CHAPTER-II

REVIEW OF LITERATURE
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In Chhattisgarh state, there is a good possibility of rajmash cultivation under Alfisols and Vertisols. This chapter deals with the review of related research work with respect to the effect of FYM, nitrogen and zinc on rajmash carried out in India and abroad. The literature on other crops has also been included due to paucity of sufficient research work on above aspects. The salient findings of various research workers on above aspects have been summarized in the following heads:

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2.1.2 Effect of FYM on nutrient concentration and uptake by rajmash
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2.1 Role of FYM in pulses

Organic manures like FYM and compost have been traditionally important inputs for maintaining soil fertility and ensuring yield stability. Bhatiya and Shukla (1982) emphasized that organic manure (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 and finally, crop yield.

Organic manures 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. These manures, besides supplying nutrients to the current crop, very often leave substantial residual effect on succeeding crop in the system. The integrated use of chemical fertilizers and FYM have marked influence on higher production and improvement in soil fertility status. Therefore, there is need to use organic manure in pulse crops and cropping systems for maintaining soil fertility and crop productivity on sustainable basis.

2.1.1 Effect of FYM on growth, yield attributes and yield of rajmash

The beneficial role of organic manure in maintaining soil fertility and crop productivity hardly needs any emphasis. Gaur and Sadashivam (1981) found that FYM significantly increased the seed yield and 12-15 t FYM application substitute about 60 kg N and 30 kg P₂O₅ ha⁻¹. In general,
FYM contains 0.5, 0.2 and 0.5 per cent of N, P₂O₅ and K₂O, respectively. An assessment made earlier showed that each tonne of FYM is equivalent to 3 kg fertilizer nutrients in a single crop and 5 kg in double cropping in terms of yield (Tandon, 1983).

The organic manure contains balanced macro and micro nutrients and ensures high crop yields. The application of organic manures into the soil results in better soil conditions and thereby significantly increase the level of N-fixation. In other study in Madhya Pradesh, Kundu et al. (1996) reported that application of FYM @ 4, 8 and 16 t ha⁻¹ increased the seed yield of soybean by 39.6, 69.5 and 85.4 per cent compared with no FYM (yield of 1.44 t seed ha⁻¹). In no FYM treatment total quantity of N fixed from atmosphere was 65.8 kg ha⁻¹, which increased to 117.4, 126.1 and 131.3 kg ha⁻¹ owing to application of 4, 8, 16 t ha⁻¹ FYM, respectively. It is thus evident that application of organic manures either in situ or through composting is necessary to take care of soil health along with the stable yield levels.

Jadhav et al. (1997) reported the possibilities of substituting 25 to 50 kg N ha⁻¹ of the recommended dose of nitrogen by FYM for attaining maximum dry matter production at harvest. Similar findings have also been reported by Kumar et al. (1994). Jasrotia and Sharma (1998) at Palampur (H.P.) noted that application of 20 t FYM ha⁻¹ subsequently increased the yield attributes and green pod yield of frenchbean. Drechsel and Reck
(1998) at Bangkok (Thailand) noted that organic manures are the primary source of crop nutrients. In their study different types of compost were compared with FYM and green manure using French bean as test crop. The study confirmed the farmer’s general opinion that FYM has high manural value for crop yields.

Purushottam and Puri (2002) at Salooni (H.P.) found that application of 10 t FYM ha$^{-1}$ gave highest plant height, pods plant$^{-1}$, seeds pod$^{-1}$ and 1000-seed weight thereby the highest yield (13.8 q ha$^{-1}$) than without FYM application. Similarly, Kumar and Puri (2002) reported that FYM had a significant effect on the growth, yield attributes, seed and straw yields of French bean. FYM application 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.

Experiments on manural scheduling in rajmash conducted at Varanasi, Durgapura, Raipur and Akola showed significant impact of FYM on grain yield in all the locations except at Akola. It was further revealed that application of FYM @ 5 t ha$^{-1}$ was more beneficial, however, recommendations cannot be generalized because nutrients response varied from place to place. Overall, there was 10.76 per cent gain in seed yield over no application of FYM (Anonymous, 2002-03).
Kumar et al. (2004) from Muzaffarpur (Bihar) stated that application of 50 t FYM ha\(^{-1}\) recorded the highest plant height, number of pods plant\(^{-1}\), weight of pods plant\(^{-1}\), length of pod and 100 seed weight resulting in higher seed and stover yield. However, effects due to application of 50 and 25 t FYM did not differ statistically. On an average, organic manure @ 12.5, 25 and 50 t FYM ha\(^{-1}\) increase the seed yield by 15.95, 24.20 and 26.45 per cent over control (no FYM), respectively. Maximum increase in yield by 15.95 per cent was recorded due to 12.5 t FYM ha\(^{-1}\), which reduced to 8.25 and 2.45 per cent with successive increase of 25 and 50 t FYM ha\(^{-1}\). Positive effect of FYM on the yield of grain legumes have also been reported by Mishra and Sharma (1995).

2.1.2 Effect of FYM on nutrient concentration and uptake by rajmash

Aider et al. (1976) conducted a field experiment with 30 t ha\(^{-1}\) of FYM and 8 t ha\(^{-1}\) of poultry manures applied with and without chemical fertilizers observed slight increase in seed yield of dry beans but high increase in phosphorus uptake. They further clarified that the small response of organic manure might be due to high soil fertility of the experimental site.

Continuous application of FYM for 5 years helped in maintaining and improving physical properties of eroded alluvial soil compared to application of chemical fertilizer alone (Bhatiya and Shukla, 1982). Organic manure can counteract the deleterious effect on bulk density that may be
caused by the continuous use of mineral fertilizers and can increase the proportion of water stable aggregates and water holding capacity (Venkateswarlu, 1984).

About 25 to 30 per cent of the N contained in compost and FYM can be absorbed during one crop season and the accumulated nutrients from the continuous application of organic matter are gradually mineralized and utilized by successive crops which sustain the productivity (Inoko, 1984 and Mathew et al., 1993). Addition of manure delayed the hydrolysis of urea, reduced the loss of N and also reduced the pH of soil. The organic carbon and available N status of the soil also increased by manure addition, but the simultaneous addition of fertilizer also increased the loss of carbon (Prasad and Singhania, 1989).

Application of FYM reduced the loss of N (Singh and Prasad, 1992). Singh et al. (1995) found that cattle manure improved organic carbon, P and K contents of soil. Jasrotia and Sharma (1998) at Palampur (HP) noticed that FYM increased P uptake by 17-20 per cent over control. Shivananda et al. (1998) at Bangalore noted that uptake of N by frenchbean was highest in ammonium sulfate treated soil followed by FYM. There was remobilization of N, P, K and S from leaves and roots to the pods. The organic amendments favoured root growth, whereas ammonium sulfate suppressed it.
2.1.3 Effect of FYM on economics of rajmash

Singh and Verma (2002) conducted an experiment on sandy loam soil of eastern UP in Frenchbean. They found that 10 t FYM ha\(^{-1}\) + 75 RDF (90:45:24 kg NPK ha\(^{-1}\)) gave the highest net return and benefit:cost ratio. Kumar and Puri (2002) noted that 10 t FYM ha\(^{-1}\) recorded higher net returns than no FYM application in rajmash.

Kumar et al. (2004) from Muzaffarpur (Bihar) reported that use of FYM improved the net return obtained from Frenchbean. The maximum net return (Rs.14365 and 16609 ha\(^{-1}\) during 1996-97 and 1997-98, respectively) was obtained from plants applied with 25 t FYM ha\(^{-1}\) but not significantly higher over 12.5 t ha\(^{-1}\). Thus, for economic returns, the application of FYM should not exceed over 12.5 t ha\(^{-1}\).

2.2 Role of nitrogen in pulses

2.2.1 Effect of N on growth, yield attributes and yield of rajmash

The use of nitrogen as booster dose in pulses promotes plant growth and rhizobial activities for nitrogen fixation. But rajmash has very poor nodulation capacity, so its N requirement is quite high as compared to other pulses. Rubes (1973) reported high seed yield with high dose of N in rajmash with high rates of N, nodule formation was inhibited until flowering which was intensive afterwards until green pod stage, the number, volume and dry matter of nodes was higher. Neptune et al. (1978) reported a positive effect of N on yield and utilization of phosphorus.
Posypanov et al. (1979) reported increasing rates of N increased the seed protein content, seed yield by 30-60 per cent and protein yield by 27.66 per cent. Sader (1979) reported increase in seed yield, seed weight, seed size and CP content and seedling dry weight increase with increased N rates. Leaf nitrate reductase activity (NRA), N content and total CP yield increase with increasing N rate. Dry matter content, leaf area and LAI increased with increase in N rate at all growth stages.

Longo (1980) in a field trial reported seed yield increase from 1.18 to 2.30 t ha⁻¹ with increase in N rate. Samtsevich et al. (1980) reported increased average seed yield by 30 and 57 per cent at the rate of 50 and 150 kg N ha⁻¹, respectively. The amino acid content in seed also increased with increasing N rates. Araya et al. (1981) observed the effect of 80 kg N ha⁻¹ as urea on seed yield, when 50% of the N was applied at sowing and 50% at 15, 22 and 29 days after emergence. In nodulating legumes (pulses) high yields were observed when nitrogen was applied to the extent of 120 kg ha⁻¹ or more (Durante and Carpne, 1981).

Scaristbrick et al. (1982) studied the effect of 0 to 200 kg N ha⁻¹ rate on P. vulgaris and found increase in seed yield with increasing rates of nitrogen application. They further described that significant benefits were obtained by applying N up to 100 kg ha⁻¹. Increased seed yield mainly resulted due to increase in number of pods m⁻². Lluch et al. (1983) reported increase in leaf area with increased nitrogen concentration. Chandra et al.
(1987) reported increased plant growth and seed yield (46.19-71.59 q ha\(^{-1}\)) with increasing N (0-50 kg ha\(^{-1}\)) and P\(_2\)O\(_5\) (0-80 kg ha\(^{-1}\)) rates with seed inoculation with *Rhizobium*.

Srinivas and Naik (1988) observed that the pod yield rose with increasing fertilizer rates from 3927 kg ha\(^{-1}\) at zero N to 13167 kg ha\(^{-1}\) at 160 kg N ha\(^{-1}\) and from 8813 kg ha\(^{-1}\) at zero P to 11366 kg ha\(^{-1}\) at 34.9 kg P\(_2\)O\(_5\). Ali and Tripathi (1988) evaluated dry matter accumulation and yield of rajmash as influenced by nitrogen levels and reported average number of pods plant\(^{-1}\), 100 seed weight, seed yield and seed protein content increased with increasing N rates. Rai and Alipit (1989) reported that application of N did not affect plant dry weight at flowering, but 90 and 20 kg N ha\(^{-1}\) increased root, pod and total dry weight at maturity. Leaf dry weight plant\(^{-1}\) was increased by 106 per cent by 30 kg N ha\(^{-1}\), with no further significant increase at higher rates.

Srinivas and Naik (1990) observed that half of the N rate, all the P and basal K\(_2\)O at 40 kg ha\(^{-1}\) were applied at planting and the remaining N was applied 25 days later. Both N and P application increased plant growth, nutrient uptake and yield of green pods. One factor quadratic response functions fitted to the yield data indicated optimum N and P application rates to be 125.6 and 143.3 kg ha\(^{-1}\), respectively. Prathiban and Thamburaj (1991) found that the number of days to 50 per cent flowering was increased by high N rates from 38 days in control without any fertilizer or inoculum to 48
days at the highest N rate (100 kg ha\(^{-1}\)). The highest yield of gram pods (21.46 t ha\(^{-1}\)) was obtained with 50 kg N ha\(^{-1}\) + *Rhizobium* inoculation. Badigala *et al.* (1992) conducted an experiment at Sangla (HP) on *Phaseolus vulgaris* cv. Him 1 (Chitra) and Jawla, which were given 0-100 kg N ha\(^{-1}\). They found that seed yield was highest with 60 kg N ha\(^{-1}\). Batra *et al.* (1992) at Hisar (Haryana) reported that shoot dry weight was 1.99-2.98 and 1.31-2.94 g pots in inoculated and uninoculated pots, respectively by increased N rates (0, 10, 20, 30, 40 and 60 ppm N as KNO\(_3\)).

At Pantnagar (UP), Sahu *et al.* (1994) conducted field trial on *Phaseolus vulgaris* cv. Udai, which was given 0-120 kg N ha\(^{-1}\) in first year and 0-150 kg N ha\(^{-1}\) in second year. They noted that the seed yield was highest with 120 kg N (1.44 t ha\(^{-1}\)) in first year and increased significantly up to 90 kg N (1.60 t ha\(^{-1}\)) in second year. Fronza *et al.* (1994) reported linear increase in seed yield with increasing rates of NPK in rajmash. Saxena and Verma (1994) reported that application of nitrogen affected the growth attributes like height, number of leaves, leaf area, fresh weight, dry weight, number of branches and yield significantly up to the highest level of nitrogen (120 kg ha\(^{-1}\)). Saxena and Verma (1995) reported increase in seed yield with increasing N and P rates, but was not affected by K application. Singh and Abidi (1995) from Ghaghraghat Crop Research Station (UP) reported that application of 125 kg N significantly increased yield and 1000 seed weight of *Phaseolus vulgaris* as compared to 75 and 100 kg N ha\(^{-1}\).
Singh et al. (1996) studied the effect of nitrogen application on Rajmash and reported increase in seed yield resulting from the increase in number of pods plant\(^{-1}\) and 100 seed weight with increase in nitrogen rate. Sharma et al. (1996) conducted an experiment during winter season at Dholi (Bihar) to study the response of *Phaseolus vulgaris* cv. Uday to 40, 80 and 120 kg N ha\(^{-1}\) applied at 100 per cent basal, 50 per cent basal + 50 per cent at first irrigation, 50 per cent basal + 50 per cent at 2\(^{nd}\) irrigation or 33 per cent each as basal, 1\(^{st}\) and 2\(^{nd}\) irrigation. Increasing level of N significantly increased seed yield, number and weight of pods plant\(^{-1}\) and number of seeds pod\(^{-1}\) up to 120 kg N ha\(^{-1}\). However, in case of seed yield, pod length and 100 seed weight, variations in 80 and 120 kg N ha\(^{-1}\) were not significant. Application of N in three equal splits gave higher seed yield and yield attributes of this crop. Dahatonde and Nalomwar (1996) noted increase in seed yield of rajmash up to 90 kg N ha\(^{-1}\).

Working in sandy loam soils in Himachal Pradesh, Kumar et al. (1997) revealed that yield of rajmash cv K-198 (Triloki) and KRC-8 (Baspa) increased with increasing levels of nitrogen up to 60 kg N ha\(^{-1}\). Working at Timbaco (Eucadar) Calvache et al. (1997) found that the applied N significantly increased seed yield, number of pods plant\(^{-1}\), number of seeds plant\(^{-1}\) and harvest index.

Andrade et al. (1998) working in Lavras (Brazil) stated that seed yield of *Phaseolus vulgaris* cv. Carioca-MG was 775, 1259 and 1464 kg ha\(^{-1}\)
with 0, 20 and 40 kg basal N ha\(^{-1}\) and 973 and 1358 kg ha\(^{-1}\) without and with 30 kg N top-dressed, respectively. Durge et al. (1998) from Akola (Maharashtra) reported that yield of rajmash cv. VL-63 increased with increasing N rates (0, 50, 100 or 150 kg N ha\(^{-1}\)). Ravinandan and Prasad (1998) at Pusa (Bihar) observed a linear increase in seed yield and pods plant\(^{-1}\) due to increase in N level from 40 to 120 kg ha\(^{-1}\). Seeds pod\(^{-1}\) and test weight increased significantly up to 80 kg N ha\(^{-1}\). Baboo et al. (1998) studied the response of rajmash to nitrogen and phosphorus. They observed the highest seed yield with 120 kg N and 100 kg P\(_2\)O\(_5\) ha\(^{-1}\). Rana and Singh (1998) at Bulandshahar (UP) observed that seed and straw yield increased significantly with each increment in N doses up to 120 kg N ha\(^{-1}\). Mean increase in seed yield with 120 kg N ha\(^{-1}\) over 0, 40 and 80 kg N ha\(^{-1}\) was 66.6, 21.7 and 7.0 per cent, respectively. Growth attributes also exhibited almost same trend.

Parmar et al. (1999) reported that the plant height, nodules plant\(^{-1}\), number of pods plant\(^{-1}\), seeds pod\(^{-1}\), seed yield, N and P uptake increase with increasing rates of N and P. Sharma and Pathania (1999) observed that yield of rajmash increased with increasing N rate (0-60 kg N ha\(^{-1}\)) and was highest with 60 kg P\(_2\)O\(_5\) ha\(^{-1}\). Sushant et al. (1999) from Faizabad (UP) reported that yield of rajmash cv. PDR 14 increased with increasing N rates (0, 50 and 100 kg N ha\(^{-1}\)). Thakuria and Choudhary (1999) carried out field experiment on rajmash cv. PDR 14 in Kumarganj
(Assam) and found that yield, pods plant$^{-1}$, seeds pod$^{-1}$ and 100 seed weight increased with increasing N rate (30, 60 and 90 kg N ha$^{-1}$). Cultivation of rajmash in North Indian Plains required application of 120 kg N ha$^{-1}$ in sole cropping (Kushwaha, 1999a).

Singh and Singh (2000) reported that seed yield increased with delay in sowing and increasing N rates, whereas, 100-seed weight increased with increasing N rate. Singh and Sakhon (2000) recorded highest seed yield 1046 kg ha$^{-1}$ with *Rhizobium* inoculation in combination with nitrogen application as compared with 574 kg ha$^{-1}$ in control. Tewari and Singh (2000) observed that plant height, number of branches and length of pod increased with successive increase in the doses of nitrogen as well as phosphorus. Application of 120 kg N ha$^{-1}$ produced significantly higher number of pods plant$^{-1}$, weight of seeds plant$^{-1}$, number of seeds pod$^{-1}$ and seed yield, whereas, 160 kg N ha$^{-1}$ significantly reduced seed yield. Singh (2000) observed that the application of N up to 75 and 100 kg ha$^{-1}$ in *P. vulgaris* significantly improved the pod size, vigour of plant and individual plant productivity. Significantly higher pod yield, net returns and rates of net profit were observed for 125 kg N ha$^{-1}$. The net profit decreased at increasing P levels. Thakuria (2000) inferred that yield of rajmash increased with increasing N rates (30, 60 and 90 kg N ha$^{-1}$) in Kumarganj (Assam). Guerra et al. (2000) while working in Brazil on common beans (*Phaseolus*
vulgaris cv. Perola) observed that yield was generally increased with increasing N rate (0, 40, 80 and 160 kg N ha\(^{-1}\)).

Singh et al. (2001) at Varanasi (UP) noticed significant linear increase in seed yield up to 240 kg N ha\(^{-1}\) (2091 kg ha\(^{-1}\)) over 80 and 160 kg N ha\(^{-1}\). The straw yield followed the similar trend. Prajapati and Patel (2001) studied the physiological variation in rajmash as influenced by nitrogen levels. They observed that most of the physiological parameters, namely fresh and dry matter production per plant, leaf area index (LAI), net assimilation rate (NAR), relative growth rate (RGR) and crop growth rate (CGR) were significantly high with 120 kg N ha\(^{-1}\). Dhanjal et al. (2001) at Baraut (UP) found that the growth and yield attributes and yield of rajmash increased with increasing rates of N up to 120 kg ha\(^{-1}\). McKenzie et al. (2001) at Lethbridge (Canada) studied the response of four cultivars of rajmash to N rates and found that seed yields ranged from 81 to 100% of maximum yields when available N rate levels (fertilizer -N plus nitrate to 30 cm just prior to sowing) were less than 80 kg N ha\(^{-1}\), but were always greater than 90% of maximum yield when available N levels were greater than 80 kg N ha\(^{-1}\). Split application of 50% N as basal + 50% at branching stage proved to be the most effective mode of application to rajmash (Ghosal, 2000). Similarly, split application of 120 kg N ha\(^{-1}\) gave 60.35, 98.5, 91.6 and 108.13% higher yield over no nitrogen at Varanasi, Akola, Durgapura and Raipur, respectively. Over the location there was 68.37 and 35.06 per
cent higher yield over control with the application of 120 and 60 kg N ha$^{-1}$, respectively (Anonymous, 2002-03).

Chandel et al. (2002) observed yield components, crop and protein yield significantly increased with increasing nitrogen levels and the highest values were registered with 120 kg N ha$^{-1}$. The nitrogen content and nutrient uptake increased with increasing nitrogen levels and highest values were recorded with 120 kg N ha$^{-1}$. Vishwakarma et al. (2002) observed that the highest dry matter production plant$^{-1}$ as well as pods plant$^{-1}$, grains pod$^{-1}$, grains plant$^{-1}$, pod length and 100-grain weight increased with the increasing rates of nitrogen up to 90 kg ha$^{-1}$. The level of nitrogen also recorded maximum water use efficiency.

Andrade et al. (2004) studied the effect of N fertilizer on grain yield and nutritive value of bean. Greater productivity in all cultivars was obtained with high N treatments. Prajapati et al. (2004) noted that higher levels of nitrogen (120 kg ha$^{-1}$) received significantly higher values of nutrient uptake and yield of rajmash.

Singh et al. (2006) conducted a field experiment for two years 1999-2000 and 2000-2001 at Agriculture Research Farm, BHU, Varanasi reported significant increase in plant height, dry weight, nodule number and dry weight, pod length, pod number and weight, seeds pod$^{-1}$, 100 seed weight, grain and straw yield in rajmash cultivar HUR 137. They further
reported significant increase in protein harvest up to the highest level of nitrogen (180 kg ha\textsuperscript{-1}).

2.2.2 Effect of N on nutrient concentration and uptake by rajmash

Stfoyanova et al. (1992) carried out field trials in 3 regions of Bulgaria and noted that seed protein content increased with increasing N rate (40, 80, 120 kg N ha\textsuperscript{-1}) at Genetal Toshero and Lom but was highest with 80 kg N at Kamobat. Seed P and K contents were not affected by N rate. Batra et al. (1992) at Hisar (Haryana) studied on Phaseolus vulgaris cv. VL-63 grown in sterile soil mixed with 20 g FYM with 0, 10, 20, 30, 40 and 60 ppm N as KNO\textsubscript{3} and noted increase in nodulation and nitrogenase activity up to 20 ppm N but it decreased at higher rates. They also found that nitrate reductase activity in leaves and total N uptake were highest with 50 ppm N. Smithson et al. (1993) at Arusha (Tanzania) noted that nitrogen application increased its concentration in the leaf but decreased the concentration of other major and minor elements in leaves.

Singh and Abidi (1995) found that protein, total sugar, reducing sugar and amino acid (lysine and tryptophan) contents were highest with 125 kg N ha\textsuperscript{-1} than 75 and 100 kg N ha\textsuperscript{-1} at Ghaghraghat (UP). Gupta et al. (1996) at Varanasi (UP) noted that uptake of NPK increased with increasing N rates (0, 40, 80 and 120 kg N ha\textsuperscript{-1})

Cruciani et al. (1998) carried out field trial in Piracieba, Sao Paulo, Brazil and observed that N fertilizer significantly increased seed yield
and N uptake compared with control in case of bean (*Phaseolus vulgaris* L.).

Shivananda *et al.* (1998) at Bangalore observed that the uptake of N by *Phaseolus vulgaris* cv. Arka Komal was highest in ammonium sulphate treated soil followed by FYM.

*Sims et al.* (1980) carried out field experiment in the Dobroudja region, Bulgaria where 10 Bulgarian and 14 foreign *Phaseolus vulgaris* cultivars with different growth habits were compared with no fertilizer, 120 kg N ha\(^{-1}\) or inoculation with *Rhizobium leguminosarum*. Seed N content varied from 19.8 to 24.9 per cent. The meteorological conditions, geographical origin of the cultivar, growth habit and N fertilizer, all had significant effects on seed protein content. The dry year of 1996 increased the protein content. The foreign cultivars had higher protein content than the local cultivar. Protein content was affected by growth habit and was in inverse proportion to the protein yield. N fertilizers increased protein content, while *Rhizobium* inoculation had no significant effect. *Singh et al.* (2006) observed significant increase in N, K, Zn, Mo and B uptake with increasing levels of N from 0 to 120 kg N ha\(^{-1}\). The highest uptake of major and micro nutrients was found with the application of 180 kg N ha\(^{-1}\).

### 2.2.3 Effect of N on economics of rajmash

Thirumalai *et al.* (1993) found that the best yield of *Phaseolus vulgaris* was obtained by applying 62.5 kg N ha\(^{-1}\), which only gave a incremental cost : benefit ratio of 1:4.12. *Singh* (1994) at Ghazipur (UP)
observed the highest net return from 120 kg N ha\(^{-1}\) applied in frenchbean. Singh (1995) carried out field trials in *rabi Phaseolus vulgaris* at Dholi (North Bihar) and noted significant response up to 90 kg N ha\(^{-1}\). The highest net return and net return rupee\(^{-1}\) of investment was also obtained with this treatment. Singh *et al.* (1996) at Varanasi (UP) found that seed yield, net return and N, P, K uptake were increased with increasing N rates from no nitrogen to 40, 80 and 120 kg N ha\(^{-1}\).

Singh (2000) observed that the application of N up to 75 or 100 kg ha\(^{-1}\) in *Phaseolus vulgaris* significantly improved the pod size, vigour of plant and individual plant productivity. Significantly higher pod yield, net return and rate of net profit were observed for 125 kg N. Singh *et al.* (2006) observed the highest net return of Rs.43,744 ha\(^{-1}\) and a benefit cost ratio of 2.37 in rajmash with the application of 180 kg N ha\(^{-1}\).

2.3 **Role of zinc in pulses**

Zinc application exhibited variable response in different pulse crops and significantly increased the nodulation, yield and carbohydrate content in seeds. Lagheamoglobin 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.

The continuous cultivation of exhaustive crops since long caused the imbalance in the supply of the major and micro nutrients. An analysis of 2, 51, 547 surface samples in different states of the country revealed that 49,
12. 5 and 3 per cent samples were found deficient in available Zn, Fe, Mn and Cu, respectively (Nayyar, 1999). Zinc deficiency has become chronic particularly in soils having alkaline reaction.

As Zn is the most deficient nutrient in the Indian soils, extensive research has been carried out on rate, method and time of application besides integrating Zn with organics. Application method of Zn to pulses is mainly soil application, foliar spray and soaking the seed in Zn solution. Corrections of micro nutrient deficiency is warranted for improving the yield potential of pulses. Among the micronutrients Zn, Fe, B and Mo improves the yield appreciably. Foliar spray of Zn, B and Mo proves to be economical (Savithri, 2000).

2.3.1 Effect of zinc on growth, yield attributes and yield of rajmash

Garg et al. (1986) reported that application of Fe and/ or Zn in the form of iron sulphate and zinc sulphate increased chlorophyll 'a' and 'b' concentrations, indole-3-acetic acid, nitrate reductase activity and dry matter yield of rajmash plants. Fe and Zn in combination were more effective in delaying the leaf senescence as compared to control. Iron alone and in combination with Zn appeared to delay senescence in rajmash plants.

Ruano et al. (1988) reported chlorophyll content decreased with increased Zn rate at different plant development stages, showing no clear correlation between chlorophyll content and plant concentration of other nutrients. Iyenger and Raja (1988) at Bangalore stated that Phaseolus
vulgaris cv. Burpee Stringless gave the highest yield with ZnSO\textsubscript{4} \( \text{@} 10 \text{ kg ha}^{-1} \). The yield data of soybean also indicated the most effective nature of soil application. Foliar spray of ZnSO\textsubscript{4} do not always increase the yield of pulses as observed by Dwivedi et al. (1990) in soybean.

Deka and Shadeque (1991) at Jorhat (Assam) reported that *Phaseolus vulgaris* cv. Pusa Parvati gave the tender pod yield of 6.05 and 6.10 t ha\(^{-1}\) with application of 0.1 and 0.2 per cent Zn, respectively. Soliman et al. (1991) at Cairo (Egypt) found that application of 200 ppm ZnSO\textsubscript{4} spray increased the seed yield. Melo et al. (1991) studied response of *P. vulgaris* to organic and inorganic source of Zn. Initial plant population and final plant population were greater with organic than inorganic Zn. Average seed yield was higher with inorganic than with organic Zn. Singh et al. (1992) at Varanasi (UP) carried out field experiment on rajmash cv. VL-63 in sandy loam soil. They found no significant effect on chlorophyll content, seed yield, 100-seed weight, dry matter (DM) or pods plant\(^{-1}\) at 0 and 5 ppm of Zn application.

Hussain et al. (1993) at Bangalore (KR) in a pot experiment noted that spraying of 0.0001, 0.001, 0.01 and 0.1 ppm zinc decreased the maturity with increasing Zn concentration on cv. Contender and Burpee. On the basis of field experimentation, the optimum level of Zn application has been found to be 11.2 kg Zn ha\(^{-1}\) for chickpea and 5.5 kg Zn ha\(^{-1}\) for soybean and other pulses. In Tamil Nadu, Sudarshan and Ramaswami (1993) found the
favourable residual effect of ZnSO₄ applied to groundnut @ 20 kg ha⁻¹ on the succeeding blackgram crop. Similarly, application of ZnSO₄ @ 25 kg ha⁻¹ for the second crop of blackgram was found beneficial and had good cumulative effect also by way of enhancing the zinc control of soil.

Singh et al. (1995) at Varanasi (UP) studied the effect of Zn (0 & 5 kg ha⁻¹) on Phaseolus vulgaris cv. HUR-15. They found that the application of Zn did not affect the yield of frenchbean. Blaylock (1995) at NW Wyoming (USA) carried out field experiment on Phaseolus vulgaris supplied with 0, 5, 6 (banded adjacent to row) and 11.2 (broadcast and incorporated) kg Zn ha⁻¹ as ZnSO₄. Zn application did not consistently affect seed yield, but did increase mature pod percentage with banded zinc giving the most consistent response. Silveira et al. (1996) at Goias (Brazil) studied the response of zinc on Phaseolus vulgaris cv. Carioca. They noticed that the number of seeds pod⁻¹ and 100-seed weight were significantly increased with increasing Zn rates (4.6-9.2 kg ha⁻¹). Pastricha and Bahl (1996) also reported that the response of pulses to zinc application varied from 10-25 kg ha⁻¹ in light textured soils. Moracs and Dynia (1998) noted that application of 0 or 20 kg ZnSO₄ ha⁻¹ did not affect the yield of beans (Phaseolus vulgaris) cv. LM 3030 in podzolic soil of Goianira, Goias, Brazil.

Working at Kanpur (UP) on sandy loam soil, Kushwaha (1999b) noted that application of 25 kg ZnSO₄ ha⁻¹ increased the seed yield of rajmash cv. PDR 14. Lima et al. (1999) at Minas Gerais (Brazil) observed
that Zn did not significantly affect yield or yield components due to satisfactory levels in the soil. Sperotto *et al.* (1999) at Santa Maria (Brazil) reported that osmotic preconditioning with zinc generally increases the height of the first pod, the number of pods plant$^{-1}$ and seeds pod$^{-1}$. Bhogal *et al.* (1999) at Pusa (Bihar) conducted an experiment on 6 *Phaseolus vulgaris* cultivars with 0, 5 or 10 kg Zn ha$^{-1}$ as ZnSO$_4$. Mean seed yield at the 3 Zn rates was 0.84, 1.05 and 1.25 t ha$^{-1}$ was highest in cv. PDR-27 at all Zn rates with PDR-20 and PDR-14 giving the next highest yields. Karaman *et al.* (1999) in a greenhouse trial observed that there was an increase in dry matter production with increasing Fe and Zn concentrations. The highest dry matter yield was obtained with 20 ppm Zn + 20 ppm Fe as Fe-EDDHA. Fe application decreased the P, Zn, Cu and Mn contents of plants, while Zn application decreased the P, Fe, Cu and Mn contents.

Trials conducted in different agro-ecological zones of India showed that soil application of 25-50 kg ZnSO$_4$ 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 performance of foliar spray of 0.5 per cent ZnSO$_4$ and seed soaking with 2 per cent ZnSO$_4$ were comparable with soil application for greengram, while for blackgram soil application is best (Savithri, 2000). McKenzie *et al.* (2001) at Alberta (Canada) noted that application of Zn did not increase seed yield of common bean.
Fageria (2002) at Santo Antonio (Brazil) noted that Zn application had a significant negative effect on dry weight of common bean root. 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).

Rajni and Meitei (2004) studied the effect of foliar spraying of boron (0.5, 1.0 ppm) and zinc (0.01, 0.10 ppm) and their combinations against control. A combined application of boron (1.0 ppm) and Zn (0.10 ppm) after 20 and 40 days of sowing of seeds were found to be beneficial for growth in terms of plant height, leaf number, branches number and shoot weight, earliness, yield in terms of number, length, fresh weight, dry weight and per cent dry matter of pod and number of seeds per pod, and quality in terms of protein content in *P. vulgaris*.

Togay *et al.* (2004) at Van (Turkey) reported that the highest seed yield (2766.0 kg ha\(^{-1}\)) was obtained with application of 25 kg Zn ha\(^{-1}\) as compared to control and 30 kg Zn ha\(^{-1}\). Teixeira *et al.* (2003) in Brazil noted that application of Zn increased the plant height, number of seeds pod\(^{-1}\), pods plant\(^{-1}\) and productivity of bean.

### 2.3.2 Effect of zinc on nutrient concentration and uptake by *rajmash*

The high cropping intensity through improved production technology and use of high analysis fertilizers has rendered the soils prone to
deficiencies of single or multiple micronutrients (Dwivedi, 1990, and Singh and Sekhar, 1993). Cokmak and Marschner (1993) at Adana (Turkey) noted that when zinc was supplied to zinc deficient plant restored the activities of the enzymes and restored leaf protein concentration more rapidly than chlorophyll content and plant growth. 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 increasing N rate but did not differ among Zn treatment. Whole plant Zn concentration increased with Zn application.

Pozzebon et al. (1996) at Santa Maria (Brazil) found that pulse crops respond well to application of micronutrients like Zn, B and Fe under deficient conditions. Zinc is known to be involved in nitrogen fixation through nodule formation (Balusamy, 1996).

Fageria and Zimmermann (1998) at Caixa Postal (Brazil) noted that uptake of zinc increases with a decrease in soil pH. Sharma et al. (1999) at Pantnagar (UP) noted that mycorrhizal roots exhibited generally higher Zn absorption rates than the non-mycorrhizal roots. Low soil fertility in general and nitrogen and phosphorus deficiency in particular is the most common abiotic constraints in Rajmash production. Aluminium and manganese toxicity and boron, iron, phosphorus and zinc deficiency may also adversely affect its production (Thung and Rao, 1999).
Fageria (2002) at Santo Antonio de Goias (Brazil) revealed that uptake of N, Mg and Cu were increased by zinc application, whereas, uptake of P was decreased. Teixeria et al. (2004) at Dourados (Brazil) found that the foliar spray of Zn (0, 50, 100, 200 and 400 g ha\(^{-1}\)) at 25 and 35 days after emergence increased the leaf content of N, K, Ca, Mg, S, B, Cu and Fe. There was also a marked decrease in P content. The chlorophyll levels were not affected by the addition of Zn. Goh and Karamanos (2004) at Manitoba (Canada) noted that soil Zn application resulted in a significant increase of Zn in plant at tissue level and also increased the seed yield. Teixeira et al. (2005) at Ipameri (Brazil) noted that seed contents of N, P, B and Cu were influenced by the application of Zn (0, 50, 100, 200 and 400 g ha\(^{-1}\)). Zinc did not affect the physiological quality of bean seeds.

Umamaheswari and Singh (2005) at Varanasi (UP) noted that the number of root nodules and leghaemoglobin content were highest at flower initiation stage at 5 kg Zn ha\(^{-1}\). Singh et al. (2006) observed that Zn application at 6 kg ha\(^{-1}\) increased the N, P, K, Zn and B uptake at higher level.

### 2.3.3 Effect of zinc on economics of rajmash

Singh et al. (2006) reported that application of 6 kg Zn ha\(^{-1}\) showed the maximum net return of Rs 42,309 ha\(^{-1}\) with a benefit:cost ratio of 2.54.
2.4 Effect of FYM x nitrogen x zinc on productivity and economics of rajmash

Jana et al. (1987) working at Mohanpur (WB) revealed that the highest yield of tender pods (45 q ha\(^{-1}\)) was obtained with basal dose of 20 t FYM + 50 kg N ha\(^{-1}\) + Zn with other micronutrient at 0.1%. The non treated control yield was 19.5 q ha\(^{-1}\). Onisie et al. (1993) at Lasi (Romania) observed that the seed yield of *Phaseolus vulgaris* ranged from 5.50 t ha\(^{-1}\) with no N to 2.8 t ha\(^{-1}\) with 30 kg N + 20 t FYM.

Pozzebon et al. (1996) from Brazil reported that split application of N through fertilization and micro nutrient treatment had no effect on N, P and K contents in above grained parts of rajmash. No positive impact on total or available N content of soil was obtained by the use of urea + FYM or poultry manure (Rao and Sitaramayya, 1997).

Sannigrahi and Borah (2000) at Tezpur (Assam) in field experiment with *Phaseolus vulgaris* cv. Contender observed that the yield of Frenchbean (36.1 t ha\(^{-1}\)) was the highest with 10 t FYM ha\(^{-1}\) + inoculation + 15 kg N ha\(^{-1}\) + 10 kg K\(_2\)O. In another study, at Hebbal, the highest N, P and K uptake was noted with FYM @ 5 t ha\(^{-1}\) + 50 kg N as compared to 50 kg N along with either 10 t FYM or 3 t poultry manure ha\(^{-1}\) (Babu and Reddy, 2000). Nutrient uptake decreased with the reduction in levels of inorganic fertilizers along or either in combination with FYM. Use of FYM increased nutrient uptake (Kumar et al., 2001).
Choudhari et al. (2001) at Nagpur (MH) revealed the application of FYM at 2.5 t ha$^{-1}$ + 50% RDF (45:30 kg N and P ha$^{-1}$) gave 12.86 pods plant$^{-1}$, seed yield of 12.61 g plant$^{-1}$ and 11.31 q ha$^{-1}$, which is statistically at par from RDF (90:60 kg N and P ha$^{-1}$). Thus, 50 per cent savings of N and P fertilizers were achieved without affecting the yield and yield component of Frenchbean.

Response of *Rhizobium* inoculation and application of sulphur @ 40 kg ha$^{-1}$ in Rajmash was found significant at Varanasi but was non significant at Akola (Anonymous, 2000-01). Similarly, at Dholi combined application of phosphorus @ 20 kg ha$^{-1}$ with nitrogen gave 52.5 per cent higher yield over nitrogen alone (Anonymous, 2001-02). Singh and Verma (2002) in sandy loam soil at Ghazipur (UP) reported that 10 t FYM ha$^{-1}$ + 90 kg N ha$^{-1}$ gave the highest net return and benefit : cost ratio. Combined application of FYM and 120 kg N ha$^{-1}$ was found to be the best (Anonymous, 2002-03).

Gopal et al. (2003) at Faizabad (UP) studied on rajmash by taking nitrogen rates (50, 100, 150 kg ha$^{-1}$) with or without 5 t FYM ha$^{-1}$. They found that plant height, number of branches plant$^{-1}$, dry matter and grain yield increases with increasing N rates with addition of FYM resulting in higher value of above parameters measured. Ram et al. (2003) at Faizabad (UP) found that plant height, number of branches plant$^{-1}$, dry matter plant$^{-1}$ and seed yield increased with increasing N rates and with the addition of FYM resulting in higher value of the parameters measured.
2.5 Energy studies

Singh et al. (1981) studied the energy requirement of paddy, cotton, maize and wheat and reported that all the crops consumed majority of energy from mechanical sources. Singh et al. (1997) concluded that energy requirement of chickpea production in Madhya Pradesh was 2336 and 5237 MJ ha\(^{-1}\) operation-wise and source-wise, respectively. Energy ratio was found 8.60 and specific energy was 4.76 MJ kg\(^{-1}\). Sharma et al. (1998) from Sehore concluded that the total production energy requirement for chickpea (*Cicer arietinum* L.) production was estimated to be 3534 MJ ha\(^{-1}\), of which their operation energy was 1204 MJ ha\(^{-1}\). The input energy ratio was 6.65.

Guruswamy et al. (2001) while studying on energy requirement for crop production under dry land agriculture found that redgram consumed maximum human and animal energy. The energy consumption were the highest for harvesting, tillage operation and sowing operations, whereas, the energy requirement for primary and secondary tillage operation was 444 MJ ha\(^{-1}\) and 125 MJ ha\(^{-1}\) for redgram. The operationwise energy consumption was 1167 MJ ha\(^{-1}\) for redgram and 1176 MJ ha\(^{-1}\) for greengram crop. The output energy of redgram from main and byproducts were 6321 MJ ha\(^{-1}\) and 23320 MJ ha\(^{-1}\), respectively. The energy ratio of redgram and greengram was 4.37 and 4.20 for the main product, but for the byproducts it was 16.08 and 12.88, respectively. The total output-input energy ratio was 20.45 for redgram followed by greengram, sorghum and sunflower.