CHAPTER - V

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Food is the top most demand of life. Since the dawn of civilization, man has started to grow the plants for food purpose. But due to increasing pressure of rising human population, the demand of food is trailing behind over its supply. Thus, the aim of agricultural research is to enhance the productivity of food crops. The productivity of the crop is mainly influenced by genetic and environmental factors. Genetic factors consist with plant and genetic material which can be changed to some extent for improving the productivity of the crop. However, environmental factors consist with weather, soil and water which are difficult to control. Only a very little control on soil and water factors influencing the production of crops can be made. Therefore, growing of high yielding and improved plant types in judicious combination of agronomic practices like land preparation, sowing, fertilizer application and water management appears to be the possible ways and means for improving the productivity of crops. Recently, soybean has been introduced as most economical crop in the farming system. Therefore, the present investigation was aimed to increase the productivity of soybean
even with a limited availability of the agricultural resources. For this purpose different soil tilth, sowing methods and bacterial inoculation with nitrogen application were tried.

Different observations on growth parameters, physiological productivity rates, yield components, seed yields and soil characteristics have been made. Data thus obtained, are tabulated and the results are described in the previous chapter. These results have focussed many interesting facts of academic and applied importance which are discussed in this chapter critically along with the opinions of some other research workers with regard to these facts.

SEASONAL EFFECTS:

The prevailing weather conditions during the period of present investigation play a great role on the growth and yield of crop, besides the effects of various treatments tried. Among many factors contributing to the success or failure of agricultural production, weather conditions play a more desicive role. The weather components viz. rainfall, temperature, light and humidity etc. influence the vital physiological processes of crop and thereby, determine the actual yields.

As a whole, the weather components were normal for cultivation of soybean crop under rainfed situation
during both the years. But seed and straw yields (biomass) were nearly double uniformly under all the treatments during the year 1990-91 than the previous year (Table 16). Such variation was probably due to the effects of weather components mainly due to rainfall - its distribution and quantum. Maximum and minimum temperature ranges were almost in the same pattern during both the years of investigations, but total rainfall during the crop season (June to October) was 499.45 and 1585.60 mm in the two consecutive years as against 1300 mm mean rainfall of the locality during the same period (Table 1). This indicates that rainfall was very low in the first year of investigation while it was quite high in the second year. Generally, yields are not proportional to the amount of precipitation. But the distribution of the rainfall and the coincidence or otherwise of a plentiful supply of soil-moisture at periods of maximum crop requirement, have a bearing on yield levels. A period of moisturestress due to long dry spells at the time of flowering and pod filling stages cause more adverse effect on the yields of soybean than if it occurs earlier or later in the growth stages. Excess moisture after sowing may reduce germination, heavy rainfall during grand growth and flowering impair the nodulation and pollination respectively.

During the year 1989-90, the rainfall was low but rains were uniformly distributed with slow intensity starting from seed bed preparation to grand growth stage
of the crop. Hence, this facilitated proper land preparation for sowing, good germination of seedlings and normal growth of crop plants. But pod formation and grain filling were affected to some extent due to termination of the rains before flowering. This appears to be probable reason for the poor yield of crop during the year as compared to succeeding year. During the year 1990-91 the total rainfall was much higher as compared to average rainfall of the locality. But its distribution coincided with an adequate supply of soil-moisture to the crop plants at critical growth stages as per requirement. During this year, heavy rains occurred between last week of June to first week of July which delayed the sowing of crop for a week. After sowing, the rainfall intensity slowed down which was most favourable for germination and quick growth of plants at early growing stage. Higher plant density per unit area of land during this year than the previous year is the indication of good germination (Table 11). Thereafter intensity of rain considerably increased till grand growth period of crop. This favoured stimulating effects on growth and development of the crop. There was a very little or no rains only in few days during flowering period which helped in good nodulation (dry weight of nodules per plant), pod formation and grain filling (Table 10, 12 and 13). Therefore, seed yield was very good during the year 1990-91 as a result of most congenial weather components.
In general, the influence of weather components affected the growth and yield of experimental crop uniformly, thereby, it could be said that the differences in growth parameters, yield attributes and yields were mainly due to different treatments tried in the experimentation.

CROP GROWTH IN GENERAL:

Studies on plant population per square metre were made initially at 15 DAS and then just at harvest. The results reveal that plant population/m$^2$ were uniform under all the treatments except method of sowing at both stages during both the years. But in line sowing method the population were slightly higher than broadcasting method during both the years (Table 11).

Gradual increase in plant-height was noted upto 90 DAS growth stage under all the treatments during both the years. It was notable that height of soybean plants increased rapidly upto 60 DAS and then the rate of elongation in plant stalks declined (Table 3). Similarly, number of basal branches per plant increased successively upto 90 DAS growth stage with the rapid rate of increase till 60 DAS growth stage. There was a negligible or no increase in both the above mentioned growth characters after 90 DAS growth stage in soybean crop.
EFFECT OF TILLAGE OPERATIONS ON GROWTH CHARACTERS:

It is evident from the results (Table 3 and 4) that plant-height and number of basal branches per plant were unaffected at all growth stages due to adequate and zero tillage operations. But adequate tillage had greater LAI values than zero tillage at all growth stages during both years (Table 5). These results indicated that soil-tilth obtained either by doing adequate tillage operations to loose the sub soil surface with the help of implements or by killing the young germinating weeds with the use of herbicide (paraquat) provided the similar conditions for germination of seeds and growth of plants. Generally, optimum soil-tilth provides loosened and well aerated conditions for sowing the seed which helps in good germination. Meanwhile germinated weeds are also destroyed in adequately cultivated lands. This condition minimized the crop-weed competition during lag growth stage of the crop. Under zero tillage method, preparatory tillage operations were eliminated by killing all the existing weeds emerged on the field with use of paraquat herbicide before sowing of the seeds. Both these seed beds provided similar situations for sowing of the seeds. The seeds were well covered in soil under both i.e. line and broadcast methods. There was adequate aeration and moisture contents in both type of seed beds for germination of the seeds. As a consequence, plant population and then growth characters such as, plant-height and number of basal branches per plant were identical
under both the soil tilth. Similar opinions have been reported by other workers from their studies (Jain et al., 1984; Wiley, 1986; Anonymous, 1991; and Tyler and Overton, 1991).

The LAI values shown their superiority under adequate tillage over zero-tillage. Due to loosening of sub soil surface under adequate tillage, provided better condition for development of rootlets which probably helped for production of slightly broader leaves and ultimately numerically higher number of basal branches per plant than zero tillage method. The results are in confirmity with the opinions of Wrucke and Arnold (1985), Knight and Lewis (1986) and Singh (1987).

**EFFECT OF TILLAGE OPERATIONS ON PHYSIOLOGICAL GROWTH ANALYSIS:**

Dry matter production per plant exhibited a linear curve pattern upto harvesting stage of the crop under both tillage methods during both the years (See Fig. 3). There was no marked difference in DM accumulation rate between adequate and zero-tillage treatments during 1990-91 but adequate tillage proved its significant superiority over zero tillage with this regard at 60, 90 DAS and harvest stages (Table 7). The DM accumulation per plant upto 30 DAS was slow during both the years. After this, the plants entered in a rapid rate of DM accumulation upto 90 DAS about 90% of total DM per plant was accumulated
upto this stage. Again the rate of DM accumulation declined from 90 DAS to harvest stage. The variation in DM accumulation rate after 30-day growth stage between the two years of experimentation was mainly due to the influence of varying rainfall conditions. The DM accumulation rate was slow under both tillage methods during the year 1990-91 than the previous year upto 60 DAS as a result of high rainfall. The rainfall became slower after 60 DAS stage during 1990-91 which resulted into a very high DM accumulation rate between 60 to 90 DAS stage. Consequently, the pattern of DM accumulation changed in 1990-91 from 1989-90. Though the values of DM accumulation rate under adequate tillage method were higher than under zero tillage at all growth stages during both the years, they reached to the level of significance during 1989-90 only after 30 DAS growth stages. Such superiority of adequate tillage method may be probably due to better root development and uptake of moisture and nutrients as a result of loosen sub soil surface. Similar results reported by Anonymous (1986), Sumarno (1987), Terreros et al. (1987) and Anonymous (1991).

In general, CGR values increased upto 60 DAS growth stage and then declined upto the harvest stage of the crop (Table 8). Thus, it exhibited a sigmoid growth pattern during both the years. Confirming the views of Sumarno (1987), Terreros et al. (1987) and Anonymous (1991).

It was noticed from the results that adequate
tillage had consistently higher CGR over no-tillage upto 60 DAS and trends reversed after this stage. There was no significant difference in CGR upto 30 DAS (lag-stage) between both the tillage operations but the values differed between them after this stage during 1989-90. The values of CGR may be attributed to LAI as also reported by Wrucke and Arnold (1985), Knight and Lewis (1986) and Singh (1987).

In general, the RGR values were higher at early growth stages and then declined till harvest stage with rapid rate after 60 DAS (Table 9). The RGR values were higher under adequate tillage method than zero tillage at 30, 60 and harvest stages and position reversed at 90 DAS.

Rate of reduction in RGR values at advancement of growth stages may be probably due to older leaves resulting in low photosynthetic efficiency. Other possibilities for reduced RGR may be due to low light penetration within the canopy at advanced growth stages. Hari Singh and Rai (1979) have also reported that low light penetration on lower leaves at advanced growth-stages due to over lapping of leaves resulted in low photosynthetic rate, thereby reduce the RGR.

**EFFECT OF TILLAGE OPERATIONS ON NODULATION:**

Studies made on number of nodules per plant, weight of fresh nodules per plant and weight of dry nodules
per plant indicated that adequate tillage operation had numerically higher values of these parameters at flowering stage (60 DAS) than zero tillage but difference were significant for number of nodules per plant during both the years. In the first year, dry weight of nodules per plant was also higher under adequate tillage over no tillage. Nodulation can grow actively if the crop is healthy and nutrient supply is adequate. Well aerated soil-tilth obtained from adequate tillage in the root zone of crop is helpful for better nodulation (Russell, 1977). The pink colour due to presence of leghaemoglobin is the characteristics of nodule fixing nitrogen which is mainly absent or low in poor growth of plant as a result of poorly aerated, moisture stressed and nutrient deficient soil. Adequately tilled seed bed provides these conditions ideally, hence contributed to superior nodulation parameters.

EFFECT OF TILLAGE OPERATIONS ON YIELD ATTRIBUTES:

The results on yield attributes such as, pods per plant, unfilled pods per plant, weight of pods per plant, seeds per pod, weight of seeds per pod, weight of seeds per plant, weight of straw per plant were mainly unaffected by both tillage operations. Numerically, plant population, number of seeds per pod, weight of seeds per pod and test-weight of seeds were higher under adequate tillage method than zero-tillage which had positive co-
relation with seed yield. On the other hand, unfilled pods per plant were numerically lower under adequate tillage than zero tillage which had negative relationship with seed yield (Table 12, 13 and 14). Thereby seed yield per plant was slightly higher with former than later. Higher straw yield per plant in adequately tilled plot over zero tillage was attributed to superior plant height and branches per plant. The superior growth characters and physiological growth rates under adequate tillage method might have resulted in superior yield attributes. Similar results have been reported by Wrucke and Arnold (1985), Anonymous (1986), Knight and Lewis (1986), Sumarno (1987), Terreros et al. (1987) and Anonymous (1991).

EFFECT OF TILLAGE OPERATIONS ON YIELDS:

Biologically yield is considered to be the weight of total dry matter production of plants after leaving root exudates (biomass) from an unit area of land. But agriculturally, yield is bifercated in two parts i.e. seed yield (economic yield) and straw yield. It is obvious from the results (Table 16) that both seed and straw yields did not differ much between adequate and zero tillage treatments. Numerically, adequate soil-tilth gave higher seed yields than no tillage during both the year. Straw yield was superior in adequate tillage treatment over zero tillage during 1989-90 only and the results reversed in the next year. Adequate tillage method heled to loosen the compacted
sub soil layer of clayey soil within the root range of the crop plants. The soil-tilth obtained from adequate tillage was friable, fine and loose textured which provided favourable conditions for proper germination of seed, adequate root development, active nodulation and efficient utilization of food nutrients and moisture by plants. Thus, adequate tillage condition might have attributed to good growth and yield attributes and ultimately yields to some extent as discussed earlier. Direct seeding under no-tillage method after killing the newly emerged weeds with the use of paraquat herbicide also provided nearly indentical seed bed condition as in case of adequate tillage. There were sufficient rains before sowing time of the crop during both the years. This had made possible to obtain the ideal seed bed by killing the weeds with herbicide under no-tillage. The seeds were kept at desirable depth where adequate moisture and air were available for germination under no-tillage condition. This may be the possible reason due to which yields did not reduce much under no tillage situation over adequate tillage. Many research workers have emphasized that soybean yield was at par between conventional and zero-tillage situations provided weeds were controlled adequately before sowing, seeds were covered properly after sowing and adequate soil moisture made available at sowing (Hughes and Baker, 1977; Buss and Camper Junior, 1981; Wiley, 1986; Terreros et al., 1987; Webber et al., 1987; and Anonymous, 1991).
EFFECT OF SOWING METHODS ON GROWTH CHARACTERS:

Both sowing methods (line and broadcast sowing) did not show marked influence on growth characters namely, plant-height and number of basal branches per plant at all growth stages of crop during both the years (Table 3 and 4). Numerically higher LAI values were recorded under line sown crop than broadcast sown crop at all growth stages during both the years but differences were significant only in the first year of experimentation. Deviation in LAI value was also significantly higher under line sowing method at 60 DAS growth (mid growth) stage during the second year of experimentation (Table 5). Line sowing method provided more ideal conditions for good germination of seeds and hence, plant density per unit area was more under this method than broadcast sown crop (Table 11). There was chances of greater intra-row competition in the line sown crop which attributed slightly taller plants than that of broadcast sown plots. The distribution of plants in cropped area under broadcast sowing treatment was uneven. Some plants got sufficient space for growth and development, whereas many other plants offered competitive stress of over crowding. This might have resulted into production of slightly lower number of branches per plant, though the differences were not significant. The distinct superiority of greater LAI values under line sowing treatment over broadcast sowing was mainly because of higher plant densities per unit area as a result of good germina-
tion. Greater photosynthetic area under line sown crop stand over other was one of the possible reasons for slight improvement in the growth parameters like plant height and number of branches per plant.

EFFECT OF SOWING METHODS ON PHYSIOLOGICAL GROWTH ANALYSIS:

DM accumulation rate was comparatively higher in line sown crop than broadcast sown crop at all growth stages during both the years but differences were significant after 60 DAS growth stage during 1989-90 and after 90 DAS growth stage during next year (Table 7). As discussed above, the growth of plants was superior under line sown crop because of more photosynthetic area (LAI). Moreover, natural resources like light, space, nutrients and water were more effectively utilized by the plants in line sowing method because of proper row spacing than that of unevenly distributed plants in broadcast sowing. This may be also a reason for greater DM accumulation rate in line sown crop. In general, accumulation of photosynthate was slow due to less foliage at early stage, hence the difference in DM production per plant was not significant upto 30 DAS stage. Though the leaves become older and some of the leaves started to fall down after 90 DAS stage, the DM accumulation rate was maximum at final stage.

In general, CGR values were greater in line sown crop over broadcast sown crop with marked differences at
advanced growth stages (60 DAS and harvest) and at early stage (30 DAS) in the two consecutive years (Table 8). The CGR values were lower during early stage as a result of low photosynthetic activity and then tended to raise up to maximum limit at grand growth stage (60 to 90 DAS) because of high photosynthetic activities as well as absorption of food nutrients in large amount. The CGR rate declined at final stage because food assimilated in plants was utilized in formation and development of seeds. The DM accumulation rate had positive relation with CGR which attributed the superior CGR values under line sown crop.

The RGR values were significantly higher in line sown crop than broadcast sown crop till 60 DAS stage and then position reversed at advanced growth stages with non-significant differences between both the methods of sowing (Table 9). This indicated that as the leaves became older, their photosynthetic efficiency was reduced.

**EFFECT OF SOWING METHODS ON NODULATION:**

Line sowing method proved superior over broadcast method with regard to number of nodules per plant, weight of fresh nodules per plant and weight of dry nodules per plant recorded at 60 DAS growth stage but difference was significant only for weight of dry nodules per plant (Table 10). The nodulation in plant roots under line sown crop was greater because of proper utilization of added
fertilizer and moisture and adequate aeration. The nodules seemed to be more active gauged from the pink colour inside the nodules indicating the presence of leghaemoglobin in line sown crop. The weight of dry nodules per plant was significantly higher in the line sown crop. Similar results have been reported by Singh (1971), Koranne et al. (1975) and Singh et al. (1991).

**EFFECT OF SOWING METHODS ON YIELD ATTRIBUTES:**

Yield attributing characters having positive relationship with seed yield namely, pods per plant, weight of pods per plant, seeds per pod, weight of seeds per pod, weight of seeds per plant and seed test-weight were superior in line sown crop over broadcast sown crop with marked differences in weight of seeds per plant during 1989-90 and pods per plant during 1990-91 (Table 12, 13, 14 and 15). But number of unfilled pods per plant were lesser in line sown crop than broadcast sown crop in first year while reversed in second year with non-significant differences (Table 12). The superiority in above yield attributing characters might have attributed to superior growth characters under line sowing method. These results are in accordance with the findings of Singh (1971), Mehta et al. (1976), Jain et al. (1989) and Singh et al. (1991).

**EFFECT OF SOWING METHODS ON YIELD:**

Seed yields per hectare were significantly higher
under line sowing method than broadcast sowing method during both the years of experimentation (Table 16). It was remarkable that plant density per unit area was significantly higher in line sown crop which was the main cause for marked superiority for yields in line sown crop. The superiority in yield attributing characters under line sowing also appeared to be one of the probable reasons for good seed yields. Straw yield per hectare was also significantly higher in line sown crop over broadcast sown crop in first year of experimentation but it was slightly lesser in the second year. Growth characters such as, plant-height and branches contribute much to straw yield which may be the reason for higher straw yield in line sown crop. Similar results have been reported by Koranne et al. (1975), Singh and Modgal (1979), Chandel and Saxena (1986), Jain et al. (1989) and Sharma and Thakur (1989).

EFFECT OF INOCULATION AND NITROGEN APPLICATION ON GROWTH CHARACTERS:

In general, plant-height did not differ among the inoculation and nitrogen application treatments during both the years of investigation (Table 3). In broader sense, the plants were shortest under control (no inoculation no nitrogen) among all treatments at all growth stages during both the years. Treatments receiving either inoculation alone or 20 Kg N/ha alone produced the plants of identical height and proved their superiority over control
at all growth stages. The treatment receiving inoculation + 20 Kg N/ha produced significantly the tallest plant at all growth stages exceptionally at early growth stage in second year of experimentation. While studying the branching per plant, the lowest basal branches per plant was recorded under control (Table 4) which was statistically at par to the treatments receiving inoculation alone as well as 20 Kg N/ha alone. Application of 20 Kg N/ha along with inoculation of seed had the maximum basal branches per plant being statistically on par to other treatments except control. These results indicated that all the treatments receiving inoculum or nitrogen had their superiority with regard to growth characters like plant-height and basal branches per plant over control (untreated plot).

The LAI values were lowest under control and the values significantly increased in order of inoculation, 20 Kg N/ha and inoculation + 20 Kg N/ha treatments. Application of 20 Kg N/ha also proved its superiority over inoculation treatment in respect of LAI. Supplementation of 20 Kg N/ha with inoculation produced the highest LAI values. These results indicated that application of 20 Kg N/ha was essential in soybean cultivation for improving the photosynthetic activities. Use of inoculants alone (a) or 20 Kg N/ha alone (b) or the combination of (a) + (b) improved the photosynthetic area and thus resulted into production of taller plants with more branches when compared with control. It is also established fact that nitrogen
is growth promoter which probably helped in the synthesis of more chlorophyll leading to greater photosynthesis and supply of its products to dividing and enlarging cells hence, ultimately resulted in production of taller plants with more branching and foliage. Similar results have been reported by Singh and Saxena (1973), Namdeo and Ghatge (1976), Rastogi et al. (1981), Bisen et al. (1983), Bisen (1986), Alam et al. (1988), Singh and Singh (1989), Jayapaul and Ganesaraja (1990) and Patel and Patel (1991).

It was notable that effect of different inoculation treatments significantly behaved in differential manner under both methods of sowing. LAI reduced with faster rate in broadcast sowing than line sowing method under control and inoculation alone treatments. But rate of reduction in LAI values under broadcast sowing over line sowing was slow when either 20 Kg N/ha alone or inoculation + 20 Kg N/ha was applied (Table 6).

The results revealed that application of a little dose of nitrogen was essential for soybean cultivation. This also confirms the views of Hatfield et al. (1974), Patil et al. (1976), Joshi et al. (1986), Patel et al. (1988) and Singh and Singh (1989).

Plant population/m² were unaffected by any of the treatments receiving inoculation and nitrogen application alone or in combination with each other. This showed that inoculation or N-application did not cause any adverse
effect on germination and then further growth of the crop plants.

**EFFECT OF INOCULATION AND NITROGEN APPLICATION ON PHYSIOLOGICAL GROWTH ANALYSIS:**

Results showed that rate of DM accumulation was the lowest under control (a) and it increased in ascending order of inoculation alone (b), 20 Kg N/ha alone (c) and inoculation + 20 Kg N/ha (d). In general, the differences in DM production per plant did not vary much between (a) and (b); (b) and (c); and (c) and (d) treatments at all growth stages during both the years (Table 7). Inoculation of bacterial culture or application of nitrogen alone or in combination with each other increased the LAI at all growth stages of crop which influenced the photosynthesis and DM accumulation rate in plants positively. These results are in conformity with the findings of Weaver and Fredrick (1972), Singh and Saxena (1973) and Rastogi et al. (1981).

The CGR value was minimum under control which increased due to inoculation alone, 20 Kg N/ha alone and inoculation + 20 Kg N/ha. The CGR followed the same pattern as in case of DM accumulation rate per plant described above. The increased LAI values due to application of nitrogen alone or in combination with appropriate bacterial culture on seed surface before sowing of seed had contri-
buted to higher CGR was also reported by Weaver and Fredrick (1972) and Reddy and Bhardwaj (1982).

Control treatment had the lowest RGR value among different inoculation and nitrogen application treatments till 60 DAS growth stage but the values reached to highest in control treatment after the advancement of the growth stages. The RGR values were lowest in control plot at early stage due to less LAI values and changed in advanced growth stages due to less shading effects on lower leaves because of smaller leaves in poorly developed plants under control plots.

**EFFECT OF INOCULATION AND NITROGEN APPLICATION ON NODULATION:**

Results shown in Table 10 indicated that inoculation and nitrogen application treatments exerted their significant influence on number of nodules per plant and weight of fresh or dry nodules per plant. Control plot (a) had the lowest number of nodules per plant followed by inoculation alone (b), 20 Kg N/ha (c) and inoculation + 20 Kg N/ha (d) but the difference between (b) and (c) was not much. Weight of fresh and dry nodules per plant followed the same pattern as followed by number of nodules/plant due to these treatments but the variation between (a) and (b); and (b) and (c) in case of weight of fresh nodules per plant and between (a) and (b) in case of weight of dry nodules per plant was not significant. The poorest
activities of nodulation under control plot gave an indication that inoculation of bacterial culture on dry surface of seeds before sowing or application of 20 Kg N/ha was essential to the crop. Further more, when inoculation and nitrogen application both were practiced together, the nodulation activities improved considerably. Similar influence of inoculation and nitrogen application on nodulation activities in soybean have been observed by Shahidullah and Hossain (1980), Adrelean and Morea (1981), Rastogi et al. (1981), Chamber (1983), Scholles et al. (1983), Prabhakaran and Subramaniam (1991) and Singh and Gopalaswamy (1991).

EFFECT OF INOCULATION AND NITROGEN APPLICATION ON YIELD ATTRIBUTES:

Yield attributing characters like pods per plant, weight of pods per plant, number of seeds per pod, weight of seeds per pod, weight of seeds per plant and test-weight were lowest under control (a) followed by inoculum (b), 20 Kg N/ha (c) and inoculum + 20 Kg N/ha (d). The variations in test-weight due to these treatments were not remarkable while other yield attributes being at par under (b), (c) and (d) treatments were significantly superior over (a) (Table 12, 13, 14 and 15). Good growth of crop plants due to (b), (c) and (d) treatments might be the possible reason for the production of superior yield attributes. The results corroborated the findings of Thakur

EFFECT OF INOCULATION AND NITROGEN APPLICATION ON YIELDS:

Both seed and straw yields per hectare did not differ much due to different inoculation cum nitrogen application treatments during the year 1989-90, but they varied significantly in the year 1990-91. On the basis of two years pooled data, no inoculation and no nitrogen produced the lowest seed yield of 1270 Kg/ha which increased by 3.20, 6.82 and 9.99 per cent due to inoculation alone, 20 Kg N/ha alone and inoculation + 20 Kg N/ha respectively. Straw yield was 2408 Kg/ha in control treatments which stepped upto 5.46, 5.23 and 9.75 per cent due to inoculation, 20 Kg N/ha and inoculation + 20 Kg N/ha respectively. Similar positive response of soybean to inoculation and nitrogen application has been reported by various workers from their studies made under varying agro-climatic conditions (Patil et al., 1976; Rastogi et al., 1981; Bisen et al., 1983; Chamber, 1983; Sharma and Pahalwan, 1983; Prodan and Prodan, 1986; Alam et al., 1988; Anonymous, 1988; Jain et al., 1988; Jayapaul and Ganesaraja, 1990; and Singh and Gopalamswamy, 1991).

Though the interactions were not found to be significant for seed and straw yields, the combined effects
of treatments have manifested the results of applied values. Among the all sixteen treatment combinations tried, the treatment consisted with adequate tillage, line sowing and inoculation + 20 Kg N/ha gave the highest seed yield during both the years, whereas combination of zero-tillage, broadcast sowing and no inoculation and no-nitrogen produced the lowest seed yield (Table 17). In general, the reduction of yield in zero tillage over adequate was not much considerable but it reduced to the greater extent by broadcast sowing as well as by eliminating the inoculation and nitrogen application. Thus, it could be asserted from the results that soybean can be grown for good harvest by eliminating adequate tillage with direct seeding in rows on weed free seed bed and application of 20 Kg N/ha along with bacterial inoculation.

**HARVEST INDEX**

Ratio of grain out of total biomass in terms of percentage is known as harvest index. It did not vary due to varying soil-tilth or sowing methods or inoculation and nitrogen application treatments alone or possible combination of all treatments during both the years. The values of HI were lesser in the first year of experimentation than the next year (Table 15). The results indicated that the treatments tried in the investigation had no effects to change the HI values. The reduction in HI values during first year of investigation was mainly due to
production of small seeds with light weight because of moisture stress at reproductive and maturity phases.

QUALITY OF SEED:

Protein content in the seed was unaffected by different soil-tilth, sowing methods and inoculation cum nitrogen application treatments. The protein content of straw was also unaffected due to these treatments. Hence, total protein content per plant did not vary due to the treatments tried in the present investigation (Table 18). Similar results have been reported by Chasney (1973). On the contrary, Joshi et al. (1982), Sharma and Pahalwan (1981) and Jayapaul and Ganesaraja (1990) have found increase in protein content due to nitrogen.

NPK STATUS OF THE SOIL BEFORE SOWING AND AFTER HARVEST OF THE CROP:

From the results, it is obvious that initial N, P and K status of the soil was fairly uniform under all treatment plots during both the years before sowing of the crop in the experimental field (Table 19). A little increase in residual nitrogen content of the soil under all the treatments was recorded after the harvest of the crop during the first year of experimentation but in the next year, there was a slight reduction in residual N-content of the soil. In general, the yield of crop during the first year was less due to moisture stress condition
existed in the soil during the period from flowering to maturity stages. Thus, the nitrogen obtained by shedding from root-nodules on advance growth stages could not be utilized by the crop and remained as a residual content in the soil. But during the next year there was adequate soil moisture upto maturity stage of crop which helped in uptake of mineralized nitrogen during advanced growth stages. Hence, the status of residual nitrogen declined. Secondly, soil was subjected to nitrogen determination immediately after the harvest of crop, thus, actual residual N-status could not be made. According to Whitny (1967) residual N-contents of the soil increased when soil analysis was made after the decomposition of plant residues and root nodules.

Both P and K contents also declined after harvest of crop over initial status of respective nutrients in the soil. This indicated that all applied P and K fertilizers were effectively utilized by the crop during both the years. Van Schreven (1958) has also mentioned that legume make high demands upon on phosphorus and potassium due to the production of ample protein containing materials.

**NITROGEN ECONOMY THROUGH INOCULATION:**

At present the price of fertilizers are increasing tremendously every year due to acute energy crises in the World particularly in developing countries like India.
There is national policy to economize the usage of costly fertilizers by introducing bio-fertilizers and organic manures in farming system. In present investigation four treatments viz., no-inoculation + no-nitrogen (a), inoculation of bacterial culture alone on seed surface before sowing (b), application of 20 Kg N/ha (c), and inoculation of bacterial culture + 20 Kg N/ha (d) were compared to see their effects on the seed yields of soybean crop. The results revealed that (a) gave the lowest seed yield of 1270 Kg/ha on the basis of two years experimentation which increased in tune of 42, 93 and 151 Kg/ha due to (b), (c) and (d) treatments respectively. Additional seed yields of 42 and 58 Kg/ha under (b) and (d) treatments due to bacterification of Rhizobium culture gave an credence to belief that application of costly N-fertilizer (non-renewable energy) could be eliminated or minimise with the use of cheaper bio-fertilizer (bacterial culture).

ECONOMICS OF THE TREATMENTS:

Determination of yield advantages in terms of monetary return appears to be a meaningful criteria for the farmers to choose a farming system on the basis of the resources available with them. Determination of monetary return for a particular farming situation, has a lacuna that the prices fluctuate from place to place and time to time. Hence, a profitable farming system for one place at a particular period may not be advantageous
for other place or time. But the economic factors like monetary returns per unit area and benefit-cost ratio determined on the basis of existing market prices of output and input may be certainly meaningful for the locality where such studies has been made.

**MONETARY RETURN:**

Cost involved for growing soybean crop under different farming practices in an unit area of land is given in Appendix XVIII (a), (b), (c) and (d). Data revealed that the total cost of cultivation per hectare area varied between Rs. 4,164.00 to Rs. 5,019.00/ha depending on the different farming practices of the treatments. Land preparation with adequate tillage required an extra investment of Rs. 640.00/ha over zero tillage. Similarly, an additional expenditure of Rs. 50.00 was needed in line sowing than the broadcast sowing. Inoculation of the seed, 20 Kg N/ha and inoculation of seed + 20 Kg N/ha needed an extra expenses of Rs. 35, 135 and 170/ha respectively over control.

Soybean grown by broadcast sowing with zero tillage and no-inoculation + no nitrogen application \((T_1S_2I_0)\) registered the lowest monetary return during both the years. Treatment \(T_2S_1I_3\) (Adequate tillage + line sowing + inoculation of seed along with 20 Kg N/ha) fetched the highest monetary return closely followed by \(T_1S_1I_3\), \(T_2S_1I_2\)
and \( T_1S_1I_2 \) treatments (Table 20). The net profit per unit area is more meaningful concept for assessment of farming practices than gross monetary return. This represents the actual profit gained by a particular farming situation and it is calculated by subtracting the cost of cultivation involved for the particular treatment from the gross monetary return realized from the produce of the respective treatments.

It is most remarkable that zero tillage had registered higher net profit per hectare over adequate tillage consistently during both the years (Table 21). This revealed that there was a very little decrease in the yields under zero tillage over adequate tillage, but the cost involved in adequate tillage operations was quite high (Rs. 640.00/ha). Hence, zero-tillage proved better and gave an additional profit of Rs. 403.00/ha over adequate tillage (Rs. 6,575.00/ha) on the basis of two years mean data. Among the two methods of sowing, line sowing gave the net profit of Rs. 6,720.00/ha which was nearly Rs. 1,000.00/ha higher than that of broadcast sowing. This remarked that handsome profit could be achieved by sowing the seeds in rows only with a very little investment (Rs. 50.00/ha) on sowing over broadcast sowing. It was most remarkable to note that line sowing was more profitable method of sowing under zero-tillage than adequate tillage situation. Seed could not be covered properly under zero
tillage when broadcast sowing was practiced. Hence, poor yields in this situation might have given lesser profit.

Use of bacterial inoculation alone or application of 20 Kg N/ha alone or combination of inoculation + 20 Kg N/ha gave an additional net profit of Rs. 316, 627 and 995/ha over control (Rs. 5,889.00/ha) on the basis of two years mean data. The results asserted that costs involved in inoculation or nitrogen application were not much high, but they helped to increase the production effectively. Hence, good profits can be obtained with them.

With regard to net profit per hectare as influenced by different treatment combinations, the maximum profit was recorded with $T_2S_1I_3$ closely followed by $T_1S_1I_3$, $T_1S_1I_2$ and $T_1S_1I_1$, $T_1S_2I_3$, $T_2S_1I_2$ and $T_1S_1I_0$. These results remarked that $T_1$ (no tillage) gave considerably good profits, when sowing was done in rows even without use of inoculation and nitrogen under agroclimatic conditions of Sagar region. On the basis of profits recorded under $T_1S_2I_3$, it can be stated that broadcast sowing could be followed under no tillage when 20 Kg N/ha was given along with seed inoculation. Broadcast sowing under adequate tillage without use of nitrogen and seed inoculation ($T_2S_2I_0$) gave the lowest return. This indicated that nitrogen application was most essential in the soils of Sagar region.
BENEFIT-COST RATIO:

The monetary return per rupee investment in the different farming practices is output-input ratio or benefit-cost ratio. This gives an estimate of benefit obtained from the farming practice for every one rupee of expenditure incurred. The results showed (Table 23) that no-tillage had greater (2.54) values over adequate tillage (2.26). The superiority of no-tillage over adequate tillage was more consistent in line sowing than broadcast sowing method because of higher yields. Consequently, combinations of zero tillage and line sowing proved to be cheaper cultivation practices even without application of N-fertilizers. Supplementation of inoculation with this combination raised the profit handsomely only with increase in a little investment. Profitability increased due to use of bacterial inoculation or nitrogen application (20 Kg N/ha) alone or combination of both over control. This remarked that rate of increase in profits due to bacterification or nitrogen application over control was quite economical.

Over all picture of above discussion concludes that no tillage with line sowing and application of 20 Kg N/ha along with seed inoculation was profitable for soybean cultivation. Similar results have been reported by Singh and Modgal (1979), Wiley (1986), Verma et al. (1988) and Sharma and Thakur (1989) from their studies.