CHAPTER-V

DISCUSSION
Pulses research in the new millennium has its task cut out to reverse the increasing trend of the population's over dependence on cereals. Our food strategy, however, can not be restricted to only one front as cereal production. There is thus, a need for multipronged strategy to feed our ever increasing millions. It is necessary, therefore, to take stock of forgotten fronts and take necessary steps in making subsequent progress in 'green revolution' to cover these, lest our 'revolution of boon' turn into harbinger of calamity. Production of pulses (the grain legumes) is one such forgotten front and its vitalness in providing nutritionally balanced meals for Indian masses calls for immediate attention.

Pulses are the important source of vegetable protein in human and animal nutrition especially in developing countries. The productivity of pulse crops is often constrained by nutrient imbalance and inadequacy especially in rainfed areas. Most pulses are cultivated on marginal and sub-marginal lands, which are impoverished of plant nutrients and consequently their yield potential is not realized. The increasing nutrient demand for augmenting of the growing population calls for exploitation and utilization of macro and micro nutrient fertilization.
In Chhattisgarh, cultivation of pulses is mostly concentrated in *rabi* season (9.13 lakh hectares) after the harvest of *kharif* rice/soybean or in the *kharif* fallow lands. Sowing of different duration of rice varieties vacate the field for *rabi* crops at varying times. Early cessation of rains during *kharif* season also led to fast depletion of moisture, as a result, sowing and germination of pulses are adversely affected. The soil of the state vary in texture, structure, bulk density and organic matter content which affects the infiltration and storage of available moisture. In Chhattisgarh, during *rabi* season pulses are mostly grown as relay crop specially in mid and low land rice. In some areas, it is also grown after field preparation by utilizing residual moisture or with partial irrigation facilities. Now there is need to shift in cropping plan and management of legumes to make this farming more profitable. The farmers perceptions about pulses that these crops are component of subsistence farming need to be changed. However, in certain pockets of state where assured irrigation is available inclusion of high value crop like frenchbean or rajmash will definitely uplift the socio-economic conditions of poor farming community of Chhattisgarh state. This will also meet their need of the household with saleable surplus in local market.

Rajmash is poor in nodulation, so its nitrogen requirement is more than other pulses. Adequate supply of macro and micro nutrients along with FYM are important for proper growth and development, which is a pre requisite for higher yield. Like other nutrients, importance of zinc cannot be
Zinc is playing role not only in improving nitrogen use efficiency, but contributes positively in the nodulating leguminous species. The addition of FYM improve the physico-chemical properties of soil and maintain the soil fertility. Therefore, in heavy soils of Chhattisgarh, it is necessary to evaluate the optimum levels of nitrogen, zinc and FYM for obtaining good yield of rajmash.

In view of this, the present investigation entitled "Effect of organic and inorganic nutrition on productivity potential, economics and energetic of rajmash (Phaseolus vulgaris L.) under Vertisols of Chhattisgarh plains" was carried out during the rabi seasons of 2004-05 and 2005-06. The treatments consisted of two FYM levels i.e. 0 and 5 t ha⁻¹, three nitrogen levels i.e. 0, 60 and 120 kg N ha⁻¹ and two zinc levels i.e. 0 and 20 kg ZnSO₄ ha⁻¹. The results of the two years experimentation on above aspects are briefly discussed in this chapter vis-a-vis the views of earlier researchers.

5.1 Seasonal effect

The growth and yield of a crop is mostly governed by the genotype, agro-management techniques and the environment to which the crop is exposed. Among the environmental factors weather condition such as rainfall, relative humidity, temperatures, evaporation, solar radiation etc play crucial role in the performance of crop under a particular farming situation.
Plate 1: A general view of experimental site of Rajmash
Rajmash (*Phaseolus vulgaris* L.) is one of the important pulse crops grown extremely under too high hills and good dry temperate condition of Himachal Pradesh. The introduction of rajmash in the plains of northern and central India as a *rabi* crop is one of the commendable contribution of the pulse scientists in the recent years. Frenchbean has now been proved a potential winter pulse crop (Ali and Kushwaha, 1987). The crop is highly sensitive to temperature and other climatic variation. Frenchbean is a slow growing crop and takes long time for the crop to cover the ground. Frenchbean is traditionally a rainy season (*kharif*) crop in the likely tracts of the country. It is more suitable as a winter (*rabi*) crop in the north eastern plains of India (Anonymous, 2000-01).

Ali and Shankar (1991) also reported the specific adaptation of frenchbean to a cool and long growing season. Sahu *et al.* (1994) and Pandey *et al.* (2004) also observed a sharp decrease in the yield of rajmash with delayed sowing because of reduced the number of pods plant\(^1\).

### 5.2 Effect of FYM on rajmash

#### 5.2.1 Crop growth

The plant height of rajmash increased with the age and was maximum at harvest. The height of the plant accelerated at increasing rate up to maturity stage, though the pace of increase was decreased from 90 DAS to maturity stage (Table 4.2). Photosynthetic food material synthesized during vegetative stage gets deposited in leaves and other growing plant...
part, leading to enlargement and development of meristmatic tissues. This causes faster growth of growing points, ultimately more plant height and number of leaves. But at the reproductive stage, the food material manufactured during photosynthesis get partitioned for the development of sink and source, leading to slow growth of plant height at this stage. Shrinkage in the tissues and development of senescence of leaves at harvest led to slow growth in plant height at this stage:

Application of 5 t FYM ha\(^{-1}\) produced significantly taller plants at all the growth stages, except at 30 DAS during both the years, at 90 DAS during 2005-06 and at harvest during 2004-05 and on mean basis (Table 4.2). Bhatiya and Shukla (1982) reported that FYM not only provides essential plant nutrients but also leads to build up organic carbon and improve the soil physical condition as well as the soil biotic life. Purushottam and Puri (2002), Kumar and Puri (2002) and Kumar et al. (2004) also noted highest gain in plant height with the application of FYM in rajmash as compared to no FYM.

Rajmash plant produced more number of branches plant\(^{-1}\) between 30 DAS to 90 DAS in comparison to 90 DAS to at harvest (Table 4.3). Application of 5 t FYM ha\(^{-1}\) produced significantly higher branches plant\(^{-1}\) at all the stages of growth, except at 30 DAS during 2004-05 and 2005-06 and at 60 DAS during 2005-06. Application of 5 t FYM ha\(^{-1}\) gave significantly higher LAI in almost every stages during both the years and on mean basis
except at 30 DAS during 2005-06, at 90 DAS and at harvest during 2005-06 (Table 4.4). Increment in the number of nodes and internodes with increase in plant height and more number of leaves plant$^{-1}$ is the cause for more LAI in taller plants as compared to stunted plants because each leaf emerges from stem node. Development of senescence in older leaves might be the cause of decline in LAI at 90 DAS (Kumar and Rao, 1999).

Significantly more dry matter was accumulated by the application of 5 t FYM ha$^{-1}$ at all the stages of growth during both the years and on mean basis (Table 4.5). Plots receiving no FYM produced lesser branches and reduced the plant height, which may be the probable cause for low dry matter accumulation in plants. This result support the findings of Singh and Rai (2004), who reported an increase in shoot weight with the application of FYM. Synthesis of photosynthetic food material during vegetative phase might be responsible for dry matter accumulation. The treatments, which accumulated more, growing degree days showed higher efficiency for heat use in terms of dry matter accumulation as well as in terms of seed yield. It is also due to the direct relationship existing between them. This increase in LAI and dry matter accumulation may be attributed due to increase in number of leaves, branches and plant height. It was reported that number of leaf and dry matter accumulation were directly correlated with plant height and number of branches (Rajput et al., 1995).
The amount and intensity of energy intercepted and photosynthetic efficiency of the leaf or canopy determine the crop growth rate (Malik et al., 1988). Use of 5 t FYM ha$^{-1}$ recorded higher CGR at 30-60 DAS and 60-90 DAS (Fig. 4.1). Rajput (1998) recorded significant correlation ($r = 0.414$) between CGR and dry matter accumulation. The RGR values were found to decrease from 30-60 DAS to 60-90 DAS. The RGR was maximum in plants treated with 5 t FYM ha$^{-1}$ (Fig. 4.2). The increase in leaf area might have affected the photosynthesis due to the plant dry matter accumulation. He also reported positive correlation between RGR and dry matter accumulation up to 45-60 DAS ($r = 0.615$), thereafter, no relations were obtained. It indicates that the growth and development of plant tissues were faster up to 60 DAS, thereafter, the rate of accumulation of dry matter per unit of dry matter present was slow resulting in lower values of RGR. Use of FYM @ 5 t ha$^{-1}$ showed higher relative growth rate than no FYM because FYM beared more number of pods and ultimately more dry matter in this stage.

Perusal of data from Table 4.6 revealed that in rajmash leaves, chlorophyll content increased up to 90 DAS. Significantly higher chlorophyll content was recorded under 5 t FYM ha$^{-1}$ at 60 DAS during both the years than 0 t FYM ha$^{-1}$. Application of 5 t FYM ha$^{-1}$ slightly delayed days to flower initiation and days to 50% flowering, whereas, it could not give impact on days to maturity (Fig. 4.5). Pods of plants treated with FYM
Plate 2: Experimental field of Rajmash showing different treatment combinations
accumulated more dry matter, although it was significant only at 90 DAS during 2005-06 and at harvest during 2005-06 as well as on mean basis (Table 4.8). It might be only due to more translocation of photosynthetic food material towards pods and due to higher partitioning coefficient (Arora et al., 1998).

Pod growth rate (Table 4.9) and relative pod growth rate (Table 4.10) was significantly higher under the plants treated with FYM @ 5 t ha⁻¹ only between 10-20 DAF during 2005-06 and between 20-30 DAF during 2004-05, whereas, no FYM recorded significantly higher pod growth rate and relative pod growth rate than 5 t FYM ha⁻¹ during 2004-05 between the period 10-20 DAF and during 2005-06 between the period 20-30 DAF. Later on, between 30-40 DAF, pod growth rate and relative pod growth rate remained unaffected by the use of FYM. Similar findings were noted by Arora et al. (1998).

5.2.2 Yield and yield attributes

The seed is the resultant of growth and yield attributing characters of rajmash. The seed yield of rajmash was significantly higher under 5 t FYM ha⁻¹ as compared to 0 t FYM ha⁻¹ during both the years as well as on mean basis (Table 4.14). The yield attributes such as number of pods plant⁻¹, number of seeds plant⁻¹, number of seeds pod⁻¹, seed weight, pod weight and 100-seed weight were maximum under 5 t FYM ha⁻¹ and minimum under no
FYM (Table 4.11 and 4.12). The superiority of growth characters viz., plant height, branches, LAI, dry matter accumulation as discussed earlier may also be the possible reasons for the production of higher yield under 5 t FYM ha\(^{-1}\).

Pod setting index was significantly higher under 5 t FYM ha\(^{-1}\) during both the years and on mean basis as compared to no FYM. Application of 5 t FYM ha\(^{-1}\) recorded significantly higher seed setting index as compared to 0 t FYM ha\(^{-1}\) during 2004-05 and on mean basis (Table 4.13). FYM is a decompose mixture of dung and urine of farm animal along with lifter and left over material from roughases or fodder fed to the cattle. It contains 0.5% N, 0.2% P\(_2\)O\(_5\) and 0.5% K\(_2\)O. It supply plant nutrients including micronutrients, improve soil physical properties like structure, aeration, water holding capacity, provide food for soil microorganism and prevent loss of nutrients by leaching or erosion. Jain et al. (1995) at Sehore observed that the application of FYM @ 5 t ha\(^{-1}\) significantly increased the plant height, number of leaves plant\(^{-1}\), number of pods plant\(^{-1}\), test weight and finally yield and also increased nodulation in soybean. Kumar and Singh (1996) also reported higher yield of soybean with FYM @ 5 t ha\(^{-1}\) and it further increased the availability of phosphorus and potassium in soil. FYM play a direct role in supplying macro and micro-nutrients and an indirect one by improving the physical, chemical and biological properties of the soils. FYM contains almost all essential nutrient elements and enhances
nodulation, root growth and finally yield of most of the pulses. The beneficial effect of FYM has been reflected in seed and stover yield of rajmash. These results corroborate the findings of Kumar and Tripathi (1999) and Kumar et al. (1999). Kumar and Puri (2002) reported that FYM had significant effect on the growth, yield attributes, seed and straw yields of frenchbean. Application of 10 t FYM ha\(^{-1}\) recorded 25.9 and 19.6% more seed and straw yields, respectively, over no FYM application. The increase in yields due to FYM application is due to its favourable effect on growth and yield attributes of the plant.

Singh and Verma (2002) observed maximum plant height, branches plant\(^{-1}\), pods plant\(^{-1}\) and 100-seed weight under 10 t FYM ha\(^{-1}\). This increase in yield attributing characters was owing to improvement in physico-chemical properties of the soil and more availability of essential nutrients to plants, which supported the vegetative growth (plant height and branches plant\(^{-1}\)) and finally increased the pods plant\(^{-1}\) as well as the 100-seed weight. The possible reason for superiority of FYM may be owing to its rich nutritional composition, which increased the vegetative, yield attributing characters and finally the yield.

The stover yield of rajmash was significantly higher under 5 t FYM ha\(^{-1}\) than 0 t FYM ha\(^{-1}\) during both the years and on mean basis (Table 4.14). The variation in the values of harvest index (HI) of rajmash remained non-significant under both the levels of FYM (Table 4.14). This indicates
that application of FYM minimize the unproductive competition between vegetative and reproductive growth, ultimately leading to economic yield improvement. Significant impact of 5 t FYM ha\(^{-1}\) in case of rajmash productivity was noted in different locations like Varanasi, Durgapura and Raipur (Anonymous, 2002-03).

5.2.3 Content and uptake of N, P, K and content and yield of protein

The nitrogen, phosphorus, potassium and protein content in rajmash were maximum under 5 t FYM ha\(^{-1}\) and minimum under no FYM during both the years and on mean basis (Table 4.20, 4.21, 4.22 and 4.23). However, significantly higher N content in seed and stover and total N uptake in rajmash were noted under 5 t FYM ha\(^{-1}\) than no FYM during both the years and on mean basis (Table 4.20). P concentration under both the levels of FYM indicated that significantly higher P content in seed was noted under 5 t FYM ha\(^{-1}\) as compared to no FYM during both the years and on mean basis (Table 4.21). The potassium content in seed and stover and total K uptake in rajmash were non-significantly influenced by both the levels of FYM during both the years and on mean basis (Table 4.22). Use of 5 t FYM ha\(^{-1}\) recorded significantly higher protein content in rajmash over 0 t FYM ha\(^{-1}\) during 2005-06 and in mean data. The protein yield of rajmash was significantly highest under 5 t FYM ha\(^{-1}\) during both the years and on
mean basis (Table 4.23). This could be explained on this basis of better availability of nutrient in crop root zone under FYM treated plots resulting from its solubilization caused by the organic acid produced from the decaying matter and also increased uptake of nutrient due to their association with mycorrhizal filaments increasing the ascribing area of roots. The response of crop to FYM application may be attributed to better nutrient availability, enhanced inherent nutrient supply capacity of the soil and its favourable effect of soil physical and biological properties (Hati et al., 2005). Vikrant et al. (2005) reported that 5, 10 and 15 t FYM resulted in significantly higher grain protein yield over the control and gave 17.99, 36.84 and 35.54% more protein yield over control, respectively. These results confirm the findings of Kumar et al. (1999).

5.2.4 Productivity rating index, production and economic efficiency, energetic and economics

The productivity rating index (Table 4.16) and production efficiency (Table 4.17) remained statistically superior under 5 t FYM ha\(^{-1}\) as compared to no FYM during both the years as well as in mean data. The higher values under 5 t FYM ha\(^{-1}\) are in accordance with higher seed yields obtained in the same treatment. On the contrary, no FYM resulted in maximum economic efficiency (Table 4.18).
The maximum energy input was noted in 5 t FYM ha\textsuperscript{-1} and the lowest energy input was observed in no FYM. Significantly highest energy output was recorded under 5 t FYM ha\textsuperscript{-1} during both the years as well as on mean basis. Significantly highest energy output-input ratio was obtained under 5 t FYM ha\textsuperscript{-1} during 2005-06 only (Table 4.24). The effect of both the FYM levels on energy use efficiency and energy productivity was found in inconsistent manner during 2004-05 where maximum values were noted in no FYM, whereas, during 2005-06 and on mean basis, maximum values was noted with 5 t FYM ha\textsuperscript{-1}. However, energy intensiveness was significantly highest under 5 t FYM ha\textsuperscript{-1} during both the years and on mean basis (Table 4.25).

The economic analysis showed that the gross and net realizations and profit Re\textsuperscript{-1} invested were the highest with 5 t FYM ha\textsuperscript{-1} during both the years and on mean basis (Table 4.26). Total dry matter production in a plant often reflects its potentiality for its biomass production, whereas, mobilization towards the seed development is an important factor for realization of economic yield and serves as the yard stick for the acceptance and rejection of treatment hypothesis. The higher gross and net realization under 5 t FYM ha\textsuperscript{-1} were obviously due to higher seed and stover yields under this treatment. The profit Re\textsuperscript{-1} invested was also highest due to the sustainability in increased yield. Singh and Verma (2002) also reported that 10 t FYM ha\textsuperscript{-1} gave the
highest net profit and benefit:cost ratio of frenchbean. Kumar and Puri (2002) also noticed that application of 10 t FYM ha\(^{-1}\) recorded higher net returns than no FYM application.

5.3 **Effect of nitrogen on rajmash**

5.3.1 **Crop growth**

The plant population noted initially at 20 DAS and finally at maturity did not differ at respective stages in response to N levels (Table 4.1). However, a slight decline of plant population at harvesting might be due to plant mortality. The plant height increased with the advancement of crop age up to maturity with a high magnitude increment between 30 to 90 DAS coinciding with the grand growth phase of rajmash crop (Table 4.2). Beyond 90 DAS, application of 120 kg N ha\(^{-1}\) produced taller plants in comparison to 0 and 60 kg N ha\(^{-1}\) at all the stages of growth during both the years and on mean basis.

The number of branches observed from 30 DAS till harvest indicates superior branching in 120 kg N ha\(^{-1}\) at all the stages, excepting at 30 DAS during 2004-05 only (Table 4.3). The leaf area index (Table 4.4), dry matter accumulation (Table 4.5), crop growth rate (Fig. 4.1), relative crop growth rate (Fig. 4.2), chlorophyll content (Table 4.6) were significantly higher with 120 kg N ha\(^{-1}\) as compared to lower levels during both the years as well as on mean basis at all the stages of crop growth. Saxena and Verma (1994) reported that nitrogen affected all the growth
Plate 3: Individual experimental plots showing different treatment combinations.
attributes significantly up to highest dose of nitrogen i.e. 120 kg N ha\(^{-1}\). An application of 60 kg N ha\(^{-1}\) over control and 120 kg N ha\(^{-1}\) over 60 kg N ha\(^{-1}\) was found significantly superior in both the years in terms of plant height, number of leaves plant\(^{-1}\), leaf area and number of branches plant\(^{-1}\). Similar trend was observed in fresh and dry weight in the second year only. Good response of nitrogen in the present study may be due to soil being poor in nitrogen and due to lack of nodule forming ability of this crop. Ali and Kushwaha (1987) have also reported favourable response of nitrogen on frenchbean.

The application of 120 kg N ha\(^{-1}\) appeared to have maximum light interception, whereas, no application of nitrogen had minimum light interception during both the years and on mean basis (Fig. 4.3). The light transmission ratio increased with the increase in nitrogen levels (Fig. 4.4). The light transmission ratio was more at 80 DAS as compared to 60 DAS in case of different levels of nitrogen. The maximum light interception ratio was observed under 120 kg N ha\(^{-1}\) at 60 and 80 DAS and the minimum was noted under no N application during both the years as well as in mean. The phenological variation due to different levels of N with respect to flower initiation, 50% flowering and maturity duration might be due to difference in vegetative growth. Increasing dose of nitrogen slightly delayed days to flower initiation, days to 50% flowering and days to maturity (Fig. 4.5). Computation of growing degree days taking into consideration the duration
as well as prevailing temperature revealed that 120 kg N ha\(^{-1}\) accumulated significantly more heat to come to flower initiation as compared to lower levels during both the years as well as on mean basis (Table 4.7). The growing degree days closely followed the duration of occurrence of various phenophases (Gupta, 2000).

A close analysis of dry matter accumulation of pods of 90 DAS and at harvest indicated higher rate of pod filling in case of 120 kg N ha\(^{-1}\) than 0 and 60 kg N ha\(^{-1}\) during both the years and on mean basis (Table 4.8). At 10-20 DAF, the pod growth rate was significantly higher in 120 kg N ha\(^{-1}\) than lower levels during both the years as well as on mean basis. At 20-30 DAF, the pod growth rate was significantly higher under 120 kg N ha\(^{-1}\) during 2004-05 and on mean basis (Table 4.9). The relative pod growth rate showed the similar trend to that of pod growth rate under different levels of nitrogen during both the years and on mean basis (Table 4.10). Prajapati and Patel (2001) and Dhanjal et al. (2001) also found that dry matter accumulation of pods, pod growth rate and relative pod growth rate were significantly high with 120 kg N ha\(^{-1}\).

5.3.2 Yield and yield attributes

The post harvest observations on rajmash, which includes number of pods plant\(^{-1}\), number of seeds plant\(^{-1}\), number of seeds pod\(^{-1}\) (Table 4.11), pod weight plant\(^{-1}\), seed weight plant\(^{-1}\) and 100-seed weight (Table 4.12)
were maximum under 120 kg N ha\(^{-1}\) during both the years as well as in mean. However, number of pods plant\(^{-1}\), number of seeds plant\(^{-1}\) and pod weight were significantly higher under 120 kg N ha\(^{-1}\) as compared to lower levels during both the years and on mean basis. Application of 120 kg N ha\(^{-1}\) gave significantly higher 100-seed weight than lower levels during both the years only. Significantly higher pod setting index and seed setting index (Table 4.13) was noted in 120 kg N ha\(^{-1}\) than lower levels during both the years and on mean basis.

In rajmash, use of 120 kg N ha\(^{-1}\) produced significantly higher seed and stover yields than lower levels of N during both the years and on mean basis. However, harvest index of rajmash remained non-significant under different levels of nitrogen (Table 4.14). Increase in growth and yield attributing characters with 120 kg N ha\(^{-1}\) in the present experiment has contributed increased in the productivity of rajmash.

Rajmash is a poor nodulating crop and has poor N\(_2\) fixation capacity (Vincent, 1974). It responds to higher levels of nitrogen as compared to many other legumes (Srinivas and Rao, 1984). Prajapati et al. (2004) also noted highest grain and straw yields under application of 120 kg N ha\(^{-1}\). Highest yield with high fertility levels might be due to the fact that nitrogen is an integral part of chlorophyll and plays a virtual role in protein synthesis. Kushwaha (1994) also reported that seed yield of french bean was highest up to 120 kg N ha\(^{-1}\). This increase was mainly due to improvement in
Plate 4: Picture showing poor nodulation in Rajmash
yield contributing characters viz. plant height, branches plant$^{-1}$, grains pod$^{-1}$ and 100-grain weight, with increasing levels of N.

Nitrogen governs above earth growth. It is essential constituent of protein, nucleic acid, nucleotide, amino acid, chlorophyll, phospholipids, alkaloids, enzyme hormones, vitamins etc. It is essential for synthesis of amino acids and impart dark green colour of plant. Being a shy nodulated crop, the fertilizer requirement of rajmash, particularly of nitrogen is like that of cereals. Singh and Verma (2002) noted that higher dose of nitrogen (120 kg ha$^{-1}$) resulted in higher yield and was found more profitable. This could be attributed to the fact that application of N increased the vegetative growth of initial stages (plant height and branches plant$^{-1}$) and finally led to higher pods and seed weight. Nitrogen caused a marked variation in grain and straw yields during both the years. A linear increase in grain yield was recorded with the increase in levels of N from zero to 120 kg N ha$^{-1}$. Frenchbean crop with little or no nodulation required large amount of N from applied or soil source and hence shows high response to nitrogen (Ali and Shankar, 1991). Further, the yield increase was mainly owing to improvement in yield attributing characters at higher dose of N application. Response of frenchbean to N up to 120 kg N ha$^{-1}$ was also reported by Kushwaha (1994) and Dwivedi et al. (1994).
5.3.3 Content and uptake of N, P, K and content and yield of protein

As regards to considerations of major nutrient contents, highest N content in seed and stover was observed in 120 kg N ha\(^{-1}\) during both the years as well as in mean (Table 4.20). Significantly highest total N uptake by rajmash was noted under 120 kg N ha\(^{-1}\) during both the years and on mean basis. The lowest total uptake of N was reported under no nitrogen. The uptake of N was highest which might be due to higher yield. Various levels of nitrogen could not give significant impact on P and K concentrations in seed and stover but uptake of P and K was significantly highest under 120 kg N ha\(^{-1}\) during both the years and on mean basis (Table 4.21 and 4.22). The protein content and protein yield of rajmash were significantly higher under 120 kg N ha\(^{-1}\) as compared to 0 and 60 kg N ha\(^{-1}\) during both the years and on mean basis (Table 4.23). Such a significant improvement in the uptake of nutrients could be attributed to better vegetative growth of the plants and proliferous root system which led to higher absorption of water and nutrients (Stevenson et al., 1990). On the contrary, the decrease in the utilization of nutrients at highest level may be due to operation of 'Law of Diminishing Returns' because at the lower level of nutrients applied there was always higher competition among the plants for applied nutrients (Tisdale et al., 1990).
Prajapati et al. (2004) noted that each successive increment of nitrogen up to 120 kg N ha\(^{-1}\) remarkably increased nutrient uptake and protein yield of rajmash crop. Highest total nutrient uptake (NPK) was recorded with higher level of nitrogen application (120 kg N ha\(^{-1}\)). The favourable effect of nitrogen fertilization on NPK uptake by plant might be due to the increased concentration of nitrogen in root zone, which may have increased in the rate of uptake by establishing a concentration gradient between soil and root system of the plant. Ravinandan and Prasad (1998) also reported similar results. Substantial increase in protein content of legumes due to nitrogen application has also been observed by Singh and Singh (2000).

5.3.4 Productivity rating index, production and economic efficiency, energetic and economics

The productivity rating index of the treatment 120 kg N ha\(^{-1}\) was the highest because of higher grain yield compared to others (Table 4.16). The production efficiency also followed the same trend (Table 4.17). The economic efficiency was maximum with no nitrogen and lowest with 120 kg N ha\(^{-1}\) (Table 4.18). The energy output was remarkably high with 120 kg N ha\(^{-1}\) during both the years and on mean basis obviously due to higher seed and stover yields (Table 4.24). But the energy output-input ratio (Table 4.24) and energy use efficiency (Table 4.25) were highest with no nitrogen. This might be possibly due to slightly higher energy requirement (input) for the
higher level of N compared to the lower level of N.

Application of 120 kg N ha\(^{-1}\) accrued the maximum gross and net realization as well as net return Re\(^{-1}\) invested (Table 4.26). Higher productivity compared to the cost of production could possibly substantiate the economic viability of this treatment. This further signifies the superiority of higher dose of N to increase the productivity of rajmash. Singh and Verma (2002) also obtained maximum net return and benefit:cost ratio with 120 kg N ha\(^{-1}\). This could be ascribed to higher grain yield obtained owing to application of higher level of N.

5.4 Effect of zinc on rajmash

5.4.1 Crop growth

The plant population at 20 DAS and at harvest stage remained unaffected due to both the zinc levels (Table 4.1). The growth parameters like plant height (Table 4.2), number of branches plant\(^{-1}\) (Table 4.3), LAI (Table 4.4), dry matter accumulation at 30, 90 DAS and at harvest (Table 4.5), chlorophyll content (Table 4.6), growing degree days at flower initiation during 2004-05 and on mean basis, at flowering on mean basis and at maturity (Table 4.7), dry matter accumulation of pods (Table 4.8), pod growth rate at 30-40 DAF (Table 4.9) and relative pod growth rate at 30-40 DAF (Table 4.10), CGR (Fig. 4.1), RGR (Fig. 4.2), light interception (Fig. 4.3) and light transmission ratio (Fig. 4.4) remained statistically non-significant due to 0 and 20 kg Zn ha\(^{-1}\) during both the years and on mean...
Plate 5: Development of pods in Rajmash
basis. Whereas, different stages of crop growth witnessed better manifestation of growth characters under 20 kg Zn ha$^{-1}$ over no zinc application. However, DMA was significantly higher under 20 kg Zn ha$^{-1}$ as compared to no zinc application at 30 DAS during 2005-06 and at 60 DAS during both the years as well as on mean basis. Application of 20 kg Zn ha$^{-1}$ accumulated significantly more heat to come to flower initiation as compared to 0 kg Zn ha$^{-1}$ only during 2005-06. To come to 50% flowering, 20 kg Zn ha$^{-1}$ accumulated maximum heat during both the years. Pod growth rate and relative pod growth rate at 10-20 DAF was significantly higher under 20 kg Zn ha$^{-1}$, whereas, at 20-30 DAF, significantly higher pod growth rate and relative pod growth rate was noted in 0 kg Zn ha$^{-1}$ than 20 kg Zn ha$^{-1}$ during both the years and on mean basis. Available Zn status in Vertisols of Chhattisgarh plains is quite high (1.2 mg kg$^{-1}$ soil) in comparison to the critical limit of 0.5 mg kg$^{-1}$ soil. This might be the reason for comparable performance of no zinc and 20 kg Zn ha$^{-1}$ (Anonymous, 2005-06).

Singh et al. (1992) observed that application of Zn at 0 and 5 ppm did not significantly affect the chlorophyll content, seed yield, 100-seed weight, DM of pods plant$^{-1}$ of frenchbean. Response of zinc @ 15 kg ha$^{-1}$ in the form of ZnSO$_4$ was non significant at Raipur, Varanasi and Akola but was significant at Durgapura (Anonymous, 2002-03). Most of the profits showed the higher available Zn in upper layers of the profiles. Available Zn
status in general followed the similar trend of organic carbon content the profiles. Decrease in available Zn with depth was also reported. The critical limit of Zn is 0.8 mg kg\(^{-1}\) soil (Srinivasarao et al., 2003).

5.4.2 Yield and yield attributes

The yield attributes like number of pods plant\(^{-1}\), number of seeds plant\(^{-1}\), number of seeds pod\(^{-1}\) (Table 4.11), pod weight, seed weight and 100-seed weight (Table 4.12) were maximum under 20 kg Zn ha\(^{-1}\) although it was not to the level of significance. Pod weight was significantly higher under 20 kg Zn ha\(^{-1}\) than no zinc only during 2004-05. Pod setting index was significantly higher under 20 kg Zn ha\(^{-1}\) than no zinc during both the years and on mean basis. However, seed setting index, though higher under 20 kg Zn ha\(^{-1}\) than no zinc but it was not to the level of significance (Table 4.13). Similarly, seed and stover yields were maximum under 20 kg Zn ha\(^{-1}\) but the differences between the two levels of zinc were not significant (Table 4.14). Harvest index was also unaffected by both the levels of zinc.

It is evident from the findings that both the zinc levels were comparable to each other in terms of growth, yield attributes and yield of rajmash during both the years and on mean basis. It might be due to poor response of zinc in the Vertisols condition of Chhattisgarh plains. Available Zn status in Vertisols of Chhattisgarh plains is quite high (1.2 mg kg\(^{-1}\) soil) in comparison to the critical limit of 0.5 mg kg\(^{-1}\) soil. This might be the
reason for comparable performance of no zinc and 20 kg Zn ha\(^{-1}\) (Anonymous, 2005-06). Pastricha and Bahl (1996) also reported that the response of pulses to zinc application varied from 10-25 kg ha\(^{-1}\) in light textured soil. Moraes and Dynia (1998) noted that application of 0 or 20 kg ZnSO\(_4\) ha\(^{-1}\) did not affect the yield of frenchbean. McKenzie et al. (2001) at Alberta (Canada) noted that application of Zn did not increase seed yield of common bean.

Zinc is a constituent of several enzyme systems regulating various metabolic reactions. It is important in the synthesis of IAA and essential for water uptake. Zinc application exhibited variable response in different pulse crops and significantly increased the nodulation, yield and carbohydrate content in seeds. Legheamoglobin content of nodules and quantity of nitrogen fixed in chickpea increased with Zn alone up to 20 ppm and decreased with 40 and 100 ppm treatment (Acharya and Biswas, 2002). The analytical data of about 250000 soil samples collected from different states of the country reflected the predominancy to Zn deficiency (48.5%). Zinc deficiency is higher in calcareous soils, sodic soils, soils with low organic matter and sandy textured soils. In zinc deficient blackgram and greengram, young and fully developed leaves develop light yellow pinkish and white tissues in between the green veins. The leaf size is reduced and become thick and brittle. Leaf margins turn upward exhibit cupping of leaves. In chickpea, the symptoms appear in the upper 1/3 part of the leaflet. The leaflet become
yellow initially and later they develop reddish/pinkish colour and the leaf size also decrease.

Trials conducted in different Agro-ecological Zones of India showed that soil application of 25-50 kg ZnSO₄ ha⁻¹ is optimum. The results of Front Line Demonstrations conducted with chickpea in MP, Bihar and Gujarat showed response up to 11 kg Zn ha⁻¹. The seed yield income per kg of Zn added ranged from 12 to 77 kg (Savithri, 2000). Khamparia (1996) at Sagar found that increased dose of Zn produced taller plants with profuse growth and higher root nodulation (number and dry weight) and had more dry weight as compared with control and also reported that seed, straw and biological yield, seed straw ratio and harvest index also increased by Zn application in soybean.

5.4.3 Content and uptake of N, P, K and content and yield of protein

Significantly higher concentration of N in seed and stover of rajmash was noted under 20 kg Zn ha⁻¹ than no zinc during both the years and on mean basis, except in stover during 2005-06, where it was non-significant. Similarly, nitrogen uptake by rajmash was significantly higher in 20 kg Zn ha⁻¹ than no zinc during both the years and on mean basis (Table 4.20). As regards to P content in seed and total P uptake, 20 kg Zn ha⁻¹ was found significantly superior over no zinc, however, P content in stover was found non-significant during both the years and on mean basis (Table 4.21).
The K content in seed and stover and total K uptake by rajmash remained unaffected due to both the levels of zinc during both the years and on mean basis (Table 4.22). Protein content and protein yield of rajmash were significantly higher under 20 kg Zn ha\(^{-1}\) than no zinc during both the years and on mean basis, except the protein yield in 2004-05, where the differences were found non-significant (Table 4.23). Increased application of nutrients improved the nutritional environment of the soil solution leading to higher availability of nutrients to plants. Further, improved synchrony between supply and plant demand, the better root proliferation, greater nodulation and leaf area enhanced the mobilization of nutrients towards the sink along with photosynthates of plant. Higher N, P and K concentration might have favoured greater source-sink relation at appropriate period of pod development stage resulting in higher yield. Significantly higher nutrient uptake and protein yield under 20 kg Zn ha\(^{-1}\) might be due to higher content of nutrients and the yields of seed and stover. Singh et al. (1995) noted that application of 0 or 5 kg Zn ha\(^{-1}\) did not affect protein content in rajmash seed. Blaylock (1995) noted that the whole plant N concentration increased linearly with increased N rate but did not differ among zinc treatments. Pozzebon et al. (1996) found that pulse crops respond well to application of zinc under deficient conditions. Zinc is known to be involved in nitrogen fixation through nodule formation (Balusamy, 1996).
5.4.4 Productivity rating index, production and economic efficiency, energetic and economics

The productivity rating index (Table 4.16), production efficiency (Table 4.17), economic efficiency (Table 4.18) showed non-significant differences due to both the levels of zinc. Heat use efficiency in terms of dry matter accumulation and in terms of seed yield (Table 4.19) also showed non-significant differences due to zinc levels during both the years and on the basis of mean data.

The energy studies in rajmash clearly indicate that the highest energy output, energy output-input ratio (Table 4.24) were obtained under 20 kg Zn ha\(^{-1}\) during both the years and on mean basis except energy output on mean basis and energy output-input ratio during 2005-06, where non-significant impact was observed. Both the levels of zinc did not produce significant impact on energy use efficiency, energy intensiveness and energy productivity (Table 4.25) during both the years and on mean basis.

The economic analysis showed that the gross and net realization and net return Re\(^{-1}\) invested were also non-significant due to both the levels of zinc during both the years and on mean basis (Table 4.26). The non-significant differences with regards to the productivity of rajmash due to both the levels of zinc resulted in comparable economic returns during both the years and on mean basis.
5.5 Interactive effects of FYM + nitrogen + zinc on productivity and economics of rajmash

As regards to interaction effects, use of FYM with nitrogen or nitrogen with zinc gave significant impact on seed yield of rajmash during both the years as well as on mean basis (Table 4.15). Application of 5 t FYM ha$^{-1}$ + 120 kg N ha$^{-1}$ and 120 kg N ha$^{-1}$ + 20 kg Zn ha$^{-1}$ gave significantly higher seed yield than their respective other treatment combinations. During 2005-06 and on mean basis, treatment combination 5 t FYM ha$^{-1}$ + 120 kg N ha$^{-1}$ + 20 kg Zn ha$^{-1}$ recorded significantly higher seed yield than other treatment combinations.

The interaction effects on economic parameters revealed that application of 5 t FYM ha$^{-1}$ + 120 kg N ha$^{-1}$ and 120 kg N ha$^{-1}$ + 20 kg Zn ha$^{-1}$ gave significantly higher net realization than other respective treatment combinations (Table 4.27). Application of 120 kg N ha$^{-1}$ + 5 t FYM ha$^{-1}$ + 20 kg Zn ha$^{-1}$ recorded maximum net realization (Table 4.27) and net profit Re$^{-1}$ invested (Table 4.28).

Singh et al. (2006) reported that application of 180 kg N ha$^{-1}$ along with 6 kg Zn ha$^{-1}$ gave the highest grain yield of frenchbean. Singh and Verma (2002) reported that application of organics as well as the inorganics significantly increased the grain yield of rajmash over control. FYM in combination with inorganics proved its superiority in increasing the seed yield compared to their individual effects.
Maximum seed yield was recorded under 10 t FYM ha\(^{-1}\) + 75% RDF to the tune of 164% over control and it was followed by 10 t FYM ha\(^{-1}\) + 50% RDF. The yield increase was mainly owing to improvement in yield attributing characters, with increased level of N coupled with FYM (Kushwaha, 1991 and Dwivedi et al., 1994). Jana et al. (1987) also obtained the highest yield with combined application of FYM + nitrogen + zinc.
Plate 6: A general view of Rajmash plot in the experimental site