3.26	3.30	3.30	3.43	3.13	3.23	3.20	3.23	3.28

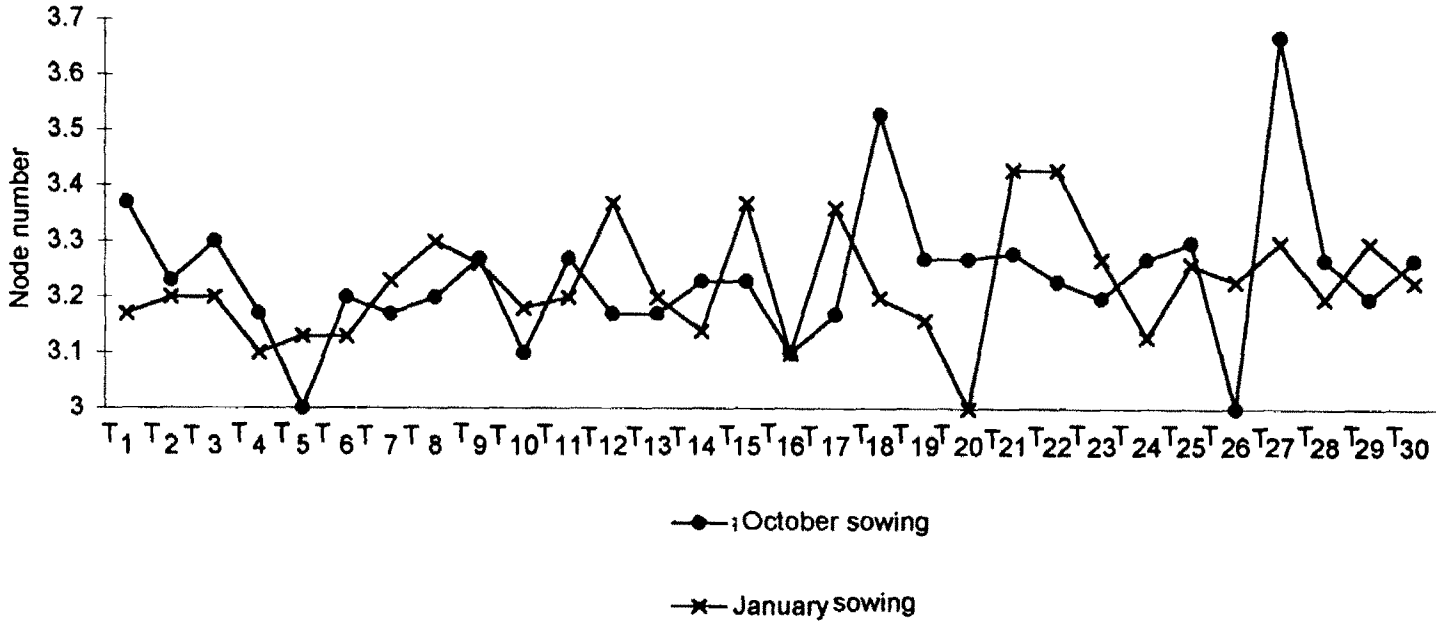
Mean (A) $\overline{A_0}$ =3.30 $\overline{A_1}$ =3.17 $\overline{A_2}$ = 3.20 $\overline{A_3}$ =3.27 $\overline{A_4}$ =3.19

Mean (C) $\overline{C_0}$ = 3.26 $\overline{C_1}$ =3.20

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.07	0.04	0.03	0.09	0.06	0.05	0.12
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Fig - 4.7: Effect of different growth regulators spray, time of nitrogen fertilization and rhizobial seed inoculation on node number (from the base of the plant) to bear first flower under October and January sown conditions



$T_1=B_1C_0A_0$,	$T_2=B_1C_1A_0$,	$T_3=B_1C_0A_1$,	$T_4=B_1C_1A_1$,
$T_5=B_1C_0A_2$,	$T_6=B_1C_1A_2$,	$T_7=B_1C_0A_3$,	$T_8=B_1C_1A_3$,
$T_9=B_1C_0A_4$,	$T_{10}=B_1C_1A_4$,	$T_{11}=B_2C_0A_0$,	$T_{12}=B_2C_1A_0$,
$T_{13}=B_2C_0A_1$,	$T_{14}=B_2C_1A_1$,	$T_{15}=B_2C_0A_2$,	$T_{16}=B_2C_1A_2$,
$T_{17}=B_2C_0A_3$,	$T_{18}=B_2C_1A_3$,	$T_{19}=B_2C_0A_4$,	$T_{20}=B_2C_1A_4$,
$T_{21}=B_3C_0A_0$,	$T_{22}=B_3C_1A_0$,	$T_{23}=B_3C_0A_1$,	$T_{24}=B_3C_1A_1$,
$T_{25}=B_3C_0A_2$,	$T_{26}=B_3C_1A_2$,	$T_{27}=B_3C_0A_3$,	$T_{28}=B_3C_1A_3$,
$T_{29}=B_3C_0A_4$,	$T_{30}=B_3C_1A_4$.		

A - Growth regulator spray

A_0 = No growth regulator spray
A_1 = Spray with BNOA 25 ppm
A_2 = Spray with GA_3 100 ppm
A_3 = Spray with 2,4 -D 2 ppm
A_4 = Spray with MH 500 ppm

B- Time of Nitrogen fertilization

B_1= Basal application of full dose(80 kg /ha)
B_2= 50 % basal + 50% top dressing 20DAS
B_3= 50 % basal + 25% top dressing 20DAS+ 25 % top dressing 30 DAS

C - Inoculation

C_0 = No inoculation, C_1= Seed inoculation with *Rhizobium sp.*

between 3 to 4 giving an indication of almost constant a position of the node (3rd and 4th from the base of the plant) to bear the first flower under varying stresses. Hence it may be conceived that position of the node to produce the first flower in French bean might be a varietal character that depends on the genotype of the plant (Table 4.12 a , 4.12b & Fig. 4.7).

4.2.6. Pod number per plant

Total number of edible pods per plant upto second picking was found to be influenced significantly by all three treatment factors (growth regulators spray, rhizobial seed inoculation and time of application of nitrogen fertilizers) besides some significant interaction effects of treatments during both October and January sowing conditions of the crop. No one of the growth regulators except BNOA 25 ppm could significantly increase mean pod number per plant under October sowing condition of the crop, while in the January sown crop BNOA (25 ppm), GA_3 (100 ppm) and 2, 4-D (2 ppm) exerted significantly superior effect and MH 500 ppm rather performed below the control. Highest mean pod number of 16.92 and 12.96 under October and January sowing of the crop respectively were obtained with inocualtion of seeds with *Rhizobium sp.* followed by foliar spray on the crop with BNOA 25 ppm (October sown crop) and 2, 4-D 2 ppm (January sown crop). Nitrogen fertilizer was applied by two split applications in both the cases. Lowest pod number on the other hand (8.80 and 8.55, respectively, in October and January sown crop) resulted from the treatment combination comprising zero inoculation, MH (500 ppm) spray and single basal nitrogen fertilization. Observed data indicated higher mean number of pods per plant under October sown condition of the crop compared to January sowing (Table 4.13 a , 4.13 b & Fig. 4.8).

Table - 4.13 a : Pod number per plant under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	13.40	14.34	10.47	11.86	8.80	14.14	15.20	10.59	12.76	9.56	12.12
B_2	14.50	15.82	12.22	13.27	10.27	14.86	16.57	13.00	13.71	10.65	13.48
B_3	14.90	15.83	12.39	13.72	10.29	15.52	16.92	12.76	14.80	10.84	13.81

Mean (A) $\overline{A_0}$ =14.56 $\overline{A_1}$ =15.78 $\overline{A_2}$ = 11.90 $\overline{A_3}$ =13.35 $\overline{A_4}$ =10.17

Mean (C) $\overline{C_0}$ =12.81 $\overline{C_1}$ = 13.46

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.08	0.07	0.05	0.15	0.12	0.09	0.19
C.D. at 5%	0.19	0.13	0.12	0.31	NS	0.18	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.13 b : Pod number per plant under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	8.58	9.38	9.30	10.38	8.55	9.10	10.09	9.70	10.93	9.03	9.50
B_2	9.86	11.85	10.71	11.64	8.66	10.53	12.81	11.45	12.72	9.86	11.01
B_3	9.99	12.44	10.66	11.87	9.81	10.06	12.91	11.06	12.96	10.50	11.22

Mean (A) $\overline{A_0}$ =9.68 $\overline{A_1}$ =11.58 $\overline{A_2}$ = 10.48 $\overline{A_3}$ = 11.75 $\overline{A_4}$ =9.40

Mean (C) $\overline{C_0}$ =10.24 $\overline{C_1}$ = 10.91

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.09	0.07	0.04	0.15	0.09	0.10	0.24
C.D. at 5%	0.21	0.14	0.10	0.31	NS	NS	0.48

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Tau *et al.* (1984) obtained more number of pods in French bean with Rhizobium inoculation which supports the present result. Significant increase or decrease in number of pods as a result of MH spray depending on variety was obtained by Arthur and Myers (1974) in French bean which is confirmed from this investigation also but the result with no significant effect on pod number by BNOA spray as reported by Alvino *et al.*, (1988) in Soybean is a contradiction.

4.2.7 Length of pod

Among the three treatment factors only growth regulators spray could exert significant influence over length of pod during October sowing of the crop. However, under January sowing condition both growth regulator spray and rhizobial seed inoculation influenced pod length significantly besides some significant treatment interaction effects. Effect of GA_3 100 ppm (Mean 11.33 cm and 11.21 cm) and 2, 4-D 2 ppm (Mean 11.31 cm and 11.14 cm) were observed superior over control in increasing length of pod during both the seasons of growth whereas, MH 500 ppm (Mean 10.32 cm and 10.19 cm) and BNOA 25 ppm (Mean 10.30 cm and 10.07 cm) proved ineffective with respect to control (Mean 10.09 cm and 10.06 cm) during the period. Nitrogen fertilizers either through basal application of full dose or through split application(s) resulted no marked (significant) difference in influencing length of pod under both October and January sowing condition of the crop (Table 4.14a & 4.14b).

4.2.8 Pod yield

Significant influence of growth regulator spray and time of nitrogen fertilization over mean fresh yield of pod was observed during both the seasons of experiment. Besides, some significant interaction effect could

Table - 4.14 a : Length of pod (cm) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	10.33	10.02	11.20	11.01	10.14	10.19	10.41	11.33	11.41	10.37	10.66
B_2	10.01	10.49	11.43	11.27	10.49	10.33	10.44	11.15	11.31	10.42	10.73
B_3	9.33	10.16	11.39	12.02	10.16	10.20	10.26	11.50	10.89	10.39	10.93

Mean (A) $\overline{A_0}$ =10.09 $\overline{A_1}$ =10.30 $\overline{A_2}$ =11.33 $\overline{A_3}$ = 11.31 $\overline{A_4}$ =10.32

Mean (C) $\overline{C_0}$ = 10.63 $\overline{C_1}$ = 10.71

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.34	0.26	0.23	0.60	0.53	0.38	0.85
C.D. at 5%	0.79	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.14 b : Length of pod (cm) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	10.07	10.09	10.90	10.91	10.06	10.20	10.22	10.80	11.36	10.43	10.50
B_2	10.00	9.91	11.22	10.97	10.06	10.12	10.14	11.55	11.34	10.43	10.57
B_3	9.81	9.99	11.29	10.97	9.84	10.17	10.10	11.50	11.30	10.35	10.53
Mean (A)		$\overline{A_0}$ =10.06		$\overline{A_1}$ =10.07		$\overline{A_2}$ = 11.21			$\overline{A_3}$ = 11.14		$\overline{A_4}$ =10.19
Mean (C)		$\overline{C_0}$ = 10.41							$\overline{C_1}$ = 10.67		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.139	0.06	0.05	0.132	0.124	0.08	0.187
C.D. at 5%	0.321	NS	0.124	0.267	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

also be traced. Seed inoculation exhibited significant influence over pod yield during October sowing season only, however, during January sowing of the crop no effect of seed inoculation could be obtained. Mean pod yield was relatively higher in October sown crop compared to January sown crop and application of BNOA 25 ppm and 2, 4 -D 2 ppm (7.98% and 10.15% over control under October sown condition and 20.12% and 15.03% over control under January sown condition) proved relatively better over GA_3 100 ppm (6.84% below and 4.42% above control during the two seasons respectively) and MH 500 ppm (adverse effect compared to control during both the growing seasons with mean yield 12.34% and 7.15% below control respectively). Split fertilization of nitrogen fertilizer was more effective under October sowing of the crop however under January sowing condition the result was just reverse and single basal nitrogen fertilization emerged superior over split nitrogen application in influencing pod yield. Maximum and munimum pod yield recorded were 68.78 gm per plant (57.29 q per ha) and 48.63 gm per plant (40.50 q per ha) under October sowing and 61.05 gm per plant (50.85 q per ha) and 43.38 gm per plant (36.13 q per ha) under January sowing condition (Table 4.15 a , 4.15 b & Fig. 4.8).

Earlier worker like Singh *et al.* (1989) obtained higher green pod yield of cowpea with no rhizobial inoculation of seeds and Duranti (1978) obtained higher average yield with single dressing of nitrogen fertilizer in beans which partially supports the present finding. Higher pod number might have contributed to increased pod yield of the crop.

Table - 4.15 a : Pod yield (g/plant) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	62.35	60.45	55.87	68.13	48.63	60.48	62.95	54.86	63.52	50.90	58.71
B_2	60.50	64.75	52.61	62.65	52.26	57.88	66.10	58.85	67.72	54.92	59.80
B_3	58.26	66.08	53.16	64.86	53.36	59.90	67.56	60.10	68.78	54.76	60.68
Mean (A)	$\overline{A_0}$ =59.86		$\overline{A_1}$ =64.64		$\overline{A_2}$ = 55.76		$\overline{A_3}$ = 65.94		$\overline{A_4}$ =52.47		
Mean (C)	$\overline{C_0}$ =58.84						$\overline{C_1}$ = 60.61				

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.71	0.56	0.45	1.26	1.02	0.79	1.78
C.D. at 5%	1.65	1.13	1.00	NS	NS	1.59	3.59

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.15 b : Pod yield (gm/plant) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	53.12	58.18	54.71	61.05	46.16	51.12	60.12	52.28	60.50	47.80	54.49
B_2	48.85	58.37	50.53	56.58	45.10	48.20	60.00	52.27	52.42	46.55	51.88
B_3	46.45	57.88	48.72	51.37	45.75	48.05	60.71	50.31	58.30	43.38	51.09

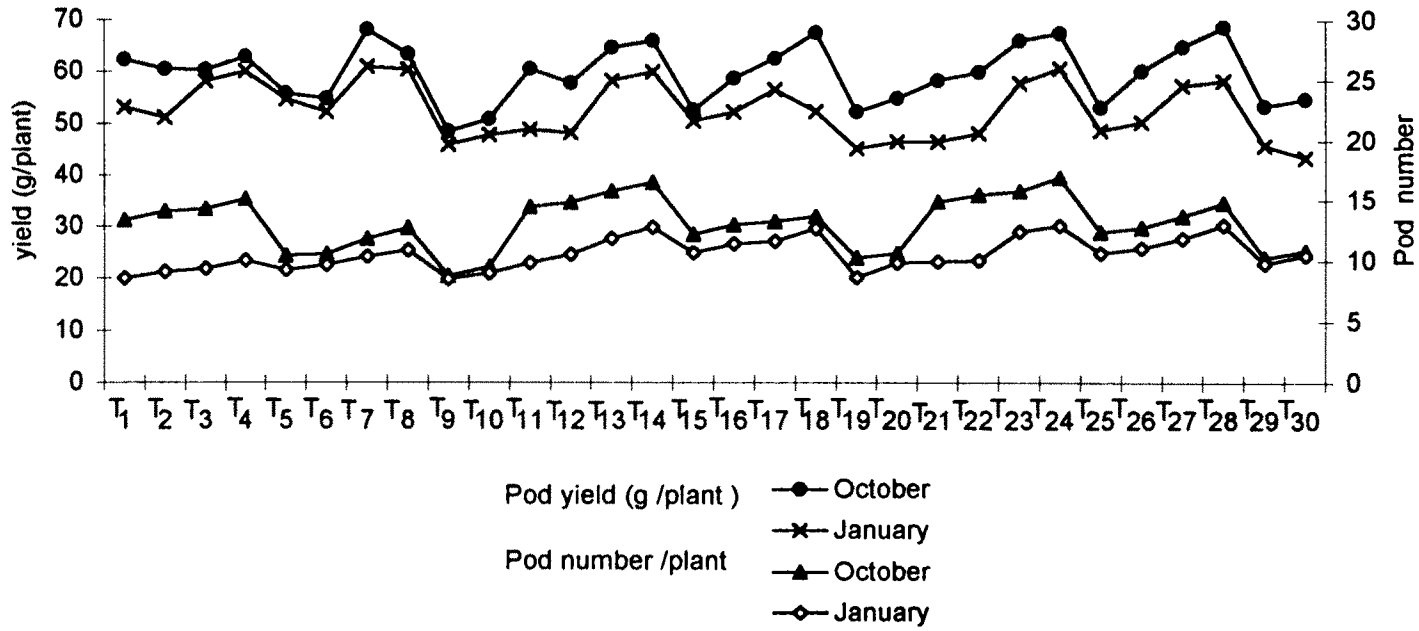
Mean (A) $\overline{A_0}$ =49.29 $\overline{A_1}$ =59.21 $\overline{A_2}$ = 51.47 $\overline{A_3}$ = 56.70 $\overline{A_4}$ =45.77

Mean (C) $\overline{C_0}$ = 52.18 $\overline{C_1}$ = 52.80

	A	B	C	AB	AC	BC	ABC
S. Em (±)	1.35	1.96	0.98	3.25	2.20	2.06	4.60
C.D. at 5%	3.12	2.94	NS	6.58	NS	4.16	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Fig - 4.8: Effect of different growth regulators spray, time of nitrogen fertilization and rhizobial seed inoculation on pod number and pod yield / plant under October and January sown conditions



$T_1=B_1C_0A_0$,	$T_2=B_1C_1A_0$,	$T_3=B_1C_0A_1$,	$T_4=B_1C_1A_1$,	
$T_5=B_1C_0A_2$,	$T_6=B_1C_1A_2$,	$T_7=B_1C_0A_3$,	$T_8=B_1C_1A_3$,	
$T_9=B_1C_0A_4$,	$T_{10}=B_1C_1A_4$,	$T_{11}=B_2C_0A_0$,	$T_{12}=B_2C_1A_0$,	
$T_{13}=B_2C_0A_1$,	$T_{14}=B_2C_1A_1$,	$T_{15}=B_2C_0A_2$,	$T_{16}=B_2C_1A_2$,	
$T_{17}=B_2C_0A_3$,	$T_{18}=B_2C_1A_3$,	$T_{19}=B_2C_0A_4$,	$T_{20}=B_2C_1A_4$,	
$T_{21}=B_3C_0A_0$,	$T_{22}=B_3C_1A_0$,	$T_{23}=B_3C_0A_1$,	$T_{24}=B_3C_1A_1$,	
$T_{25}=B_3C_0A_2$,	$T_{26}=B_3C_1A_2$,	$T_{27}=B_3C_0A_3$,	$T_{28}=B_3C_1A_3$,	
$T_{29}=B_3C_0A_4$,	$T_{30}=B_3C_1A_4$.			

A - Growth regulator spray

A_0 = No growth regulator spray
A_1 = Spray with BNOA 25 ppm
A_2 = Spray with GA_3 100 ppm
A_3 = Spray with 2,4 -D 2 ppm
A_4 = Spray with MH 500 ppm

B- Time of Nitrogen fertilization

B_1= Basal application of full dose(80 kg /ha)
B_2= 50 % basal + 50% top dressing 20DAS
B_3= 50 % basal + 25% top dressing 20DAS+ 25 % top dressing 30 DAS

C - Inoculation

C_0 = No inoculation, C_1= Seed inoculation with *Rhizobium sp.*

4.2.9 Seed pod number

Number of pods retained after second picking upto the stage of final harvest for collection of seeds (seed pods) were found to be influenced singificantly by all three treatment factors (growth regulators spray, rhizobial seed inoculation and time of nitrogen fertilization) besides some significant interaction effects during both the seasons of growth. While GA_3 100 ppm proved best effecting and superior (Mean 7.32 and 5.83) over control (Mean 6.61 and 4.63), MH 500 ppm yielded the least influence (Mean 5.65 and 4.10) during both October and January sowing of the crop. Significant increase in number of seed pods was obtained from split fertilization of nitrogen fertilizer than from single basal application. Seed inoculation with *Rhizobium sp.* also proved effective and significantly superior over 'no inoculation' with respect to seed pod number per plant (Table 4.16 a , 4.16 b & Fig. 4.9).

4.2.10 Seed number

Number of seeds per pod was significantly influenced by all three treatment factors and their all possible interaction effects during both the seasons of experiment. Seed number per pod ranged between 3.08 to 3.45 under January sown condition and between 4.54 to 5.26 under October sown condition of the crop. Statistical analysis of the data revealed that among the growth regulators, BNOA 25 ppm only could effectively influence the number of seeds per pod (2.4% over control) during October sowing of the crop while under January sown condition GA_3 100 ppm (Mean 3.30), BNOA 25 ppm (Mean 3.29) and 2, 4 -D 2 ppm (Mean 3.26) increased mean seed number per pod by 3.44%, 3.13% and 2.2% respectively over control. Increased number of seeds per pod was also noticed as a result of rhizobial inoculation of the crop to the tune of 1.2%

Table - 4.16 a : Seed pod number per plant under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	6.09	6.78	7.45	6.35	4.93	6.68	7.17	8.05	7.24	5.74	6.65
B_2	6.01	6.27	6.83	7.13	5.36	6.87	7.35	7.38	7.68	5.95	6.68
B_3	6.73	6.79	7.00	6.61	5.50	7.31	7.39	7.26	7.20	5.43	6.82

Mean (A) $\overline{A_0}$ =6.61 $\overline{A_1}$ =6.96 $\overline{A_2}$ =7.32 $\overline{A_3}$ = 7.03 $\overline{A_4}$ =5.65

Mean (C) $\overline{C_0}$ = 6.39 $\overline{C_1}$ = 7.04

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.024	0.05	0.012	0.11	0.21	0.27	0.16
C.D. at 5%	0.056	0.102	0.027	0.22	NS	NS	0.32

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.16 b : Seed pod number per plant under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	4.44	4.69	5.43	4.06	3.59	4.94	5.83	6.12	4.92	4.14	4.81
B_2	4.29	4.36	5.93	4.21	3.44	4.81	5.29	5.99	5.48	4.89	4.87
B_3	4.45	5.08	5.50	4.18	3.91	4.86	5.54	6.01	5.35	4.52	4.94
Mean (A)		$\overline{A_0}$ =4.63		$\overline{A_1}$ =5.11			$\overline{A_2}$ = 5.83		$\overline{A_3}$ = 4.70		$\overline{A_4}$ =4.10
Mean (C)		$\overline{C_0}$ =4.50							$\overline{C_1}$ = 5.25		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.109	0.059	0.052	0.17	0.11	0.11	0.25
C.D. at 5%	0.253	0.120	0.116	NS	0.24	0.22	0.50

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.17 a : Seed number per pod under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	4.99	5.22	4.80	4.54	4.99	5.09	5.22	4.73	4.61	5.03	4.92
B_2	4.90	5.24	4.69	4.89	4.74	5.10	5.26	4.72	5.01	4.79	4.94
B_3	5.22	5.11	4.83	4.92	4.98	5.17	5.16	4.86	5.07	5.16	5.05

Mean (A) $\overline{A_0}$ =5.08 $\overline{A_1}$ =5.20 $\overline{A_2}$ = 4.77 $\overline{A_3}$ = 4.84 $\overline{A_4}$ =4.94

Mean (C) $\overline{C_0}$ =4.94 $\overline{C_1}$ = 5.0

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.01	0.005	0.807	0.013	0.02	0.008	0.018
C.D. at 5%	0.025	0.012	0.016	0.027	0.036	0.017	0.038

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.17 b : Seed number per pod under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	3.22	3.18	3.18	3.30	3.09	3.15	3.23	3.25	3.29	3.13	3.20
B_2	3.27	3.29	3.30	3.16	3.09	3.17	3.40	3.45	3.22	3.08	3.24
B_3	3.13	3.34	3.30	3.35	3.11	3.23	3.32	3.34	3.27	3.19	3.26
Mean (A)		$\overline{A_0}$ =3.19		$\overline{A_1}$ =3.29			$\overline{A_2}$ = 3.30		$\overline{A_3}$ =3.26		$\overline{A_4}$ =3.11
Mean (C)		$\overline{C_0}$ = 3.22							$\overline{C_1}$ =3.25		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.01	0.009	0.008	0.02	0.02	0.013	0.03
C.D. at 5%	0.035	0.019	0.018	0.043	0.041	0.027	0.061

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

and 0.9% over control respectively during the two seasons. Besides three split applications of nitrogen fertilizer proved superior over basal fertilization by 2.64% and 1.87% respectively under October and January sowing condition (Table 4.17a & 4.17b). . Earlier worker Arthur *et al.* (1974) reported either increase or decrease in seed number with application of MH 500 ppm depending on the variety.

4.2.11 Seed yield

Significant contribution of growth regulators, seed inoculation with *Rhizobium sp.*, and time of nitrogen fertilization towards mean seed yield of the crop was observed. October sown crop gave relatively higher seed yield compared to January sown crop under all the treatments provided. Mean seed yield was highest under GA_3 100 ppm (35.37% and 47.98% over control) while BNOA 25 ppm (23.97% and 22.29% over control) and 2, 4 -D 2 ppm (28.90% and 8.49% over control) also significantly contributed to increased seed yield during October and January sowing of the crop respectively. MH 500 ppm yielded no better than control and rather performed below the control by about 2.43% and 9.56% respectively during the two seasons. Split nitrogen fertilization over single basal application also proved significantly superior with an added seed yield of 3.31% and 4.19% respectively under October and January sowing condition of the crop. Nearly 10.39% and 17.2% increased seed yield was recorded as a result of bacterial inoculation of the seeds under these two sowing seasons respectively. Maximum and minimum seed yield recorded were 16.24g/plant (13.53 q/ha) and 9.69 g/plant (8.07 q/ha) under October and 7.44 g/plant (6.19 q/ha) and 3.57 g/plant (2.97 q/ha) under January sown condition of the crop (Table 4.18a , 4.18b & Fig. 4.9).

Table - 4.18 a : Seed yield (g/plant) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	10.22	13.55	15.34	12.10	9.93	11.28	14.22	16.49	14.15	11.55	12.88
B_2	9.69	12.52	13.87	14.68	10.06	11.59	14.61	15.01	16.24	11.46	12.97
B_3	11.66	13.25	14.60	13.69	11.0	12.43	14.71	15.17	15.33	11.23	13.31
Mean (A)		$\overline{A_0}$ =11.14		$\overline{A_1}$ =13.81			$\overline{A_2}$ =15.08		$\overline{A_3}$ =14.36		$\overline{A_4}$ =10.87
Mean (C)		$\overline{C_0}$ = 12.41							$\overline{C_1}$ =13.70		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.132	0.095	0.047	0.103	0.202	0.128	0.286
C.D. at 5%	0.305	0.192	0.103	NS	0.409	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

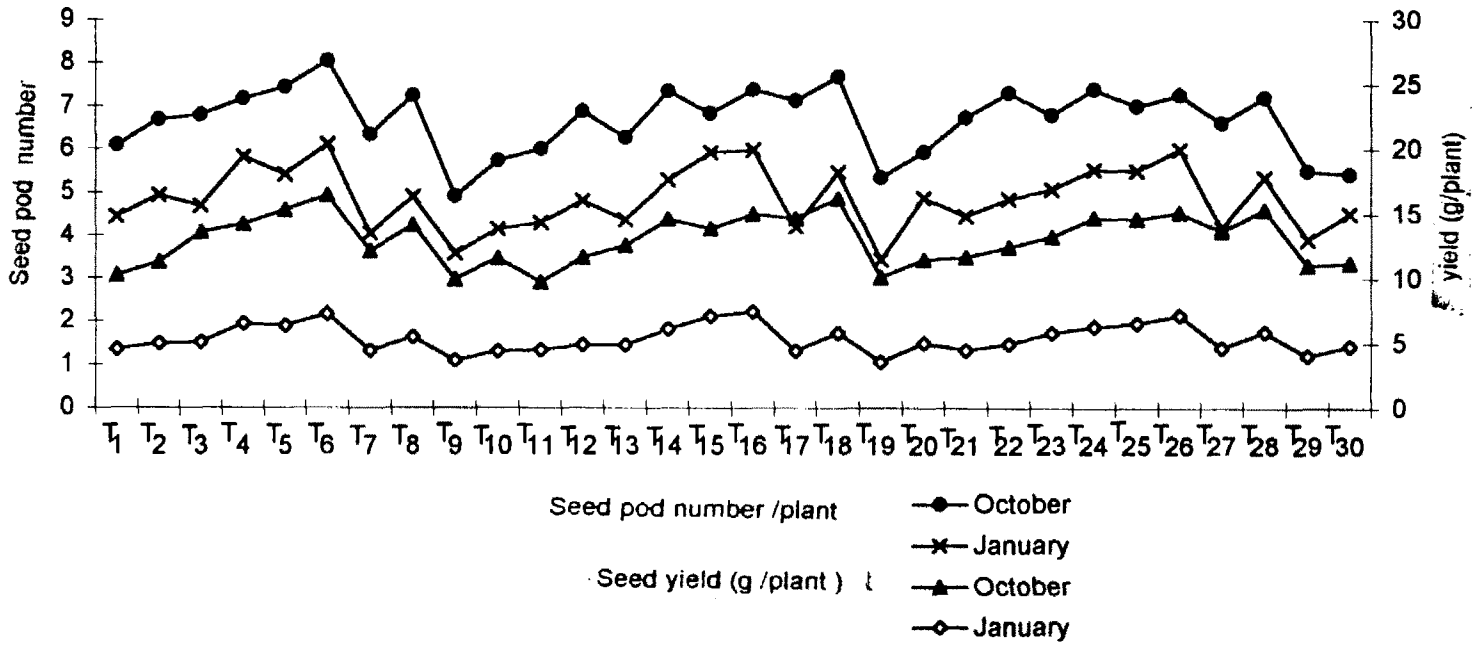
Table - 4.18 b : Seed yield (g/plant) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	4.52	5.06	6.32	4.43	3.70	4.98	6.48	7.22	5.44	4.39	5.25
B_2	4.50	4.88	7.10	4.43	3.57	4.86	6.08	7.44	5.82	5.01	5.37
B_3	4.47	5.80	6.53	4.69	4.06	4.98	6.29	7.19	5.88	4.84	5.47
Mean (A)		$\overline{A_0}$ =4.71		$\overline{A_1}$ =5.76			$\overline{A_2}$ = 6.97		$\overline{A_3}$ = 5.11		$\overline{A_4}$ =4.26
Mean (C)		$\overline{C_0}$ = 4.94							$\overline{C_1}$ = 5.79		

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.046	0.022	0.036	0.08	0.05	0.03	0.07
C.D. at 5%	0.105	0.045	0.08	NS	0.10	0.60	0.141

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Fig - 4.9: Effect of different growth regulators spray, time of nitrogen fertilization and rhizobial seed inoculation on seed pod number and seed yield / plant under October and January sown conditions



$T_1=B_1C_0A_0$,	$T_2=B_1C_1A_0$,	$T_3=B_1C_0A_1$,	$T_4=B_1C_1A_1$,
$T_5=B_1C_0A_2$,	$T_6=B_1C_1A_2$,	$T_7=B_1C_0A_3$,	$T_8=B_1C_1A_3$,
$T_9=B_1C_0A_4$,	$T_{10}=B_1C_1A_4$,	$T_{11}=B_2C_0A_0$,	$T_{12}=B_2C_1A_0$,
$T_{13}=B_2C_0A_1$,	$T_{14}=B_2C_1A_1$,	$T_{15}=B_2C_0A_2$,	$T_{16}=B_2C_1A_2$,
$T_{17}=B_2C_0A_3$,	$T_{18}=B_2C_1A_3$,	$T_{19}=B_2C_0A_4$,	$T_{20}=B_2C_1A_4$,
$T_{21}=B_3C_0A_0$,	$T_{22}=B_3C_1A_0$,	$T_{23}=B_3C_0A_1$,	$T_{24}=B_3C_1A_1$,
$T_{25}=B_3C_0A_2$,	$T_{26}=B_3C_1A_2$,	$T_{27}=B_3C_0A_3$,	$T_{28}=B_3C_1A_3$,
$T_{29}=B_3C_0A_4$,	$T_{30}=B_3C_1A_4$.		

A - Growth regulator spray

A_0 = No growth regulator spray
A_1 = Spray with BNOA 25 ppm
A_2 = Spray with GA_3 100 ppm
A_3 = Spray with 2,4 -D 2 ppm
A_4 = Spray with MH 500 ppm

B- Time of Nitrogen fertilization

B_1= Basal application of full dose(80 kg /ha)
B_2= 50 % basal + 50% top dressing 20DAS
B_3= 50 % basal + 25% top dressing 20DAS+ 25 % top dressing 30 DAS

C - Inoculation

C_0= No inoculation, C_1= Seed inoculation with *Rhizobium sp.*

Variation in seed yield with sowing date was reported earlier by Iglesias *et al.* (1984). Samtsevich *et al.* (1980) obtained higher seed yield in bean plants with rhizobium inoculation. Increased seed yield with GA_3 application was reported by Shyamal *et al.* (1990).

4.2.12 Germination percentage of offspring seeds (seeds produced)

Seeds raised from October and January sown crop when put to germination test (rolled -towel test) in the following seasons, revealed that seeds of October sown crop could retain higher germinability compared to those raised from the January sown crop in general. Among the three treatment factors growth regulator spray only could significantly influence germinability of the seeds produced (offspring seeds). Neither seed inoculaton, nor time of nitrogen fertilization could however play any significant role in this respect. Higher germination (above 80%) of the offspring seeds was recorded under influence of BNOA 25 ppm, GA_3 100 ppm and 2,4 -D 2 ppm (84.2%, 85.9% and 85.6% respectively) in the October sown crop and under influence of GA_3 100 ppm and 2,4 -D 2 ppm (81.9% and 82.2% respectively) in the January sown crop. No significant interaction effects of the treatment factors could be detected during both the seasons of experiment (Table 4.19a & 4.19b).

4.2.13 Length of offspring seeds (seeds produced)

Length of offspring seeds of both October and January sown crop were influenced significantly as a result of different growth regulators spray on the mother plant. But their effects rather lay below the control, In other words growth regulators spray rather reduced mean length of the offspring seeds (seeds produced) compared to control (no growth regulator

Table - 4.19 a : Germination percentage of seeds produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	60.68	66.70	68.36	67.24	63.20	60.25	67.22	68.34	67.82	62.51	63.23
	(76.01)*	(84.40)	(86.40)	(85.00)	(79.70)	(75.40)	(85.00)	(86.40)	(85.80)	(78.70)	(82.40)
B_2	58.70	66.72	68.32	68.06	61.80	58.73	66.27	68.05	68.13	62.26	64.70
	(73.00)	(84.40)	(86.30)	(86.00)	(77.70)	(73.10)	(83.80)	(86.00)	(86.10)	(78.30)	(87.70)
B_3	58.06	65.92	67.56	67.50	60.93	59.10	66.20	67.22	67.50	60.68	64.06
	(72.00)	(83.30)	(85.40)	(85.30)	(76.40)	(73.60)	(83.70)	(85.00)	(85.30)	(76.00)	(80.90)
Mean (A)		$\overline{A_0}$ =59.25 (73.90)		$\overline{A_1}$ =66.50 (84.20)		$\overline{A_2}$ = 67.97 (85.90)		$\overline{A_3}$ = 67.70 (85.60)		$\overline{A_4}$ =61.89 (77.80)	
Mean (C)		$\overline{C_0}$ = 64.65 (81.70)						$\overline{C_1}$ = 64.68 (81.70)			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.83	0.67	0.49	1.19	0.98	0.83	1.37
C.D. at 5%	1.91	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

* Figures in parenthesis indicate actual values before arc-sine transformation.

Table - 4.19 b : Germination percentage of seeds produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	45.36	57.21	64.49	64.94	44.81	45.95	56.30	64.29	64.67	45.00	55.30
	(50.60)	(70.70)	(81.50)	(82.10)	(49.70)	(50.60)	(69.20)	(81.20)	(87.70)	(50.00)	(67.60)
B_2	44.23	55.77	64.53	65.18	43.85	45.19	56.79	65.51	65.12	45.38	55.15
	(48.70)	(68.40)	(81.60)	(82.40)	(47.30)	(50.30)	(70.00)	(82.80)	(82.30)	(50.70)	(67.30)
B_3	46.34	57.48	64.77	65.18	44.42	45.38	56.59	65.28	65.10	44.62	55.51
	(52.40)	(71.10)	(81.80)	(82.40)	(49.00)	(50.70)	(69.70)	(82.50)	(82.30)	(49.30)	(67.90)
Mean (A)		$\overline{A_0}$ =45.41 (50.70)		$\overline{A_1}$ =56.69 (70.10)		$\overline{A_2}$ = 64.81 (81.90)		$\overline{A_3}$ = 65.03 (82.20)		$\overline{A_4}$ =44.68 (49.40)	
Mean (C)		$\overline{C_0}$ = 55.23(67.50)						$\overline{C_1}$ = 55.41(67.80)			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	1.22	1.39	0.89	2.95	2.11	2.14	3.59
C.D. at 5%	2.81	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

* Figures in parenthesis indicate actual values before arc-sine transformation.

spray). Seed inoculation or time of nitrogen fertilization, however, proved statistically insignificant in influencing length of the offspring seeds. Highest mean seed lengths of 16.22 mm and 16.19 mm were obtained under control (no growth regulators spray) during the two seasons which were statistically at per with those obtained as a result of spray with MH 500 ppm and BNOA 25 ppm during both the seasons. Seeds of lower mean length were obtained under influence of GA_3 100 ppm (14.61 mm and 14.83 mm, respectively) and 2,4 -D 2 ppm (14.81 and 15.05 mm) when raised from October and January sown crop respectively. Interaction effects of treatment factors emerged ineffective in influencing length of offspring seeds by any means (Table 4.20a & 4.20b).

4.2.14 Breadth of offspring seeds (seeds produced)

Among the three treatment factors only growth regulators spray had significant influence over breadth of offspring seeds of both October and January sown crop. Rhizobial seed inoculation or time of nitrogen fertilization on mother plants, however, did not affect seed breadth of offspring seeds by any means. Highest mean breadth of offspring seeds were obtained under GA_3 (100 ppm) and 2, 4 -D (2 ppm) spray in both of October and January sown crop (5.41 mm and 5.32 mm under GA_3 and 5.31 mm and 5.44 mm under 2, 4 -D respectively, whereas, control (no growth regulator) treatment yielded seeds with lowest values for seed breadth (5.04 and 4.89 respectively). BNOA (25 ppm) and MH (500 ppm) had intermediate effects. Effects of interaction of the treatment factors were also observed to be insignificant. (Table 4.21a & 4.21b).

Table - 4.20 a : Length of seeds (mm) produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	16.08	15.70	14.65	14.82	15.97	16.14	15.78	14.60	14.86	16.05	15.47
B_2	16.12	15.73	14.62	14.85	15.99	16.75	15.68	14.56	14.71	16.02	15.50
B_3	16.12	15.77	14.60	14.72	16.00	16.06	15.68	14.65	14.83	16.08	15.45

Mean (A) $\overline{A_0}$ =16.22 $\overline{A_1}$ =15.72 $\overline{A_2}$ =14.61 $\overline{A_3}$ = 14.81 $\overline{A_4}$ =16.02

Mean (C) $\overline{C_0}$ =15.45 $\overline{C_1}$ = 15.49

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.351	0.259	0.215	0.579	0.481	0.366	0.820
C.D. at 5%	0.810	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.20 b : Length of seeds (mm) produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	16.18	15.61	14.80	15.06	16.08	16.17	15.63	14.88	15.06	16.00	15.54
B_2	16.21	15.68	14.83	15.06	16.04	16.19	15.64	14.84	15.02	16.09	15.56
B_3	16.18	15.64	14.83	15.05	16.09	16.21	15.60	14.79	15.05	16.12	15.55

Mean (A) $\overline{A_0}$ =16.19 $\overline{A_1}$ =15.63 $\overline{A_2}$ =14.83 $\overline{A_3}$ =15.05 $\overline{A_4}$ =16.07

Mean (C) $\overline{C_0}$ =15.56 $\overline{C_1}$ = 15.55

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.25	0.14	0.15	0.33	0.33	0.21	0.47
C.D. at 5%	0.58	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.21 a : Breadth of seeds (mm) produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	5.046	5.236	5.400	5.326	4.996	5.026	5.216	5.416	5.296	5.016	5.198
B_2	5.050	5.210	5.413	5.353	5.296	5.076	5.236	5.436	5.316	4.996	5.238
B_3	5.060	5.223	5.386	5.286	5.013	4.993	5.200	5.416	5.306	5.013	5.190

Mean (A) $\overline{A_0}$ =5.042 $\overline{A_1}$ =5.220 $\overline{A_2}$ =5.411 $\overline{A_3}$ = 5.314 $\overline{A_4}$ =5.055

Mean (C) $\overline{C_0}$ =5.220 $\overline{C_1}$ = 5.197

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.036	0.027	0.020	0.061	0.046	0.039	0.087
C.D. at 5%	0.083	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.21 b : Breadth of seeds (mm) produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	4.863	5.286	5.303	5.466	5.033	4.876	5.300	5.320	5.450	4.983	5.188
B_2	4.900	5.323	5.320	5.440	5.020	4.910	5.296	5.330	5.416	5.036	5.199
B_3	4.903	5.300	5.316	5.433	5.020	4.886	5.283	5.336	5.456	5.026	5.196
Mean (A)		$\overline{A_0}$ =4.89		$\overline{A_1}$ =5.298		$\overline{A_2}$ =5.321		$\overline{A_3}$ = 5.443		$\overline{A_4}$ =5.020	
Mean (C)		$\overline{C_0}$ =5.195						$\overline{C_1}$ = 5.193			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.001	0.009	0.009	0.020	0.021	0.013	0.029
C.D. at 5%	0.023	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

4.2.15 Specific gravity of offspring seeds (seeds produced)

Seeds with relatively higher specific gravity resulted from October sowing of the crop whereas January sown crop produced seeds with lower values of specific gravity. Spraying the crop with growth regulators significantly contributed to specific gravity of the offspring seeds during both the seasons of experiment. All the growth regulators employed exerted significantly higher influence over control (1.022 and 0.970 respectively during October and January sowing) and GA_3 100 ppm emerged a greatest influencing growth regulator among them. Effect of rhizobial seed inoculation or different periods of nitrogen fertilization over the main crop had no significant influence over specific gravity of the seeds produced (offspring seeds). Interaction effects of the treatment factors also proved ineffective in influencing seed specific gravity (Table 4.22a & 4.22b).

4.2.16 Weight of offspring seeds (seeds produced)

Seeds of October sown crop were bolder in size compared to those of January sown crop. Among the four growth regulators employed, GA_3 (100 ppm) most effectively contributed to seed weight of offspring seeds (Mean seed weigth 0.431 g and 0.362 g) as a result of foliar spray on October and January sown crop respectively. Least seed weights (Mean 0.331 g and 0.319 g) were obtained under control (no growth regulator spray) during both the seasons of experiment. However, no effect of seed inoculation with Rhizobium culture over seed weight of offspring seeds could be detected. Basal fertilization lay at par with split fertilization of nitrogen fertilizer in contributing towards mean seed weight of offspring seeds of October sown crop whereas, the result was different.

Table - 4.22 a : Specific gravity of seeds produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	1.020	1.256	1.366	1.276	1.233	1.023	1.266	1.363	1.263	1.223	1.229
B_2	1.026	1.263	1.356	1.273	1.236	1.016	1.256	1.366	1.270	1.233	1.230
B_3	1.030	1.253	1.363	1.266	1.230	1.020	1.256	1.353	1.273	1.230	1.227

Mean (A) $\overline{A_0}$ =1.022 $\overline{A_1}$ =1.258 $\overline{A_2}$ =1.361 $\overline{A_3}$ = 1.270 $\overline{A_4}$ =1.231

Mean (C) $\overline{C_0}$ =1.230 $\overline{C_1}$ = 1.227

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.0038	0.0028	0.0033	0.0063	0.0074	0.004	0.009
C.D. at 5%	0.0088	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.22 b : Specific gravity of seeds produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	0.982	1.004	1.076	1.006	1.006	0.965	1.027	1.090	1.013	1.020	1.019
B_2	0.972	1.037	1.086	0.996	1.006	0.965	1.027	1.083	1.033	1.016	1.023
B_3	0.961	1.024	1.076	1.006	1.013	0.975	1.031	1.090	1.006	1.013	1.020

Mean (A) $\overline{A_0}$ =0.970 $\overline{A_1}$ =1.025 $\overline{A_2}$ =1.083 $\overline{A_3}$ = 1.010 $\overline{A_4}$ =1.012

Mean (C) $\overline{C_0}$ =1.017 $\overline{C_1}$ = 1.024

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.0035	0.0025	0.0022	0.0056	0.0050	0.0035	0.0079
C.D. at 5%	0.0082	NS	NS	NS	NS	NS	NS

A : growth regulator spray — A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)

B : time of nitrogen fertilization — B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),

C : inoculation — C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)

N. S. - Not significant.

Table - 4.23 a : Weight of seeds (g) produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	0.336	0.383	0.429	0.420	0.404	0.332	0.380	0.433	0.424	0.400	0.394
B_2	0.329	0.381	0.433	0.421	0.396	0.331	0.378	0.431	0.422	0.402	0.392
B_3	0.332	0.382	0.432	0.421	0.402	0.329	0.386	0.430	0.420	0.401	0.393

Mean (A) $\overline{A_0}$ =0.331 $\overline{A_1}$ =0.381 $\overline{A_2}$ = 0.431 $\overline{A_3}$ = 0.421 $\overline{A_4}$ = 0.400

Mean (C) $\overline{C_0}$ = 0.3934 $\overline{C_1}$ = 0.3931

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.001	0.0007	0.0001	0.0016	0.0015	0.0009	0.002
C.D. at 5%	0.002	NS	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.23 b : Weight of seeds (g) produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	0.316	0.339	0.366	0.331	0.334	0.320	0.334	0.363	0.336	0.339	0.339
B_2	0.321	0.340	0.363	0.333	0.336	0.319	0.338	0.360	0.330	0.333	0.338
B_3	0.321	0.342	0.360	0.335	0.334	0.317	0.342	0.358	0.336	0.336	0.342

Mean (A) $\overline{A_0}$ =0.319 $\overline{A_1}$ =0.340 $\overline{A_2}$ = 0.362 $\overline{A_3}$ = 0.333 $\overline{A_4}$ = 0.335

Mean (C) $\overline{C_0}$ = 0.33800 $\overline{C_1}$ = 0.33806

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.001	0.0008	0.0007	0.0016	0.0018	0.001	0.0026
C.D. at 5%	0.002	0.0016	NS	NS	NS	NS	NS

A : growth regulator spray — A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)

B : time of nitrogen fertilization — B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),

C : inoculation — C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)

N. S. - Not significant.

with split nitrogen fertilization emerging superior over basal application in January sown crop. No significant interaction of treatment factors with respect to seed weight of offspring seeds could be detected (Table 4.23a & 4.23b).

4.2.17 Total nitrogen contnent of plant material

All three treatment factors employed proved effective in influencing total nitrogen content of the plant material (leaf, root and shoot) during January sowing of crop however, growth regulator spray alone and not the rhizobial seed inoculation or varied time of nitrogen nutrition of the mother plants exhibited significant difference compared to respective controls during October sowing of the crop. Nitrogen content (after onset of flowering) ranged between 2.87% to 3.64% under January sown condition while the range lay between 3.00% to 3.69% in the October sown crop. Split fertilization proved significantly superior over single basal nitrogen application in the January sown crop. Rhizobial seed inoculation also proved better over 'zero' inoculation. Some interaction effects of seed inoculation, growth regulator spray and time of nitrogen fertilization also were detected during both of the two different seasons of growth (Table 4.24a , 4.24b & Fig. 4.10).

Earlier worker Saito *et al.* (1977) reported augmented nitrogen content in bean cultivars when inoculated with *Rhizobium* sp. which partially supports the present finding. Improvement in nitrogen content with addition of nitrogen on rhizobial inoculation was observed by Ruschel and Ruschel (1975).

Table - 4.24 a : Total nitrogen content (%) of plant material (after onset of flowering) under different treatments during October sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	**Mean(B)**
B_1	3.08	3.06	3.25	3.35	3.25	3.09	3.05	3.47	3.39	3.29	3.33
B_2	3.12	3.13	3.11	3.00	3.33	3.35	3.26	3.27	3.02	3.58	3.22
B_3	3.01	3.00	3.27	3.11	3.30	3.18	3.16	3.58	3.69	3.54	3.28
Mean (A)	$\overline{A_0}$ =3.14		$\overline{A_1}$ =3.11			$\overline{A_2}$ = 3.32		$\overline{A_3}$ = 3.26		$\overline{A_4}$ =3.38	
Mean (C)	$\overline{C_0}$ = 3.16							$\overline{C_1}$ =3.33			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.05	0.06	0.08	0.13	0.09	0.07	0.10
C.D. at 5%	0.11	NS	NS	0.26	0.2	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.24 b : Total nitrogen content (%) of plant material (after onset of flowering) under different treatments during January sowing condition

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	3.03	3.12	3.04	2.87	3.14	3.16	3.26	3.35	3.04	3.40	3.14
B_2	3.10	2.82	3.17	2.97	3.03	3.35	3.26	3.43	3.36	3.64	3.21
B_3	3.01	3.08	3.14	3.18	3.10	3.36	3.48	3.61	3.54	3.34	3.28
Mean (A)		$\overline{A_0}$ =3.17		$\overline{A_1}$ =3.17		$\overline{A_2}$ = 3.29		$\overline{A_3}$ = 3.16		$\overline{A_4}$ =3.27	
Mean (C)		$\overline{C_0}$ =3.05						$\overline{C_1}$ = 3.37			

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.04	0.03	0.07	0.08	0.012	0.10	0.13
C.D. at 5%	0.09	0.06	0.14	0.16	NS	NS	0.26

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

4.2.18 Total protein content of offspring seeds (seeds produced)

Significant variation in total protein content in the offspring seeds of both October and January sown crop was recorded. In the former occasion such variation was attributed to significant influence of different growth regulators. Spray and varied time of nitrogen fertilization on the main crop. Seed inoculation with *Rhizobium* sp. however, did not evoke any respose in this regard in the October crop. In January sown crop, on the other hand, all three treatment factors eg. growth regulator spray, seed inoculation and time of nitrogen fertilization on mother plants significantly contributed to total protein content of the seeds produced.(offspring seeds) Some interaction effects of treatment factors also proved contributory. Seed protein content of the offspring seeds of October sown crop ranged between 20.09 to 22.03% and that of January sown crop between 20.07 to 22.93% under different treatments. (Table 4.25a , 4.25b & Fig. 4.10).

Table - 4.25 a : Total protein content(%) of seeds produced (offspring seeds) under different treatments from October sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	20.18	20.29	21.68	21.48	21.32	20.41	20.09	21.23	21.18	20.13	20.79
B_2	20.60	21.20	21.20	21.25	21.92	21.73	20.96	21.78	22.03	21.84	21.50
B_3	21.84	20.61	20.39	21.82	21.95	21.34	20.82	21.28	21.39	21.09	21.35

Mean (A) $\overline{A_0}$ =21.01 $\overline{A_1}$ = 20.66 $\overline{A_2}$ = 21.52 $\overline{A_3}$ = 21.52 $\overline{A_4}$ = 21.37

Mean (C) $\overline{C_0}$ =21.28 $\overline{C_1}$ = 21.15

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.113	0.053	0.082	0.125	0.178	0.169	0.186
C.D. at 5%	0.260	0.107	NS	NS	NS	NS	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Table - 4.25 b : Total protein content(%)of seeds produced (offspring seeds) under different treatments from January sown crop

	C_0					C_1					
	A_0	A_1	A_2	A_3	A_4	A_0	A_1	A_2	A_3	A_4	Mean(B)
B_1	20.21	21.10	21.98	22.00	22.68	21.33	21.98	22.31	22.30	22.18	21.80
B_2	21.49	21.12	22.21	22.44	21.88	22.39	20.07	22.46	22.28	22.25	21.85
B_3	21.05	22.21	22.50	21.94	22.25	21.42	22.28	22.56	22.83	22.93	22.19

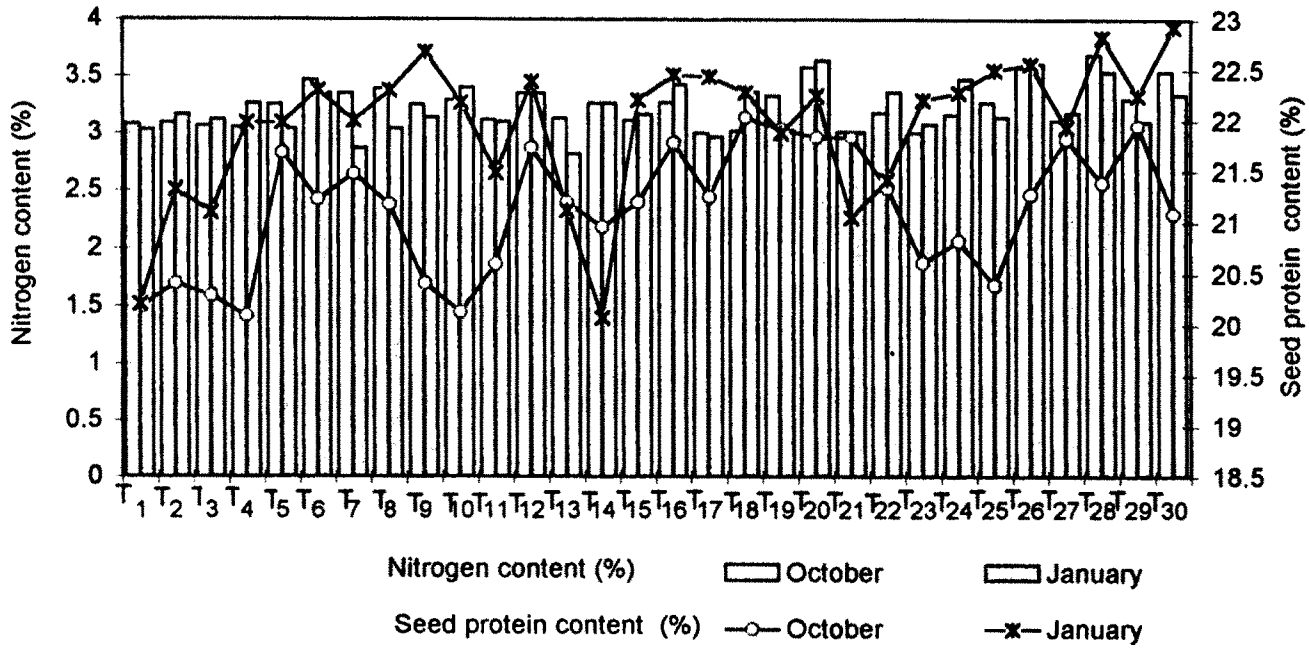
Mean (A) $\overline{A_0} = 21.31$ $\overline{A_1} = 21.46$ $\overline{A_2} = 22.33$ $\overline{A_3} = 22.29$ $\overline{A_4} = 22.36$

Mean (C) $\overline{C_0} = 21.80$ $\overline{C_1} = 22.10$

	A	B	C	AB	AC	BC	ABC
S. Em (±)	0.086	0.076	0.09	0.148	0.166	0.102	0.207
C.D. at 5%	0.198	0.153	0.20	0.329	NS	0.206	NS

A : growth regulator spray	A_0 (no growth regulator), A_1(BNOA 25 ppm), A_2 (GA_3 100 ppm), A_3(2,4 -D 2 ppm), A_4 (MH 500 ppm)
B : time of nitrogen fertilization	B_1 (Basal application @ 80 kg per ha), B_2 (50 % basal + 50% top dressing 20 DAS), B_3 (50% basal + 25% top dressing 20 DAS + 25% top dressing 30 DAS),
C : inoculation	C_0 (no inoculation), C_1 (seed inoculation with *Rhizobium sp.*)
	N. S. - Not significant.

Fig - 4.10 : Effect of different growth regulators spray, time of nitrogen fertilization and rhizobial seed inoculation on Nitrogen content (%) of plant material and protein content of seeds produced under October and January sown conditions



$T_1=B_1C_0A_0$, $T_2=B_1C_1A_0$, $T_3=B_1C_0A_1$, $T_4=B_1C_1A_1$, $T_5=B_1C_0A_2$, $T_6=B_1C_1A_2$,
$T_7=B_1C_0A_3$, $T_8=B_1C_1A_3$, $T_9=B_1C_0A_4$, $T_{10}=B_1C_1A_4$, $T_{11}=B_2C_0A_0$, $T_{12}=B_2C_1A_0$,
$T_{13}=B_2C_0A_1$, $T_{14}=B_2C_1A_1$, $T_{15}=B_2C_0A_2$, $T_{16}=B_2C_1A_2$, $T_{17}=B_2C_0A_3$, $T_{18}=B_2C_1A_3$,
$T_{19}=B_2C_0A_4$, $T_{20}=B_2C_1A_4$, $T_{21}=B_3C_0A_0$, $T_{22}=B_3C_1A_0$, $T_{23}=B_3C_0A_1$, $T_{24}=B_3C_1A_1$,
$T_{25}=B_3C_0A_2$, $T_{26}=B_3C_1A_2$, $T_{27}=B_3C_0A_3$, $T_{28}=B_3C_1A_3$, $T_{29}=B_3C_0A_4$, $T_{30}=B_3C_1A_4$

A - Growth regulator spray

A_0 = No growth regulator spray
A_1 = Spray with BNOA 25 ppm
A_2 = Spray with GA_3 100 ppm
A_3 = Spray with 2,4 -D 2 ppm
A_4 = Spray with MH 500 ppm

B - Time of Nitrogen fertilization

B_1 = Basal application of full dose(80 kg /ha)
B_2 = 50 % basal + 50% top dressing 20DAS
B_3 = 50 % basal + 25% top dressing 20DAS+ 25 % top dressing 30 DAS

C - Inoculation

C_0 = No inoculation, C_1 = Seed inoculation with *Rhizobium sp.*

CHAPTER V

SUMMARY AND CONCLUSION

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Experiment 1

The experiment on germination study under different levels of fertilizers with or without rhizobial inoculation was conducted with a view to isolating a most effective combination out of the treatments that would be potentially able to provide higher germination of seeds with quicker emergence rate and good seedling stand in the field condition which may assure better yield in turn depending on other input factors provided. Analysis of the resulting data indicated that germination percentage, seedling shoot length, seedling root length and emergence rate were better with lower dose of N.P.K(@ 20 : 10 : 10 kg per ha) fertilizers whereas seedling fresh and dry weight were higher with fertilization at higher dose (@ 80 : 40 : 40 kg per ha). Seed inoculation visibly failed to influence germination percentage of seeds as well as physical characteristics of the seedlings. Emergence rate on the other hand was probably enhanced by inoculation of seed by rhizobial strain to some extent. Chlorophyll content (chlorophyll a, chlorophyll b and total chlorophyll) of the cotyledonany leaf of seedlings though increased with increased rate of fertilization, no prominant role of seed inoculation over chlorophyll content was visible. Mean values for germination percentage of seeds as well as all other seedling characteristics studied were higher during October sowing of the crop, with exception with regard to chlorophyll content of the cotyledonary leaf of the seedlings which was relatively higher, when sowing was done during the month of January.

From the above finding it may be concluded and recommended that for better germinability of seeds with good seedling stand October sowing

may be favoured over January sowing of the crop with low rate of basal fertization .

Experiment 2

Crop yield normally depends upon a number of vegetative and reproductive components. Growth and reproduction study on French bean with rhizobial seed inoculation, varied time of nitrogen fertilization and different growth regulator spray revealed that out of the four growth regulators tried (GA_3 100 ppm, BNOA 25 ppm, 2,4 -D 2 ppm and MH 500 ppm) GA_3 100 ppm and BNOA 25 ppm emerged as most important as they could influence most of the vegetative and reproductive characters under study favourably that led to reasonable pod or seed yield in turn during both the seasons of experiment (October and January sowing) compared to other two. Effect of 2, 4-D (2 ppm) followed that of GA_3 (100 ppm) and BNOA (25 ppm) in majority of the cases or lay statistically at per with some exceptions depending on the characters studied. Result indicated that MH (500 ppm) spray failed to derive beneficial effect in the sense that it could not be contributory to final pod or seed yield of the crop.

Nitrogen fertilization in split doses (2 or 3) was found more effective and superior over single basal application with respect to a number of yield attributing vegetative and reproductive parameters with exception for a) pod length which was not effected by time of Nitrogen fertilization, b) the period of flower initiation which was shortened with single basal nitrogen fertilization and c) the pod yield itself where some ambiguity could be detected regarding superiority of basal or split application during the two seasons of growth (October and January).

Significant influence of seed inoculation over control could be detected with respect to dry matter accumulation, pod length (January sown crop), pod number, seed pod number, seed number per pod, pod yield (October sown crop), seed yield of the crop and nitrogen content of plant material (January sown crop) but plant height, number of primary branches, period of initiation of flowering & position of the first flowering node were not effected by seed inoculation.

Interaction effects of different treatment factors (growth regulator spray, seed inoculation and time of nitrogen fertilization) also yielded some significant result that varied depending on the growing seasons and the characters studied except for the character for position of first flowering node which was influenced neither by any treatment factors nor by any of their interaction effects and remain unaltered under the varying stresses. Moreover it was noticed that although the growth regulators exerted significant influence over most of the vegetative and reproductive characters during both the seasons of experiment their effects were more distinctive during January sowing of the crop in many occasions in comparison to control.

As regard total nitrogen content of plant material (leaf + root + shoot) significant contribution of growth regulator spray, rhizobial seed inoculation and split nitrogen fertilization was observed in January sown crop while growth regulator spray alone influenced total nitrogen content of plant material in October sown crop. Some interaction effects of treatment factors also influenced plant nitrogen significantly. GA_3 (100 ppm) and MH (500 ppm) spray yielded higher nitrogen content during both the seasons.

Regarding quality assessment of offspring seeds (seeds produced), some physical criteria of seeds allied with seed quality (seed length, seed breadth, seed specific gravity and seed weight) besides germination potential of the seeds were assessed. Total protein content, another important bench-mark for quality assessment of French bean seeds was also estimated. Results revealed that values for germinability of seeds produced form October sown crop was comparatively higher than those raised from January sown crop. Growth regulators spray on mother plants alone and neither bacterial seed inoculation nor time of nitrogen fertilization brought about any significant contribution towards germinability of the offspring seeds (seeds produced). The same was also true for the parameters like length, breadth and specific gravity of the offspring seeds.

Regarding germinability of offspring seeds, out of the four growth regulators tried GA_3 (100 ppm) and 2,4-D(2 ppm) performed better (germination above 80%) over others. Mean length of the offspring seeds was found maximum under control (no growth regulator spray) during both the seasons of experiment. However, growth regulator BNOA (25 ppm) and MH (500 ppm) also proved effective almost to the similar extent. Breadth and specific gravity of offspring seeds also were influenced as a result of spraying the mother plant with growth regulators and GA_3 proved most effective in this respect.

Seed weight, another vital parameter for seed quality assessment was found to be influenced on the other hand as a result of growth regulator spray (in seeds raised from both October and January sown crop) on the main crop and both growth regulators spray and time of nitrogen fertilization (in seeds of January sown crop). Growth regulator

spray yielded seeds of relatively higher weights compared to control. Total protein content of offspring seeds, was influenced significantly under different treatment factors depending on seasons of experiment and was slightly higher in the seeds of January sown crop compared to those raised from October sowing. Among the growth regulators GA_3 (100 ppm), 2,4-D (2 ppm) and MH (500 ppm) contributed almost equally over BNOA (25 ppm) and control (no growth regulator). Some significant interaction effects were also noticed.

Based on the results of the experiment , it may be concluded that a) use of growth regulators like BNOA (25 ppm), GA_3 (100 ppm) or 2,4-D (2 ppm) as foliar spray, b) split application of nitrogen fertilizer and c) bacterial seed inoculation if provided as input treatment either singly or in combination with others, may be beneficial in influencing vegetative and reproductive characters leading to pod and seed yield of the crop. For this, October sowing should be preferred over January sowing condition of the crop, especifically for seed yield which is considerably low under January sown condition.

CHAPTER VI

FUTURE SCOPE OF RESEARCH

FUTURE SCOPE OF RESEARCH

Results of present investigation indicated that growth regulator spray, rhizobial seed inoculation and time of nitrogen fertilization , all have beneficial effect over growth, yield and seed quality of French bean. However, their effectiveness were not uniform and varied depending on the agro-ecological factors of the micro-climate and the genotypic constitution of the bio-agents involved. Keeping these findings in view future research work may be concentrated on:

1) Selection of strain or mixture of strains having more compatibility with the crop variety (genotype) under study and optimisation of their doses.

2) Trial with more number of growth regulators particularly with some new ones.

3) Quality assessment on once-over harvesting for economisation of cost of cultivation.

4) Bio-chemical studies on nodular activity in relation to yield and quality.

5) Investigation on the influence of phosphatic fertilizers over plant growth and yield.

6) Multilocational trial with newly released short duration bushy type varieties in the Gangetic plain of West Bengal.

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* Original not seen.

CORRIGENDUM

Page in between	Plate No.	Denoted as	To be denoted as
57 - 58	3	G_o - G_4	A_o - A_4
		D_2 -	B_2
		R_o -	C_o