CHAPTER - 2

REVIEW OF LITERATURE
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### REVIEW OF LITERATURE

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2.1 Mineral nutrition of plants

Soil has occupied the most important place in traditional agriculture from time immemorial. It is the matrix which not only supports the plants but also provides them with water and minerals. It consists of mineral, organic matter, water, air and living organisms. Of these mineral matter, obtained from the parent rocks, forms the bulk of soil solids and is the main natural source of mineral nutrients for plants. Inorganic ions of the soil derived mostly from mineral constituents, are termed as mineral nutrients except nitrogen. However, it is also considered as a mineral nutrient because it is taken up and metabolised in the similar fashion as other mineral nutrients. Some of these mineral nutrients are essential for plant growth and development. Others may be beneficial only under certain conditions, while still others may even be harmful. Of the essential mineral elements, N, P and K play the most important role as they are removed by crops in large quantities by virtue of their function in various metabolic processes of cell to maintain the life cycle of plants. However, the other macro and micro-nutrients are equally important in view of their proven limiting effect on crop productivity.
2.1.1. Brief history

The concept of mineral nutrition of plants can be traced back to the Greek period, when Aristotle (384 B.C.-322 B.C.) recognised that the nutritive function separated the living from the dead. Cato (234-149 B.C.) was the earliest Roman agriculturist, who emphasised the importance of ploughing and urged the need for careful conservation of manure (Bould, 1963). The seventeenth century is thought to be the beginning of researches on plant nutrition with Van Helmont (1577-1644) drawing the attention to the importance of nutrients for plants (Bould, 1963).

Glauber in 1656 found that saltpeter, obtained from cattle manure, was effective for plant growth. Later Home in 1755 found that saltpeter, epsom salts and potassium sulphate were needed to increase plant growth and development. However, the modern concept of plant nutrition dates back to the beginning of the 19th century. The credit for introducing scientific experimental methods in plant nutrition studies goes to de Saussure, who in 1804 analysed the plant ash and correlated the mineral contents of plant ash with that of the soil supporting its root system. Further he maintained that mineral elements, including nitrogen, supplied by the soil were essential for growth and development of plants.
By the middle of the 19th century it had become quite clear to the farm scientists that growth of crop plants was proportionate to the amount of inorganic nutrients present in the soil. During this period different workers in different places, namely Boussingault in France, Lawes and Gilbert in England, Liebig in Germany and Salm-Horstmar in France made sustained field trials to solve various problems of mineral nutrition of plants and made the most significant contribution in this regard (Russell, 1950).

In the early part of the present century, considerable attention was paid to soil solution and ion exchange of the mineral elements. Later, Gregory (1937), Lundegardh (1947, 1951), Russell (1961) and Bould (1963) wrote excellent reviews and books on mineral nutrition and leaf analysis emphasising, among the aspects, the need for further researches in this field.

2.2 Role of NPK in plant metabolism

Mineral nutrients are necessary for maintenance of the physical organisation and functioning of living cells by virtue of their function in the generation of energy, building molecules, participating in the repair of protoplasm and regulation of metabolic process (Nason and McElrey, 1963). Among various nutrients, nitrogen, phosphorus
and potassium are considered to be of prime importance. It has been established that a balanced dose of nitrogen, phosphorus and potassium in the presence of adequate amount of other essential nutrients gives much better results than an unbalanced dose. Therefore, the part played by each of these macronutrients in plant growth and development is briefly considered below.

2.2.1 Nitrogen

Plants contain more atoms of nitrogen than of any other element derived from the soil (Viets, 1965) and nitrogen is the fourth most abundant element in plants after carbon, hydrogen and oxygen. It is mainly absorbed as nitrate and is reduced and incorporated into organic compounds (Bandurski, 1965; Beevers and Hageman, 1969). Being a structural component of wide arrays of vital biomolecules such as amino acids, nucleotides, porphyrins and several co-enzymes, nitrogen evidently plays a central role in cellular metabolism. Hence, several morphological and physiological factors, like succulence of fruits, length and breaking strength of fiber, root growth, fruiting capacity, resistance to lodging, winter hardiness, disease resistance, physiological maturity and yield of many crops have been known to be governed by the nitrogen supply to the crops (Black, 1973).
The deficiency of nitrogen results in stunted growth and decreased yield and quality of fruits, vegetables and grains. When the nitrogen supply is a limiting factor, both the rate and the extent of protein synthesis are depressed and flowering and fruit setting are adversely affected (Agarwala and Sharma, 1976).

2.2.2. Phosphorus

The plants absorb phosphorus from the soil as monovalent ($\text{H}_2\text{PO}_4^-$) or divalent ($\text{HPO}_4^{2-}$) anions (Epstein, 1978). It is a constituent of lipoproteins, nucleic acids, nucleoproteins and several co-enzymes, e.g. TPP, ATP, NADP etc. (Devlin and Witham, 1986). Being a constituent of ADP, phosphoglyceraldehyde and ribulose phosphate, phosphorus is involved in the basic reaction of photosynthesis. It increases the growth of plant roots, which can feed the plants more efficiently. In grain legumes it enhances nodulation, nodule growth much more than root and shoot growth (Cassman et al., 1980).

Because of the functions of phosphorus in the growth and metabolism of plants, its deficiency leads to a general reduction of most of the metabolic processes, including cell division and expansion, respiration, and photosynthesis (Terry and Ulrich, 1973). Its deficiency causes many visible effects, viz. acute leaf angle, lack of tillering, prolonged
dormancy of lateral buds, premature leaf fall, decrease in size and number of flower primordia and small fruits or seeds. Besides these, its deficiency results in disturbing nitrogen metabolism which causes the accumulation of soluble organic nitrogenous compounds (free amino acids and amides) and decrease in protein content (Bains and Bhardwaj, 1976). Phosphorus deficiency also results in an increase in the accumulation of free reducing sugar, suggesting an involvement of phosphorus in carbohydrate metabolism (Devlin and Witham, 1986). A correlation between phosphorus supply and phytohormones balance has also been noticed in plants as evidenced by the relationship between its deficiency and a decrease in the number of flowers (Bould and Parfitt, 1973) and delay in flower initiation (Rossiter, 1978).

2.2.3. **Potassium**

Potassium is the only monovalent cation essential for all plants. It exists in the soil in exchangeable, non-exchangeable (fixed form) and soluble forms (Black, 1973). It is abundantly present in the cytoplasm and in vacuolar cell sap. Birner and Lucan in 1866 gave the first proof that it is indispensable for flowering plants and cannot be replaced by other nutrients (Reed, 1942). A relationship of potassium to starch formation suggested earlier, has been firmly established by recent investigators (Greenberg and Preiss, 1965; Nitsos and Evans, 1968, 1969). Potassium
affects several other important functions, like osmoregulation, water transport and the translocation of carbohydrates in plants and it also enhances the ability of the plants to resist diseases, insect attacks, cold and other adverse conditions. Potassium counteracts the ill effects of excessive nitrogen. It gives strength to the stalks thereby increasing the resistance of plants to lodging. According to Rains (1976), potassium is important for protein synthesis. Besides, it acts as a catalytic agent and activator for a large number of enzymes, such as pyruvate kinase, acetic thiokinase, succinyl CoA synthetase (Evans and Sorger, 1966; Rains, 1976).

In legumes, potassium plays a crucial role by enhancing the production of starch and sugar that benefit the symbiotic bacteria and thus enhances the fixation of nitrogen. Deficiency of potassium results in a decrease in the reducing sugars and proteins. Its deficiency limits CO₂ diffusion through stomata thus resulting in the increase in stomatal resistance. Visually, potassium deficiency creates rosette habit of vegetables, shortening of internodes in oilseed crops and cereals, increased tillering in barley and death of terminal bud and marginal scorching of leaves in many crops (Hewitt, 1963).
2.3 Basal application of phosphorus in relation to *Cicer arietinum* L.

The requirement of phosphorus for different crops has been worked out from time to time in different parts of India (Bains and Bhardwaj, 1976). However, the work on this line on pulses has not been given due attention compared to other crops like cereals and sugarcane etc. The available literature on the work done in relation to phosphorus application for ameliorating the performance of chickpea (*Cicer arietinum* L.) by several workers are reviewed below:

Sharma and Richharia (1962) carried out field experiment during rabi seasons of 1955-56 and 1956-57 to study the effect of placement of phosphate with and without potash on yield of gram variety BR 77. They applied three levels of phosphorus (0, 44.83 and 67.25 kg P$_2$O$_5$/ha), two levels of potassium (0 and 44.83 kg K$_2$O/ha) and two methods of applications (at surface and at ploughsole) in nine possible combinations. The experiment was laid out in randomised block design with four replications and the sources of phosphorus and potassium were single superphosphate and muriate of potash respectively. They found phosphorus to produce bold grains by increasing size and weight of grains with the resultant increase in total yield of grains. It was also noted that phosphorus application @ 44.83 and 67.25 kg P$_2$O$_5$/ha giving equal effects,
significantly produced higher yield than control (0 kg P$_2$O$_5$/ha) in both the years. The inclusion of potassium in the treatment did also prove beneficial. Regarding the methods of application, it was reported that placement at ploughsole gave significantly more yield than that given by placement at surface.

Shukla (1964) performed field trial during the rabi seasons of 1955-56 and 1956-57 to observe the effect of phosphorus and nitrogen individually and in combination on the performance of variety BR 77. Three levels each of phosphorus and nitrogen @ 0, 33.62 and 67.25 kg P$_2$O$_5$/ha and 0, 11.20 and 22.41 kg N/ha was applied. The experiment was done according to randomised block design and each treatment was replicated eight times. The effect of these treatments was observed on various growth and yield parameters like plant height, number of branches, number of pods, grain yield and straw yield. It was found that the crop in relation to these attributes showed positive response to phosphorus application and 33.62 kg P$_2$O$_5$/ha proved optimum. He also found that increasing levels of nitrogen in the absence of phosphorus lightly depressed grain yield but in combination with phosphorus, particularly the use of 22.41 kg N/ha had a positive relationship with yield. It was concluded that application of 22.41 kg N/ha in combination
with 33.62 kg \( P_2O_5/ha \) proved best for most of the plant attributes including seed yield.

Pandey (1969) conducted pot experiment on chickpea variety T87 to find out the effect of phosphorus, nitrogen and molybdenum on nodule formation. He applied phosphorus at the rate of 0.1, 0.2, 0.3 and 0.4g per pot; nitrogen at the rate of 0.1, 0.2 and 0.3g per pot and molybdenum was used as foliar spray at the rate of 110 and 100 ppm in the form of molybdic acid after 21 days of sowing. A uniform dose of potassium at the rate of 0.1g per pot was also given. It was found that application of phosphorus, nitrogen and molybdenum increased the number of nodules per plant. However, heavier doses of any of these nutrients were not found beneficial for nodule formation.

Singh (1970) laid out an experiment in a split plot design to find out the effect of phosphorus and nitrogen and also the number of cultivation on chickpea. Three levels of phosphorus, i.e. 0, 45 and 90 kg \( P_2O_5/ha \) and two levels of nitrogen, i.e. 0 and 22.5 kg N/ha were applied to sub-plots, and three levels of cultivation, viz. one preparatory cultivation, two preparatory cultivations and three preparatory cultivations were given to main plot. It was reported that application of phosphorus increased both seed and straw yield upto 45 kg \( P_2O_5/ha \) which were found to be 72 and 68.3% higher in comparison to 0 kg \( P_2O_5/ha \) respectively.
Singh (1971) conducted field experiment during 1964-65 to study the response of gram variety Type 1 to four levels of phosphorus (0, 22.5, 45.0 and 67.5 kg P/ha) and three levels of nitrogen (0, 11.25 and 22.5 kg N/ha). The application of phosphorus gradually increased the height, branches and dry weight of stem, roots and leaves of the plant. They also reported that an increase in the dose of phosphorus increased the number and dry weight of nodules significantly and with 67.5 kg P$_2$O$_5$/ha, a maximum 138 nodules having 471 mg dry weight per plant were produced. Phosphorus application was also proved beneficial for the grain yield and yield determining characters, like number of fruiting branches, number of pods and the size of grains and 22.5 kg P$_2$O$_5$/ha proved optimum for grain yield in both the years. He also found that the nitrogen, protein, phosphorus and carbohydrate contents in the grain and straw increased considerably with the application of phosphatic fertiliser. Application of nitrogen had little stimulatory effect on the growth of plants. However, the effect of nitrogen on nodulation was more pronounced than on growth of root and foliage and 22.5 kg N/ha proved best.

Sinha (1971) investigated the effect of two doses of phosphate, viz. 30 and 60 kg P$_2$O$_5$/ha and three methods of their application, viz. broadcast, in contact with the seed and 3.5 cm below the seed during 1966-67 and 1967-68 in a
randomised block design experiment with four replications. The trial was performed under irrigated condition. Two additional treatments, i.e. 10 kg N/ha and one control (0 kg N/ha) were also included. He studied various growth and yield characteristics, namely plant height, number of branches, number of effective pods per plant, seed yield, straw yield, total phosphorus uptake and per cent phosphorus uptake from fertiliser. He observed that with a basal dressing of 60 kg P$_2$O$_5$/ha with 10 kg N/ha showed superiority to the dose of 30 kg P$_2$O$_5$/ha with 10 kg N/ha on all the above mentioned characteristics, except the number of branches per plant and the seed yield in 1967-68. However, no significant difference in grain yield was observed in both the years. None of the characters studied was significantly affected by the various methods of phosphorus application.

Singh and Yadav (1971) laid out an experiment in split plot design to study the effect of three levels of phosphorus, viz. 0, 45 and 90 kg P/ha, two levels of nitrogen, viz. 0 and 22.5 kg N/ha and three levels of cultivation (one, two and three preparatory cultivations) on chickpea. Different levels of cultivation were given into mainplots and different levels of fertiliser into sub-plots. They studied various growth and yield parameters, namely plant height, number of branches, number of pods, 1,000 seed
weight, seed yield, straw yield and protein per cent in grain. They found that application of phosphorus at the rate of 45 kg and 90 kg per hectare increased seed yield by about 72 and 63 per cent, respectively over control. However, the difference between values given by these levels of phosphorus was not statistically significant. Application of 45 kg P/ha proved optimum in all the characters studied except the number of branches per plant.

Sharma and Singh (1972) conducted a field experiment in a split plot design to observe the response of chickpea to three levels of phosphorus, viz. 0, 44 and 80 kg P₂O₅/ha. The result of the two years study showed that the application of phosphorus increased the grain yield of gram but the values given by different levels of phosphorus were statistically equal. They concluded that the low increase in yield might be owing to higher initial phosphate status of the soil.

Sinha (1972) conducted field experiment during 1965-66 and 1966-67 to investigate the effect of two doses of phosphate (30 and 60 kg P₂O₅/ha) and three methods of their application (broadcast, in contact with the seed and 3.5 cm below the seed) on chickpea variety NP 58 under rainfed condition. Two additional treatments, i.e. 10 kg N/ha and an unfertilised control were also included in the programme. He reported that with a basal dose of 10 kg N/ha, 30 kg P₂O₅/ha proved optimum on growth, yield and total P uptake. However,
percentage uptake of fertiliser phosphorus increased significantly up to 60 kg $P_2O_5$/ha.

Chundawat et al. (1976) conducted field trial for three years in rabi seasons of 1969-70, 1970-71 and 1971-72 to find out the effect of three levels of phosphorus, i.e. 15, 30 and 45 kg $P_2O_5$/ha, three levels of nitrogen, i.e. 0, 15 and 30 kg N/ha and two levels of seed treatment with rhizobia culture, i.e. non-inoculated and inoculated in 3x3x2 confounded design with four replications on chickpea variety RS 10. They used calcium nitrate and single superphosphate as sources of nitrogen and phosphorus respectively and were applied 5 cm below seeds. Phosphorus application increased the grain and straw yield in all the three years. However, grain yield was found significantly higher due to the application of 30 and 45 kg $P_2O_5$/ha during 1969-70 and 45 kg $P_2O_5$/ha during 1971-72 over 15 kg $P_2O_5$/ha. Application of 30 and 45 kg $P_2O_5$/ha increased grain yield by 25.1 and 30.1% respectively, over 15 kg $P_2O_5$/ha. In 1969-70, application of 45 kg $P_2O_5$/ha gave significantly higher yield than 30 kg $P_2O_5$/ha. It was also noted that application of phosphorus increased the straw yield, branches and pods/plant. Application of 30 and 45 kg $P_2O_5$/ha increased the straw yield by 20.1 and 28.4 per cent over 15 kg $P_2O_5$/ha respectively. Regarding the effect of inoculation it was observed that seed treatment with rhizobium culture markedly influenced the
straw yield, branches and pods/plant and test weight over untreated plants. Inoculation also increased seed yield considerably and it was significantly superior to no inoculation in 1969-70.

Rathi and Singh (1976) conducted field experiment during rabi season of 1972-73 to study the effect of phosphorus and nitrogen on the performance of chickpea variety T3. They applied four levels of phosphorus (0, 25, 50 and 75 kg P₂O₅/ha) and three levels of nitrogen (0, 10 and 20 kg N/ha) in randomised block design with four replications. Various growth and yield parameters such as plant height, number of branches, number of pods, 1,000 grain weight, grain yield/plant, grain yield (q/ha) and straw yield were studied. It was found that application of phosphorus significantly increased all the characteristics studied except plant height. The significant maximum grain and straw yield were obtained under 75 kg P₂O₅/ha.

Mudholkar and Ahlawat (1979) laid out field experiments during rabi seasons of 1970-71 and 1971-72 with different treatments in different years to study the response of chickpea variety C 235, to phosphorus, nitrogen and molybdenum application. In 1970-71, they applied three levels of phosphorus (0, 40 and 80 kg P₂O₅/ha) in main plots and two levels of molybdenum (0 and 0.25 kg Mo/ha) in subplots, in a split plot design experiment with six replications. In
1971-72, the treatments consisted of three levels of phosphorus, viz. 0, 40 and 80 kg P₂O₅/ha; two levels of nitrogen, i.e. 0 and 25 kg N/ha and two levels of molybdenum, i.e. 0 and 0.25 kg Mo/ha in a randomised block design with six replications. The sources of phosphorus, nitrogen and molybdenum were single superphosphate, urea and sodium molybate respectively. Application of phosphorus resulted in significant improvement in yield components, viz. pods/plant, grain weight/plant and 1,000 grain weight in 1971-72. The similar trend was also found in 1970-71 but the differences were not significant. Grain yield increased significantly owing to phosphorus application in both the seasons. However, the differences between 40 and 80 kg P₂O₅/ha were not significant in any of the seasons. The per cent grain yield increase with 40 and 80 kg P₂O₅/ha over control (0 kg P₂O₅/ha) was 5.35 and 11.9 in 1970-71 and 19.34 and 15.76 in 1971-72 respectively. Application of nitrogen failed to affect the yield components and grain yield. However, application of molybdenum improved pod number and grain yield significantly.

Suryawanshi and Chaudhari (1979) carried out field experiment during rabi seasons of 1971-72 and 1972-73 to find out the response of chickpea to phosphorus and nitrogen fertilisation. The treatments consisted of three levels of basal phosphorus (0, 25 and 50 kg P₂O₅/ha), two levels of foliar application of phosphorus (5 and 10 kg P₂O₅/ha) and
two levels of foliar application of nitrogen (5 and 10 kg N/ha). The design of the experiment was factorial randomised block and each treatment was replicated thrice. A uniform basal dose of 25 kg N/ha was also applied. They observed that basal application of 25 kg P₂O₅/ha significantly increased seed yield by 3.65 q/ha over control during 1971-72. However, the values did not differ critically in 1972-73. Pooled analysis, however, confirmed the beneficial effect of 25 kg P₂O₅/ha, as the average seed yield increased by 2.56 q/ha over control. Application of higher dose of phosphorus (50 kg P₂O₅/ha) was not economical. The effect of foliar application is mentioned on page 57.

Singh and Sharma (1980) carried out a split plot design experiment during 1975-76 and 1976-77 with all combinations of four doses of phosphorus, viz. 0, 4.5, 9 and 13.5 kg P/ha in the sub-plots, and three profile soil moisture levels, viz. 125, 160, and 200 mm/m, with and without 50 mm of additional irrigation water allocated to the mainplots. They studied the dry matter accumulation at various growth stages. Various yield components, namely number of pods/plant, number of grains/pod, 1,000 grain weight and seed yield/ha were also observed at harvest. Phosphorus application increased the dry matter accumulation significantly at all the stages of growth and the extent of increase was found to be more with the application of the
first 4.5 kg P/ha than with the subsequent increase of 4.5 kg P/ha. Grain yield was also found to increase due to phosphorus application in both the years and the highest grain yield was recorded 1394.0 and 1855.3 kg/ha with 13.5 kg P/ha in 1975-76 and 1976-77 respectively. The mean yield with 13.5 kg P/ha was 19.9, 7.0 and 2.9% higher than the yield obtained with 0, 4.5 and 9.0 kg P/ha respectively. However, the dose 9 kg P/ha proved optimum for obtaining seed yield. They also studied the uptake of N, P and K at harvest and found that higher dose of phosphorus were effective in increasing N, P and K uptake. It was concluded that phosphorus application resulted in root proliferation which might have helped in better nodulation, more nitrogen fixation and better utilisation of phosphorus and potassium.

Prasad and Sanoria (1981) conducted field experiment during 1979-80 to study the response of chickpea variety Type 1 to phosphorus application and seed bacterisation. They applied three levels of phosphorus, viz. 50, 100 and 150 kg P₂O₅/ha and three types of inoculation (no inoculum, Rhizobium H₄⁴+ Azotobacter B₄ and Rhizobium H₄⁵+ Azotobacter B₄) in nine possible combinations. Various parameters namely plant population, optimum dry weight(ODW)/plant, grain yield and grain crude protein per cent were studied. Among these parameters only crude protein per cent of seed was found statistically significant and the value increased
significantly up to 150 kg P₂O₅/ha along with either of the inoculum. However, the maximum grain yield was found in treatment 50 kg P₂O₅/ha along with *Rhizobium H₄5 + Azotobacter B₄* and showed 2.38% increase over 50 kg P₂O₅/ha along with *Rhizobium H₄4 + Azotobacter B₄* and 23.31% over 50 kg P₂O₅/ha along with no inoculum.

In split plot design, Dwivedi and Singh (1982) carried out field experiment during rabi seasons of 1977-78 and 1978-79 to study the effect of phosphorus and sulphur application on nutritional quality of five varieties of chickpea namely K468, H208, C235, F61 and JR130. Phosphorus and sulphur were applied at 0, 20, 40 and 60 kg P₂O₅/ha and 0, 20 and 40 kg S/ha respectively. The sources of phosphorus and sulphur were diammonium phosphate and elemental sulphur respectively. A uniform basal dose of 20 kg N/ha was also given to each plot. They studied protein, methionine and cysteine content in seeds. A gradual increase in protein content by increasing doses of phosphorus was observed. However, the treatments had no significant effect on methionine and cysteine content. Moreover, sulphur application significantly improved grain quality. Among different varieties, F61 was found to be best in performance followed by K468 and contained highest amount of protein, methionine and cysteine during both the years.
Ghosh and Ghosh (1982) carried out a pot experiment using labelled phosphorus to find out the relative fertiliser use efficiency of three varieties of chickpea namely BG 203, BG 209 and P 4701. They applied three levels of phosphorus, viz. 0, 40 and 80 kg P/ha and four moisture levels, viz. 1/3, 1/2, 1 and 3 bar in a factorial patterns making twelve treatments. $KH_2PO_4$, labelled at the rate of 0.6 m Ci/g of P was used as phosphorus source. Plants were harvested at 70 days after sowing and the dry matter was recorded. It was observed that application of phosphorus increased dry matter upto 40 kg P/ha and the highest dose (80 kg P/ha) had deleterious effect. However, the application of phosphorus upto 80 kg P/ha increased the P content of the plants as well as per cent P derived from fertiliser. They also found more than two-fold increase in P derived from fertiliser at 80 kg P/ha as against 40 kg P/ha and the differences in phosphorus uptake was statistically significant.

Gupta and Singh (1982) carried out field experiment for two consecutive rabi seasons of 1977-78 and 1978-79 to study the effect of phosphorus, nitrogen and sulphur nutrition on protein and amino acids contents of chickpea variety Radhey. The design of the experiment was randomised block. They applied three levels each of phosphorus (0, 40 and 80 kg $P_2O_5$/ha), nitrogen (0, 10 and 20 kg N/ha) and sulphur (0, 15 and 30 kg S/ha). The sources of phosphorus, nitrogen
and sulphur were superphosphate, urea and elemental sulphur respectively. The amount of sulphur present in superphosphate was balanced through gypsum. It was noticed that application of phosphorus markedly increased the protein content in grains. Nitrogen and sulphur were also found to enhance the protein content in grain appreciably. They have also computed the response equation for phosphorus application which showed a quadratic equation and optimum dose of phosphorus was found to be 69.45 and 67.07 kg P₂O₅/ha for 1977-78 and 1978-79 respectively. Eighteen amino acids in total were recognised in chromatogram of grain flour, when maximum doses of phosphorus, nitrogen and sulphur were applied.

Shukla and Yadav (1982) conducted a green-house pot experiment to study the effect of phosphorus and zinc on nodulation and nitrogen fixation in chickpea variety G130. In a completely randomised design in all possible combinations of five levels of phosphorus (0, 25, 50, 100 and 250 ppm/pot) and six levels of zinc (0, 5, 10, 20, 40 and 100 ppm/pot) were given. A basal application of N, K, Fe, Mn & Cu at the rate of 25, 75, 10, 5 and 1 ppm/pot respectively were also given. The sources of phosphorus and zinc were diluted H₃PO₄ and ZnSO₄·7H₂O respectively. The number, dry matter and leghaemoglobin content of nodules and amount of nitrogen fixed, generally increased with zinc upto 19 ppm and phosphorus alone upto 50 ppm and decreased with their higher levels. However, the adverse effect of higher dose of
phosphorus (250 ppm P) was counteracted by the application of 5 to 10 ppm Zn and the adverse effect of higher doses of Zn (40 and 100 ppm Zn) was counteracted by the addition of 25 to 50 ppm P. Maximum nodulation and nitrogen fixation was found by the application of 25 to 50 ppm P along with 5 to 10 ppm Zn. It was suggested that the increase in nodulation and nitrogen fixation with balanced P and Zn nutrition might be due to an increase in leghaemoglobin, K and Fe concentration in nodules and increased plant growth. It was concluded that balanced phosphorus and zinc nutrition was essential not only for plant growth but also for maximum activity of Rhizobium for nitrogen fixation.

Singh and Bajpai (1982) conducted field experiment in 1977-78 and 1978-79 to investigate the response of chickpea variety RS10 to basal phosphorus and foliar application of zinc and sulphuric acid. The experiment was laid out in randomised block design with three replications. They applied four levels of phosphorus (0, 20, 40 and 60 kg P/ha), three levels of zinc (0, 5 and 10 kg ZnSO₄/ha as foliar spray) and two levels of sulphuric acid (0, and 0.1% solution as foliar spray). The source of phosphorus was single superphosphate. Foliar spray of ZnSO₄·H₂SO₄ was done at 30 and 40 days after sowing respectively. Various growth and yield parameters, namely plant height, number of branches, number of pods, grain yield and straw yield were studied. Application of phosphorus was
reported to increase branches and number of pods/plant significantly. But plant height remained unaffected by phosphorus application in both the years. The maximum number of pods/plant were recorded at 40 kg P/ha in both the years. Phosphorus application on was also reported to increase grain yield in both the years but straw yield only in 1978-79. However, the higher dose of phosphorus (60 kg P/ha) significantly reduced the grain yield over 40 P/ha in both the years. Application of phosphorus at 20 and 40 kg P/ha increased seed yield by 11.8 and 16.9% in 1977-78 and 17.2 and 43.9% in 1978-79 respectively over the control. They concluded that increase in yield by phosphorus application was owing to increasing number of branches and number of pods/plant. Foliar application of zinc also increased the grain yield significantly but H$_2$SO$_4$ did not have any effect.

Yadav and Shukla (1982) conducted two pot experiments to study the effect of applied P and Zn on their absorption and distribution in chickpea plants grown upto 64 days in loamy-sand (Typic-Torripsamments). In the first experiment four levels of tagged phosphorus, viz. 25,50,100,250 ppm at 0.25 m Ci/g P$_2$O$_5$ were applied and in second experiment they included 5 ppm tagged Zn at 0.1 m Ci/g Zn alongwith five levels of P (0,25,50,100 and 250 ppm) in all possible combinations. It was observed that during 64 days of growth 4.9 to 11.4 and 0.64 to 1.50% of fertiliser P and Zn were utilised by chickpea plants respectively. They also observed
that absorption of phosphorus from fertiliser was generally higher than that from soil as well as more with zinc than that without it. It was found that up to 50 ppm P about 75% of absorbed P was translocated to shoots. However, at higher P levels (100 and 250 ppm) more P was retained in roots. Utilisation and translocation of both soil and fertiliser Zn were considerably increased in combination with 25 ppm P but with higher levels (250 ppm P) it decreased. The results of those two field trials showed that applied P and Zn affected absorption and distribution of soil and fertiliser P and Zn in roots and shoots depending upon their levels.

Dixit et al. (1983) laid out an experiment during rabi season of 1978 to find out the effect of phosphorus on the performance of three varieties of chickpea, namely Pink 2, T 87 and Narsingpur-bold. Five levels of phosphorus at the rate of 0, 20, 40, 60 and 80 kg P$_2$O$_5$/ha were applied in a randomised block design experiment with three replications. A basal dose of 25 kg N/ha was also given to each plot. The increasing levels of phosphorus upto 80 kg P$_2$O$_5$/ha increased the yield attributing characteristics considerably. The application of 20 and 40 kg P$_2$O$_5$/ha increased the grain yield but significant increase in yield was obtained at 60 kg P$_2$O$_5$/ha over no phosphorus. Further increase in phosphorus levels upto 80 kg P$_2$O$_5$/ha increased the grain yield by 1.8 q/ha but it was not significant. The interaction effect between variety x phosphorus was not found significant.
Raghu and Choubey (1983) carried out experiment during rabi season of 1976-77 to study the response of chickpea variety JG 221 to irrigation and fertisation. Four soil fertility levels (no inoculation, inoculation with *Rhizobium*, inoculation + 25 kg N/ha and inoculation + 25 kg N + 50 kg P₂O₅/ha) were applied to sub-plot and six irrigation treatments (no irrigation, one irrigation at 45 DAS, one irrigation at 75 DAS, one irrigation at 90 DAS, two irrigation at 45 and 75 DAS and two irrigation at 45 and 90 DAS) were given to main plot. Treatments were replicated four times in a split plot design. Among different irrigation levels, it was found that two irrigation at 45 and 75 DAS gave significant maximum yield over other levels of irrigation. Soil fertility treatments had significant effect on grain yield in both the years. However, the significantly higher grain yield was obtained with inoculation + 25 kg N + 50 kg P₂O₅/ha as compared to rest of the fertility treatments. Thus it was found that application of phosphorus had beneficial effect on seed yield.

Verma and Bohra (1983) in a randomised block design during rabi season of 1979-80 studied the response of two chickpea varieties, namely type 3 and JG 74 to phosphorus application and varying rates of seeding. The treatments comprised of four phosphorus levels, viz. 0, 25, 50 and 75 kg P₂O₅/ha and three seed rates, i.e. 50, 75 and 100 kg/ha. A basal dressing of 10 kg N/ha was also applied uniformly to
all the plots. They did not observe any significant grain yield difference between the two varieties. However, the rates of phosphorus application brought about significant variation in grain yield and the application of 50 kg $P_2O_5$/ha proved optimum and economical for both varieties.

Raju and Varma (1984) carried out experiment during rabi seasons of 1978-79 and 1979-80 under rainfed condition to study the response of three chickpea varieties (type 3, Pant G 110 and K 468) to phosphate application in relation to farm-yard manure and rhizobia inoculation. Three levels of phosphorus, i.e., 20, 40 and 60 kg $P_2O_5$/ha tested in the presence of farm-yard manure (3 tonnes/ha) and Rhizobium inoculation according to factorial randomised block design having eighteen treatment combinations. Each treatment was replicated thrice. The source of phosphorus was single superphosphate. The amount of phosphorus was adjusted keeping in view the amount of phosphorus supplied by farm-yard manure. A basal application of 30 kg $K_2O$/ha was also given to all plots in the form of muriate of potash. They studied various growth and yield parameters, namely, plant height, number of branches/plant, dry matter production/plant, number of pods/plant, grain weight/plant, 100 grain weight, straw yield, grain yield and percentage increase of grain yield. Increasing levels of phosphorus significantly increased the growth parameters. It was noted that significant more number of filled pods, grain weight/plant and 100 grains weight were produced in 60 kg $P_2O_5$/ha in comparison to 40 and 20 kg $P_2O_5$/ha. The highest grain and straw yield per hectare were
also obtained in 60 kg P$_2$O$_5$/ha. The grain yield per hectare was 22.1 and 15.9 per cent higher due to 60 and 40 kg P$_2$O$_5$/ha respectively than 20 kg P$_2$O$_5$/ha. However, the rate of output in grain yield was maximum from 20 to 40 kg P$_2$O$_5$/ha rather than 40 to 60 kg P$_2$O$_5$/ha indicating higher response to applied fertilizer at lower rates of application. They have also calculated the net return per unit of fertilizer and it was found maximum (₹ 377/ha) at lower rate of 20 kg P$_2$O$_5$/ha but was reduced at 40 kg P$_2$O$_5$/ha (₹ 216/ha) and 60 kg P$_2$O$_5$/ha (₹ 150/ha). However, the most profitable rate of phosphate was marked out to be 45.4 kg P$_2$O$_5$/ha. Among different varieties, Type 3 gave significantly higher grain yield than other varieties. However, neither farm-yard manure nor inoculation affected grain production.

During rabi seasons of 1980-81 and 1981-82, Singh et al. (1984) carried out field experiment to study the response of chickpea varieties to phosphorus application and seeding rates. They studied three phosphorus levels, viz. 0, 17 and 34 kg P/ha, three levels each of three cultivars, viz. C 235, BG 209 and Pant G 114 and seeding rates, viz. 50, 70 and 100 kg/ha. Each treatment was replicated twice. The performance of crop under these treatments was tested with respect to various yield parameters, viz. pods/plant, 1,000 grain weight, grain yield, and straw yield and phosphorus uptake at harvest was also studied. Application of 17 kg P/ha
significantly increased the pod number, 1,000 grain weight, grain and straw yield and phosphorus uptake over control (0 kg P/ha). No significant additional increase was observed in any of the characters when the dose was raised to 34 kg P/ha. The optimum dose of phosphorus worked out was 26 kg P/ha. Among different varieties G 114 had significant higher yield attributes, grain and straw yield and phosphorus uptake than BG 209 and C 235. It was also reported that seed rate of 75 kg/ha gave markedly higher grain and straw yield than 50 kg/ha. However, the 100 kg/ha seed rate proved at par with 75 kg/ha.

Mahajan et al. (1985) conducted field experiment during rabi season of 1976 to study the uptake and utilisation of soil and fertiliser phosphorus by chickpea variety JG 62 under different phosphorus levels and soil fertility gradients. The design of the experiment was split plot with four levels of $^{32}$P labelled phosphorus @ 0, 30, 60 and 90 kg P$_2$O$_5$/ha as sub-plot treatments and four levels of fertility gradients, i.e. $\mathcal{Y}_0$ (173 kg N, 8.9 kg P and 240 kg K/ha), $\mathcal{Y}_1$ (194 kg N, 11.9 kg P and 263 kg K/ha), $\mathcal{Y}_2$ (214 kg N, 21.8 kg P and 287 kg K/ha) and $\mathcal{Y}_3$ (235 kg N, 27.2 kg P and 329 kg K/ha) as main plots. These different soil fertility gradients were created in the field in previous season by applying graded dose of fertiliser (0, 75, 150 and 300 kg N and K$_2$O/ha and 0, 85, 170 and 340 kg P$_2$O$_5$/ha for $\mathcal{Y}_0$, $\mathcal{Y}_1$, $\mathcal{Y}_2$, $\mathcal{Y}_3$ and $\mathcal{Y}_4$ fertility gradients respectively. Various
parameters, namely, grain, straw and total dry matter yield, phosphorus uptake, per cent phosphorus derived from fertilizer (% P dff), per cent utilisation of applied phosphorus and soil phosphorus uptake were studied. All the above mentioned parameters except per cent utilisation of applied phosphorus increased significantly with every successive increase in phosphorus level. They observed significant decrease in per cent utilisation of applied phosphorus in grain, straw and plant with increasing phosphorus levels. Fertility status of the soil also gave similar effects like applied phosphorus in case of all the parameters studied except per cent phosphorus derived from fertiliser which was found to be decreased significantly with increasing fertility status of soil.

Nagarjun et al. (1985) in a green house pot experiment studied the response of two varieties of chickpea (CO 1 and G 62404) to the application of phosphorus, copper and Rhizobium inoculation. They applied three levels of phosphorus (0, 20 and 40 ppm P$_{2}$O$_{5}$/pot) as superphosphate, three levels of copper (0, 5 and 10 ppm CuSO$_{4}$/pot), and two levels of Rhizobium (inoculated and uninoculated) in all possible combinations and thus there were 36 treatments with two replications. The design of the experiment was completely randomised block design. They have studied various characteristics, namely grain yield, shoot dry
weight, root dry weight, dry weight of nodule and total dry matter. Among these parameters, only grain yield was affected by the phosphorus application and 40 ppm P\textsubscript{2}O\textsubscript{5}/pot was noted to be significantly superior to the low levels (0 and 20 ppm P\textsubscript{2}O\textsubscript{5}/pot). On the other hand the difference shown by the two lower doses did not differ significantly. Considering Rhizobium inoculation, they found an increase of 50.7% grain yield due to inoculation over uninoculation, besides increasing shoot dry weight, root dry weight, nodule dry weight and total dry matter production. They also noted that copper at 5 ppm gave higher grain yield. Regarding varietal difference, G 62404 gave significant higher grain yield than CO 1. From this pot experiment it was suggested that production of chickpea could be increased through application of phosphorus at 40 ppm P\textsubscript{2}O\textsubscript{5}/pot and copper at 5 ppm CuSO\textsubscript{4}/pot along with appropriate Rhizobium inoculation.

Rao and Singh (1985) carried out field experiment for two consecutive years (1978-79 and 1979-80) to study the effect of phosphorus and bio-fertilisers on nodulation and nitrogen content of nodules in chickpea. The design of the experiment was randomised block and consisted of four levels of phosphorus, viz. 0, 20, 40 and 60 kg P\textsubscript{2}O\textsubscript{5}/ha and three bacterial inoculations, viz. no culture, Rhizobium culture and phosphobacterin, (var. Pseudomonas striata) culture,
comprising twelve treatment combinations. A uniform basal dose of 30 kg K/ha was also applied at the time of sowing. Phosphorus application was found to increase dry weight of nodules significantly at all stages of crop growth in both the years and 40 kg P₂O₅/ha proved optimum. Nitrogen content of nodules was also significantly increased by the application of phosphorus at different stages of crop growth over control. Rhizobium culture significantly increased nodule dry weight and nitrogen content of nodules over no culture. However, they did not find any significant increase in dry weight of nodules and nodule nitrogen content by treating the seeds with phosphobacterin.

A field experiment was conducted by Shaktawat and Sharma (1985) to find out the response of three varieties of chickpea (BG 209, GNG 16 and RSG 2) to phosphorus application and seed rate. The trial was conducted according to split plot design. Four levels of phosphorus, viz. 0, 25, 50 and 75 kg P₂O₅/ha were given to the sub-plots, while three seed rates (50, 75, and 100 kg seed/ha) and varieties were kept in main-plots. Each treatment was replicated thrice. A uniform basal dose of 20 kg N/ha was also given. The effect of phosphorus was found significant on grain yield. Application of 25, 50 and 75 kg P₂O₅/ha increased the grain yield by 0.9, 2.1 and 2.9 q/ha representing 10.2, 23.7 and 32.7% increase respectively over control (0 kg P₂O₅/ha).
However, increasing levels of phosphorus did not influence the grains/pod. Seed rate of 100 kg/ha was found optimum for grain yield. Among the varieties tested, BG 209 gave the highest grain yield with 11.2 q/ha, followed by RSG 2 with 11.0 q/ha and GNG 16 with 8.7 q/ha.

Yadav et al. (1985) conducted field experiment during winter seasons of 1977-78 and 1979-80 to find out the response of different chickpea varieties to phosphorus fertilisation. They applied three levels of phosphorus, i.e. 0, 30 and 60 kg P₂O₅/ha on four chickpea varieties, namely Radhey, T 3, K 468 and Kailash, in randomised block design. Each treatment was replicated four times. A uniform basal dose of 20 kg N/ha was applied at the time of sowing. It was noted that increase in phosphorus from 0 to 30 kg P₂O₅/ha increased the grain yield significantly in both seasons. However, further increase in phosphorus dose did not improve the grain yield. Grain yield differences due to varieties were significant during 1979-80 only and variety T 3 gave the significant maximum yield.

Borgohain and Agarwal (1986) conducted field experiment during rabi seasons of 1980-81 and 1981-82 to investigate the effect of rate and sources of phosphorus and irrigation levels on chickpea variety Gora Hissari. In a split plot design experiment, they allocated three levels of phosphorus, i.e. 0, 40 and 80 kg P₂O₅/ha to sub-plot and three sources of phosphorus, viz. single
superphosphate, triple superphosphate and phosphocompost and three levels of irrigation, viz. no irrigation, irrigation at ID/CPE = 0.2 and ID/CPE = 0.4 to the main plot. Fruiting branches/plant was increased by 14.05 and 28.59% due to 40 and 80 kg P₂O₅/ha over control (0 kg P₂O₅/ha) based on two years average. The increase in number of pods/plant and grains/pod was in the order of 2.6 and 3.9 and 0.2 and 0.4% due to 40 and 80 kg P₂O₅/ha over no phosphorus respectively in 1981-83. Regarding the grain and straw yield they observed that application of 40 and 80 kg P₂O₅/ha gave 13.7, 21.6 and 20.1 and 40.0% increase in grain and 1.5, 9.0 and 22.0 and 43.6% increase in straw yield over no phosphorus during 1980-81 and 1981-82 respectively. Application of 80 kg P₂O₅/ha also resulted in higher grain yield upto 7.0 and 16.6% over 40 kg P₂O₅/ha in 1980-81 and 1981-82, respectively. Phosphorus also improved harvest index as compared to no phosphorus in 1980-81, however 40 and 80 kg P₂O₅/ha did not show significant difference on this parameter. Pertaining to irrigation levels, one irrigation based on ID/CPE = 0.2 increased grain yield by 15.2% and two irrigations at ID/CPE = 0.4 by 28.0% over no irrigation during 1981-82. The interaction effect of irrigation and phosphorus gave 13.3 q/ha grain yield with two irrigations scheduled at ID/CPE = 0.4 at 80 kg P₂O₅/ha and the value was significantly higher than that given by 40
and 0 kg $P_2O_5$/ha with same level of irrigation in 1981-82. The effect of different sources of phosphorus was not found significant on any of the parameters studied.

In a randomised block design Khandkar et al. (1986) conducted field experiment during rabi seasons of 1980-81 and 1981-82 to study the effect of phosphorus and nitrogen on chickpea. They applied three levels each of phosphorus, i.e. 0, 30 and 60 kg $P_2O_5$/ha and nitrogen, i.e. 0, 10 and 20 kg N/ha in all possible combinations. The sources of phosphorus and nitrogen were superphosphate and urea respectively. They studied grain yield, nitrogen and phosphorus content of grain at maturity. In 1980-81 the grain yield increased significantly upto 30 kg $P_2O_5$/ha which was 23% higher than that of 0 kg $P_2O_5$/ha, but in 1981-82 the grain yield increased significantly upto 60 kg $P_2O_5$/ha which was 35% higher than that of control. The variation in grain yield during two years, was suggested, due to sufficient winter rain in 1981-82 in comparison with dry winter season in 1980-81. The phosphorus content of seeds increased significantly by the phosphorus application in both the years. But the nitrogen content of grain increased significantly due to phosphorus fertilisation only in 1980-81.

Rao et al. (1986) conducted pot experiment to study the effect of phosphorus, nitrogen and dual inoculation with
Rhizobium and Glomus fasciculatum on chickpea variety BG 212. The experiment was laid out in simple randomised block design and the treatments consisted of two levels each of phosphorus, viz. 0 and 50 kg $P_2O_5$/ha and nitrogen, viz. 0 and 20 kg N/ha and four levels of inoculation, viz. uninoculated (control), Rhizobium sp., Glomus fasciculatum and Rhizobium X G. fasciculatum. Application of 50 kg $P_2O_5$/ha appreciably improved nodule number, nodule dry weight, dry matter of shoot and shoot nitrogen content at 45 days of plants over 0 kg $P_2O_5$/ha specially with dual inoculation of Rhizobium and G. fasciculatum. Application of phosphorus was also found to be beneficial to grain yield in conjunction with 20 kg N/ha, especially with dual inoculation with both the organisms.

In a randomised block design experiment Khokar and Warsi (1987) studied the response of chickpea variety C 235 to fertiliser application during the rabi seasons of 1984-85 and 1985-86. The fertiliser treatments included control (without fertiliser), Rhizobium inoculation, $N_{18}P_{46}K_{20}, K_{40}, K_{60}, N_{18}P_{46}K_{20}, N_{18}P_{46}K_{40}, N_{18}P_{46}K_{60}$ and $N_{18}P_{46}K_{60}Zn_{25}$ kg/ha. The sources of N, P and K were urea, single superphosphate and muriate of potash. It was observed that application of phosphorus at the rate of 46 kg $P_2O_5$/ha increased the grain yield by 57% as compared to control. On the other hand application of 18 kg N/ha or inoculation of Rhizobium culture increased the grain yield by 22% over
control. However the highest grain yield which was 72% more than control was given by combined dose of 8 kg N, 46 kg P₂O₅, 60 kg K₂O, 25 kg ZnSO₄/ha. They also found the similar trend for straw yield.

Yadav et al. (1987) conducted pot experiment to find out the effect of phosphorus and zinc on chickpea variety G 130. They applied four levels of phosphorus, i.e. 25, 50, 100 and 250 ppm and five levels of zinc i.e. 5, 10, 20, 40 and 100 ppm. The sources of phosphorus and zinc were phosphoric acid and ZnSO₄ respectively. They studied flowering behaviour pod number/plant, seed number/pod and seed yield. Time of flowering was delayed by the deficiency as well as excess of phosphorus. Intensity of flowering with time was consistently higher with 25 ppm P than with other treatments. Production of flower/plant, pods/plant and seeds/pod were maximum at 25 ppm and 50 ppm P, but decreased with higher phosphorus levels. However, the values for seed weight per plant given by different levels of phosphorus did not significantly differ from each other. Application of zinc between 5 and 20 ppm seemed to be beneficial for flower production and seed yield.

Joshi et al. (1988) carried out twenty four field trials during rabi season of 1984 to find out the response of chickpea variety G1 (Vikas) to NPK fertilisation under
protective irrigation. They applied three levels of phosphorus (0, 20 and 40 kg $P_2O_5$/ha), three levels of nitrogen (0, 10 and 20 kg N/ha), and two levels of potassium (0 and 20 kg K/ha) in ten combinations in a randomised block design experiment. The sources of nitrogen, phosphorus and potassium were urea, single superphosphate and muriate of potash respectively. Out of twenty four field trials twelve were conducted at Walva and remaining at Tasgaon zones of Sangli district. The twenty four experiments on twenty four cultivators' fields formed twenty four replications. Application of phosphorus increased the grain and straw yield significantly at both the places as well as average for the district and 40 kg $P_2O_5$/ha proved optimum for grain yield. The increase in grain yield due to 40 kg $P_2O_5$/ha was 1.43 q/ha over no phosphorus application.

Pandey and Babu (1988) conducted pot experiment to study the effect of phosphorus application on different enzymes at various growth stages of chickpea variety JG 62. They applied three levels of phosphorus, i.e. 30, 60, and 80 kg $P_2O_5$/ha along with a uniform basal dose of nitrogen (25 kg N/ha) and potassium (40 kg $K_2O$/ha). The sources of phosphorus, nitrogen and potassium were single superphosphate, urea and muriate of potash respectively. The enzymes studied were nitrate reductase, glutamate dehydrogenase and glutamine synthetase. Phosphorus
application was reported to affect the enzymatic activity significantly. Nitrate reductase and glutamate dehydrogenase activity increased when phosphorus was applied at the rate of 60 kg $P_2O_5$/ha. It was also observed that nitrate reductase activity increased consistently till flowering (13th week), thereafter, the activity declined drastically. Glutamate dehydrogenase activity in leaves was maximum during pod development stage, but in nodules maximum activity was noticed during vegetative stage. Lower dose (30 kg $P_2O_5$/ha) was found most favourable for glutamine synthetase. Higher dose of phosphorus (80 kg $P_2O_5$/ha) was proved detrimental for the activity of enzymes.

Tomar et al. (1988) carried out field experiment for four rabi seasons (1978-79 to 1981-82) to find out the response of three varieties of chickpea, viz. H 355, JG 221 and JG 315 to different levels of phosphorus and seeding rates. In a split plot design, they applied four levels of phosphorus, viz. 0, 25, 50 and 75 kg $P_2O_5$/ha to the sub-plots and three seeding rates, viz. 50, 75 and 100 kg seed/ha and varieties to the main plots. Each treatment was replicated thrice. A uniform basal dose of 20 kg N/ha was also applied at the time of sowing. It was observed that application of phosphorus upto 50 kg $P_2O_5$/ha resulted in significant higher seed yield. The average seed yield increase due to 25 and 50 kg $P_2O_5$/ha was recorded to be
1.82 q/ha (9.6%) and 3.72 q/ha (19.7%) over no phosphorus. The variety H 355 gave the highest grain yield of 22.28 q/ha. Among different seeding rates 50 kg/ha proved optimum for the economical cultivation of chickpea.

Idris et al. (1989) conducted field experiment to find out the effect of phosphorus application on chickpea (variety CM 88) during rabi season of 1985-86. They applied five levels of phosphorus, i.e. 0, 40, 60, 80 and 100 kg P\(_2\)O\(_5\)/ha along with a uniform basal application of 20 kg N/ha and 24 kg K\(_2\)O/ha at the time of sowing. The sources of phosphorus, nitrogen and potassium were single superphosphate, urea and potassium sulphate respectively. The design of the experiment was randomised block and each treatment was replicated four times. Application of phosphorus increased significantly the number and weight of nodules/plant over control (0 kg P\(_2\)O\(_5\)/ha). It was also observed that phosphorus at 40, 60, 80 and 100 kg P\(_2\)O\(_5\)/ha increased significantly the grain yield (kg/ha) by 18, 59, 40 and 14 per cent and biomass yield (kg/ha) by 32, 32, 53 and 14 per cent respectively as compared to control. Among different doses of phosphorus, 60 kg P\(_2\)O\(_5\)/ha appeared to be the most economical for grain yield and 80 kg P\(_2\)O\(_5\)/ha for straw yield. Highest dose of phosphorus (100 kg P\(_2\)O\(_5\)/ha) depressed both the grain and biomass yield of chickpea. Application of phosphorus did not cause any increase in percentage of nitrogen and phosphorus in shoot as well as in
grain. However, the content of nitrogen in grain (kg/ha) increased significantly by 17, 57, 40 and 14 per cent and in shoot (kg/ha) by 46, 39, 58 and 23 per cent as a result of 40, 60, 80 and 100 kg P$_2$O$_5$/ha respectively in comparison with 0 kg P$_2$O$_5$/ha. Similarly the phosphorus content of grain increased by 11, 50, 20 and 6 per cent and in the shoot by 43, 29, 55 and 16 per cent as a result of 40, 60, 80 and 100 kg P$_2$O$_5$/ha respectively over control.

Javiya et al. (1989) conducted field experiment during rabi season of 1982-83 to study the response of chickpea to different levels of phosphorus, nitrogen and irrigation. In a split plot design experiment they applied three levels of phosphorus, i.e. 0, 25 and 50 kg P$_2$O$_5$/ha and two levels of nitrogen, i.e. 0 and 20 kg N/ha to sub-plots and three moisture regimes, viz. no irrigation, 20 and 40% A.S.M. to the main plot. Each treatment was replicated four times. Various parameters, namely pods/plant, 100 grain weight, grain yield (q/ha), grain protein content and water use efficiency were studied. The values recorded for grain yield (q/ha), pods/plant, 100 grain weight and water use efficiency were significantly more than those for control (0 kg P$_2$O$_5$/ha). However, the effect of phosphorus on grain protein content was found non-significant. Increasing soil moisture level and nitrogen also increased grain yield and yield attributes.
Singh and Kamath (1989) performed a pot experiment in green house condition during rabi seasons of 1982-83 and 1983-84 to study the effect of phosphorus on chickpea variety BG 231. They applied nine levels of phosphorus, viz. 0, 15, 30, 45 and 60 kg P$_2$O$_5$/ha as full basal, 15 kg P$_2$O$_5$/ha as two foliar spray, 14 kg P$_2$O$_5$/ha as three foliar spray, 30 and 50 kg P$_2$O$_5$/ha half as basal and half as top dressing. A uniform basal dose of nitrogen and potassium at the rate of 10 and 20 ppm respectively was also applied to each pot. The sources of phosphorus, nitrogen and potassium were $^{32}$P labelled single superphosphate (Sp. activity 0.3 m Ci/g P$_2$O$_5$), urea and potassium chloride respectively. In top dressing single superphosphate was applied 25 days after basal application. It was found that basally applied phosphorus upto 45 kg P$_2$O$_5$/ha increased dry matter production and phosphorus uptake. Split application of phosphorus gave very poor result than full basal application. They also found steady and significant increase in % Pdff value and fertiliser phosphorus uptake with increase in the rates of basal application of phosphorus. The maximum utilisation of phosphorus (10.6%) was observed at 45 kg P$_2$O$_5$/ha. Split application of phosphorus half at sowing and the remaining half at 25 days after sowing did not show any beneficial effect in relation to phosphorus uptake. The effect of foliar spray on these attributes is described on page 57.
Parihar (1990) carried out field trial during rabi seasons of 1982-83 and 1983-84 to study the effect of phosphorus and irrigation schedule on chickpea variety C 235. He applied three levels of phosphorus, i.e. 25, 50 and 75 kg P₂O₅/ha and three levels of irrigation based on IW/CPE ratios of 0.4, 0.6 and 0.8 in a randomised block design experiment. Each treatment was replicated four times. A uniform basal dose of nitrogen (20 kg N/ha) and potassium (20 kg K₂O/ha) was also applied at the time of sowing. He observed that increasing levels of phosphorus significantly increased the pods/plant, seeds/plant and 1,000 seeds weight. However, the significant increase in grain yield was noticed upto 50 kg P₂O₅/ha. Water use efficiency also increased significantly upto 50 kg P₂O₅/ha. Irrigation at 0.4 IW/CPE (3 irrigations) ratio gave significantly higher grain yield and water use efficiency than other irrigation levels.

Billore and Mridula (1991) carried out field experiment during post rainy seasons of 1985-86 and 1986-87 to study the effect of sources of phosphorus on two chickpea varieties, viz. Ujjain 24 and ICCC 4 under different fertility levels. The treatments of all the combinations of four sources of phosphorus, viz. single superphosphate (SSP), diammonium orthophosphate (DAP), IFFCO-complex as orthophosphate and ammonium polyphosphate (APP) as
polyphosphate; three fertility levels ($F_1 = 10:20:30$, $F_2 = 20:40:30$ and $F_3 = 30:60:30$ NPK kg/ha) and two varieties were tested in a split plot design with three replications. Various growth parameters, namely crop growth rate (CGR), relative growth rate (RGR), growth efficiency (GE), dry matter/plant and at harvest seed yield/plant were studied. It was found that APP and DAP were equally effective on CGR, RGR, GE and dry matter/plant. However, the seed yield was significantly higher with APP. IFFCO-complex was the least effective for the growth enhancement. Ujjain 24 gave the maximum seed yield/plant. However, more shoot biomass was recorded in ICCC 4 than Ujjain 24.

Raju et al. (1991) conducted field experiment during rabi seasons of 1978-79 and 1979-80 to study the effect of phosphorus on three chickpea varieties, viz. Type 3, Pant G 110 and K 468. The treatments consisted of three levels of phosphorus, viz. 20, 40, and 60 kg $P_2O_5$/ha, farm-yard manure (F.Y.M.) at the rate 10 kg N/ha and Rhizobium inoculation. The experiment was laid out in randomised block design. Each treatment was replicated thrice. The source of phosphorus was single superphosphate. It was observed that application of phosphorus increased seed yield upto 60 kg $P_2O_5$/ha which was 6.1 and 3.9 q/ha more than obtained with 20 kg $P_2O_5$/ha during 1978-79 and 1979-80 respectively. Like seed yield, straw yield, nodule number/plant and nodule dry weight/plant increased significantly upto 60 kg $P_2O_5$/ha. They also
studied uptake of nitrogen, phosphorus and potassium and found that increasing levels of phosphorus from 20 to 60 kg $P_2O_5$/ha significantly increased the uptake of these nutrients. Among varieties, Type 3 showed best performance with regard to various attributes studied.

Singh and Ram (1992) conducted field experiment during rabi seasons of 1982 and 1983 to study the effect of phosphorus and sulphur on the concentration and uptake of N, Ca and Mg in chickpea. The experiment was laid out according to randomised block design. Three levels of phosphorus, viz. 30, 60 and 90 kg $P_2O_5$/ha and three levels of sulphur, i.e. 40, 80 and 120 kg S/ha were applied. A uniform basal dose of nitrogen (20 kg N/ha) and potassium (60 kg $K_2O$/ha) was also given to each plot. Content of N, Ca and Mg increased significantly in nodules, plants (at flowering), grain and straw (at harvest) up to 60 kg $P_2O_5$/ha but at higher level (90 kg $P_2O_5$/ha) the contents of these nutrients decreased significantly. The similar trend was also found on the uptake of nitrogen by grain and straw and Ca and Mg by grain. Application of sulphur also increased the uptake of N, Ca and Mg by different plant parts.

2.4 Foliar nutrition

For centuries farmers have found it profitable to add manures and other forms of decaying organic matter to
their fields. In Europe and America with the advent of chemical fertilisers in the middle of the last century, the application of these fertilisers to soil for maintaining its fertility became equally liberal. It was however, found that added fertilisers were rendered unavailable to the crop after its application owing to various reasons, including fixation, volatilisation, microbial degradation and leaching. Critical studies have revealed that about 70% of soil applied phosphorus (Russell, 1950) and about 50% of nitrogen (Anonymous, 1971) is rendered unavailable to crops. Moreover, the increasing cost of these fertilisers poses a grave problem for the poor farmers in developing countries. In fact, many of them are not able to apply the recommended basal dose of nutrients, due to economic constraints. Therefore, farm scientists have developed several techniques to overcome these problems. One of them is the conventional method of top dressing. However, it has proved difficult to adopt for several crops and is also wasteful to some extent like basal application. As a result, our national productivity suffers and projected targets are never achieved. The novel technique of foliar application of nutrients seems to be a good alternative as it has been proved a universally acceptable and economically sound practice for conveniently and efficaciously supplementing the fertiliser requirements of various crops at different
stages of growth particularly under adverse condition. Other reasons that commend the adoption of this technique are:

1. Quick fixation of nutrients in the soil rendered them unavailable to the crop. The remedy for such 'hidden hunger' of plants, is the application of appropriate nutrients to the leaves of standing crop in the form of dilute sprays.

2. Another problem is the slow response of plants to some soil applied nutrients which may often cause their deficiency. This acute problem can be controlled by foliar application of the particular nutrient.

3. Some crops that remove large quantities of fertilisers during early vegetative growth consequently require nutrients as supplements at later stages when soil application is not easily feasible. For example sugarcane requires additional nitrogen at later growth stages when the soil application of this nutrient becomes impractical (Ali, 1981). This requirement is conveniently fulfilled by foliar application. Cereals (like wheat, barley and triticale), oil seeds, pulses and many other crops require nutrients at grain filling stage and the technique of foliar application of nitrogen and phosphorus has been found to increase the yield and improve the quality of seed in these crops (De, 1971; Afridi and Wasiuddin, 1979; Afridi, 1983; Sherchand and Paulsen, 1985; Samiullah et al., 1986).
4. Foliar application has been found very successful in the case of micronutrients provided they are mobilised in or near the leaves to which these are applied. Boron and copper compounds seem to be readily absorbed and transported to all parts of the plants and one or two dilute sprays give satisfactory result (Boynton, 1954).

5. Finally, under hilly regions or where soil are sandy and porous or highly alkaline, acidic or water-logged, foliar feeding has been found advantageous over soil application of mineral nutrients (Bould, 1963).

Though, the credit for the first published report (1844) has been accorded to Griss (Wittwer and Teubner, 1959). Forsyth was the first to note the significance of this technique in 1803 (Bould, 1963). With the use of radioisotopes since 1951, the research in this field has become much easier as it not only permits accurate measurement of the quantities of nutrients absorbed by the foliage but also of their subsequent translocation up to the root, shoot tips and other points of metabolic activity (Silberstein and Wittwer, 1951; Wittwer and Lundahl, 1951; Wittwer and Bukovac, 1969).

The effectiveness of foliar nutrition highly depends on the ability of the applied nutrients penetration through the cuticular cracks and outer wall's highly waxy and cutinised epidermal cells. Once having penetrated through the
cuticle, further movement of nutrients through outer epidermal cell walls probably takes place mostly through the fine, thread-like, submicroscopic structure called ectodesmata. Lastly when the substance reaches the plasma membrane of an epidermal cell, it is believed to be absorbed by mechanism similar to those that operates in root cells (Noggle and Fritz, 1986).

After absorption by leaves, the nutrients are transported to other plant parts, including roots. This transport of leaf-applied nutrients occurs via the phloem. The rate and amount of transport varies with each element. Nitrogen was reported to move to the places of high metabolic demand rather than to the points of lowest concentration (Williams, 1955 and Baver, 1963). However, Humbert (1968) found the movement of leaf-applied nutrients from the region of high concentration to low concentration.

The uptake of leaf-applied nutrients and their subsequent translocation is observed readily by changes in colour, composition, growth and yield of various organs of the plants. It is an active and irreversible process dependent on temperature, light and oxygen and occurs against concentration gradients and is influenced adversely by metabolic inhibitors. Some mineral nutrients like calcium, magnesium, nitrogen, potassium and zinc are
absorbed very rapidly, while others like iron, molybdenum, phosphorus and sulphur are absorbed slowly (Wittwer 1964; Wittwer and Bukovac, 1969).

Absorption of nutrients by leaves and their subsequent metabolism vary largely with plant type, species, leaf area, morphological stage, rate of growth, nutrient status, prevailing weather conditions, time of spraying and pH of spray solution (Wittwer and Teubner, 1959; De, 1971).

Considerable work on foliar feeding has been done abroad on vegetables (Mayberry, 1951; Montelaro et al., 1952; Martin, 1954; Wittwer et al., 1957), fruit trees (Fisher and Walker, 1955), Sugarcane (Burr et al., 1956) and sugarbeet (Klechkovski, 1956; Thorne and Watson, 1956). In India also adequate research on foliar nutrition of various crops have been reported (Anonymous, 1958; Kannan and Ranganathan, 1963; Ranganathan and Govindan, 1964; and De et al., 1968, Bangal et al., 1983 and Singh et al., 1993).

It seems that not much attention has been paid to pulse crops and chickpea in particular. However, at Aligarh (India), Samiullah and his associates made significant contribution regarding the foliar feeding to lentil and summer moong (Akhtar et al., 1984; Samiullah et al., 1986; Khan, 1988).

It is evident from the foregoing facts that foliar feeding of mineral nutrients has considerable bearing on
the productivity of plants and this aspect has been reviewed from time to time by several workers (Boynton, 1954; Bukovac and Wittwer, 1957; Wittwer and Teubner, 1959; Afridi and Wasiuddin, 1979; Kannan, 1990). The meagre literature available on the response of chickpea to foliar application of phosphorus is being reviewed below:

Singh et al. (1971) conducted field experiment during rabi season of 1967-68 to study the effect of spray of phosphorus on chickpea. They applied various levels of phosphorus at different stages of growth on leaves as foliar spray at the rate of 22 kg P₂O₅/ha at branching, 22 kg P₂O₅/ha half at branching and half at flower initiation, 33 kg P₂O₅/ha at branching, 33 kg P₂O₅/ha at flower initiation, 33 kg P₂O₅/ha, half at branching and half at flower initiation. Soil application of phosphorus as band placement at the rate of 40 kg P₂O₅/ha was also done and this treatment was taken as control. The trial also included four seed rates, viz. 60, 70, 80 and 90 kg/ha. The design of the experiment was randomised block. Each treatment was replicated thrice. They reported that chickpea could utilise phosphorus as spraying through leaf absorption and could meet its requirement. Applied phosphorus utilisation efficiency could be increased from 25 to 50% when applied as spray as compared to band placement. A saving in cost of fertiliser by change of method of application from band placement to foliar by 25 to 50% was reported.
Suryawanshi and Chaudhari (1979) conducted field experiment during rabi seasons of 1971-72 and 1972-73 to find out the response of chickpea to leaf applied phosphorus and nitrogen. The treatments were consisted of three levels of basal phosphorus (0, 25 and 50 kg P$_2$O$_5$/ha) and foliar application of two levels each of phosphorus (5 and 10 kg P$_2$O$_5$/ha) and nitrogen (5 and 10 kg N/ha) in twelve combinations. The design of the experiment was factorial randomised block and each treatment was replicated thrice. A uniform basal dose of 25 kg N/ha was also applied. Foliar application of higher dose of phosphorus (10 kg P$_2$O$_5$/ha) and nitrogen (10 kg N/ha) did not increase the grain yield over their respective lower doses. However, foliar application of 5 kg P$_2$O$_5$/ha and 10 kg N/ha with basal application of 25 kg P$_2$O$_5$/ha resulted in yield increase of 4.62 q/ha over foliar application of 5 kg P$_2$O$_5$/ha and 10 kg N/ha without soil application of phosphorus.

Singh and Kamath (1989) conducted pot experiment in green house condition for two successive rabi seasons of 1982-83 and 1983-84 on chickpea variety BG 231. They applied various levels of phosphorus @ 0, 15, 30, 45 and 60 kg P$_2$O$_5$/ha as full basal; 15 kg P$_2$O$_5$/ha as two foliar spray; 15 kg P$_2$O$_5$/ha as three foliar spray; 30 and 50 kg P$_2$O$_5$/ha, half as basal and half as top dressing. A uniform basal dose of nitrogen and potassium at the rate of 10 and 20 ppm respectively were given to each pot. The sources of
phosphorus, nitrogen and potassium were labelled single superphosphate (sp. activity 0.3 m Ci/g P₂O₅), urea and potassium chloride respectively. In top dressing treatments, phosphorus was applied at 25 days after basal application. The plants in pots were harvested at flowering and several parameters, namely dry matter/pot, total phosphorus uptake/pot, % pdff and phosphorus utilisation percentage were studied. Foliar application of phosphorus at 15 kg P₂O₅/ha whether applied in 2 or 3 sprays brought about significant increase in total phosphorus uptake over control (0 kg P₂O₅/ha) but it was inferior to soil application of the fertiliser at equivalent dose (15 kg P₂O₅/ha). Foliar application of 2 or 3 sprays was inferior to soil application of equivalent dose (15 kg P₂O₅/ha) as revealed by the higher fertiliser phosphorus uptake as well as percentage utilisation of phosphorus obtained from the soil application by the crop than the foliar spray. From the study they concluded that foliar application alone, cannot be a substitute for soil application of phosphorus even at lower level (15 kg P₂O₅/ha) particularly in soil of poor fertility status and in the absence of adequate number of leaves on the plants.

2.5 Nitrogenase

Nitrogen is an essential nutrient for proper growth and development of plants. Though nitrogen is an abundant
element, making up almost 80 per cent of the earth's atmosphere, it is useless to the vast majority of organisms, until it is converted into highly oxidized states (NO$_3^-$ or NO$_2^-$) or more reduced state (NH$_3$). Nitrogen from the atmosphere can be fixed abiologically (industrial synthesis, ultraviolet radiation, lightening) as well as biologically. Biological nitrogen fixation is much more important as it contributes to more than 70% of the input into world's soil and water nitrogen (Lodha and Nainawatee, 1989). Biologically only a few genera of prokaryotes (bacteria, cyanobacteria and actinomycetes) can convert dinitrogen to ammonia. These organisms are known as diazotrophs, which contain nitrogenase, a Fe-Mo protein, that catalyses the reduction of dinitrogen into ammonia (NH$_3$) at the expense of metabolic energy under anoxic conditions. The energy which is derived from the breakdown of glucose or other carbohydrates, is supplied in the form of adenosine triphosphate (ATP), the universal energy currency of the cell. Biological nitrogen fixation can be affected indirectly or directly by mineral nutrients, i.e. N, P, Ca, Fe, Mo, Co etc. (Marschner, 1986). Phosphorus is a macronutrient, which affects nodulation and nodule growth much more than root or shoot growth (Cassman et al., 1980). Therefore, it is not surprising that legumes have particularly a high phosphorus requirement for optimum growth, nodule formation and N$_2$-fixation. Though the afore-
mentioned facts clearly indicate that phosphorus plays an important role in symbiotic biological $N_2$-fixation in legumes, very little attention seems to have been paid on this aspect in chickpea. As meagre literature is available on chickpea in relation to phosphorus nutrition on nitrogenase activity, work on this aspect on some other $N_2$-fixing crops have also been included in the following review:

Bethenfalvay and Yoder (1981) conducted pot experiment in sterile rooting medium to study the effect of phosphorus on nitrogenase activity and mycorrhizal infection in soybean ($Glycine$ max L. Merr. cv. Lancer). They applied four levels of phosphorus, viz. 0, 20, 100 and 500 μM phosphorus to the sterile medium. Plants were inoculated with Rhizobium japonicum strain 61A118 and grown in the presence or absence of the endomycorrhizal fungus Glomus fasciculatus Gerdemnnet Trappe. Plants grown at the highest phosphorus level (500 μMP) had six times higher shoot dry weight than those grown in the lowest phosphorus regime (4 μMP). They did not find nodulation at the lowest phosphorus regime, but the dry weight of nodule increased 200-fold from the 20 to the 500 μMP treatment. Nitrogenase activity as measured by acetylene reduction technique increased significantly with increasing levels of phosphorus. However, the relative efficiency of nitrogen
fixation increased significantly with increasing phosphorus stress. They suggested that decreasing nodule phosphorus content might indicate a shift in electron allocation by nitrogenase to reduce $N_2$ to $NH_4$ rather than $H^+$ to $H_2$. Hydrogen evolution was not detected at 4 and 20 $\mu$MP, but the significant highest value was recorded for 500 $\mu$MP than that for 100 $\mu$MP. Infection by *G. fasciculatus* at 500 $\mu$MP was negligible. However, at all other levels the mycorrhizal plants had significant higher values for all the parameters studied than those for non-mycorrhizal plants.

A pot experiment was conducted in green house by Bouton *et al.* (1981) to study the effect of phosphorus and liming on acetylene reduction and yield of young alfalfa (*Medicago sativa* L. cv. Team) in highly weathered acid Bladen or Bradson top soils. Lime ($CaCO_3$) was thoroughly mixed by hand into soil and 1200 g soil samples were transferred to plastic pots. They added the following fertiliser materials as solids or solution to each pot: phosphorus as $Ca(H_2PO_4)_{2}.H_2O$ at three rates (0, 120 and 480 $\mu$g $g^{-1}$ soil); potassium as KCl (0.20 meq 100 $g^{-1}$ to the Bradson and 0.50 meq $g^{-1}$ to the Bladen to give approximately 0.60 meq 100 $g^{-1}$ of exchangeable K); magnesium as $MgSO_4.7H_2O$ (0.80 meq 100 $g^{-1}$ soil), boron (1.0 $\mu$g $g^{-1}$ soil) and trace elements solution of 3.5 $\mu$g $Zn$ $g^{-1}$ soil and 0.3 $\mu$g $Mo$ $g^{-1}$ soil. Acetylene reduction was assayed as a measure of
N₂-fixation. In site, they measured acetylene reduction on whole pots twice at 18 and 36 days after planting on and at termination (46 days after planting) on washed roots. It was observed that phosphorus and liming increased N₂-fixation and yield of alfalfa. Phosphorus application also increased root and nodule dry weight.

Kessel and Roskoski (1983) conducted pot experiment to assess the effect of different fertilisers and soil shading on nodulation and acetylene reduction of *Inga jinicuil* seedling. Fertilisers were applied one week after transplanting. A factorial design was employed with treatments allocated to bags which contained 7 kg soil in completely random manner. The treatments were four levels of superphosphate (0.0, 2.1, 5.3 or 10.5 g/bag which were equal to: 0, 105, 265 or 525 kg P/ha) with 0.0, 0.92 or 4.6 g urea/bag (0, 96 or 482 kg N/ha) or 0.0 or 2.7 g MgO+ 2.3 g MgCl₂.6H₂O/bag (0 or 0.394 69 kg Mg/ha, or 0.0, 0.4 or 2.0 g KCl/bag (0, 52 or 260 kg/ha): or 0.0 or 0.3 g Na₂MoO₄·2 H₂O/bag (0 or 30 kg Mo/ha). Seedlings were harvested at 8, 10, 12 and 14 months after the fertiliser addition. They noted that of all nutrients tested, only phosphorus had its significant effect on nodule number during the first 10 months of growth and plants grown with intermediate phosphorus levels (105 or 265 kg P/ha) produced significantly more nodules/plant than either control (0 kg
P/ha) or those seedlings receiving highest phosphorus level, viz. 525 kg P/ha. However, by 12th month, though the number of nodules were more than by 10th month, but the differences in values given by various levels of phosphorus were not significant. Neither potassium, magnesium, nor molybdenum significantly affected nodule number/plant. The acetylene reduction activity was first detected in 10 months old seedlings and the seedlings which received 265 kg P/ha exhibited significantly higher acetylene reduction activity at 10 and 12 months than the plants which received other phosphorus levels. However, by the final harvest the acetylene reduction activity for all phosphorus levels were similar. Nitrogen application inhibited nodulation and acetylene reduction throughout the experiment. Low levels of potassium stimulated and high levels inhibited acetylene reduction activity compared to unfertilised control plants. Neither magnesium nor molybdenum affected acetylene reduction.

Sankar et al. (1984) conducted pot experiment to study the effect of phosphorus on nitrogenase activity in groundnut variety J-11. They applied four levels of phosphorus, viz. 0, 30, 60 and 90 kg P₂O₅/ha. A uniform basal dose, each of nitrogen and potassium @ 20 kg/ha was given to each pot. Various parameters namely dry matter/plant, leaf area/plant, nodule number/plant, nodule dry weight/plant, nitrogenase activity and leghaemoglobin
content of nodule were studied. All the above parameters increased significantly with increasing levels of phosphorus. They suggested that the influence of phosphorus on nitrogenase activity might be due to the increased supply of photosynthates.

Dhingra et al. (1988) conducted field trial from 1980-81 to 1984-85 to study the response of lentil to phosphorus application and Rhizobium inoculation. They applied four levels of phosphorus (0, 20, 40 and 60 kg P₂O₅/ha). It was found that phosphorus application from 0 to 60 kg P₂O₅/ha significantly increased the number and dry weight of nodules and nitrogenase activity. The nitrogenase activity of intact root nodules were 17.53, 22.39, 27.39 and 29.17 n mol/h/g dry weight of nodules with 0, 20, 40 and 60 kg P₂O₅/ha respectively. Rhizobium inoculation was also found to increase nodulation, nitrogenase activity and grain yield. The interaction effect between phosphorus application and Rhizobium inoculation was significant in 3 out of 5 years and it was concluded that the combination of Rhizobium with 20 kg P₂O₅/ha gave seed yield equivalent to 40 kg P₂O₅/ha without Rhizobium inoculation.

Idris et al. (1989) conducted field experiment during the winter season of 1985-86 to study the effect of phosphorus on biological nitrogen fixation in chickpea
variety CM-88. They applied four levels of phosphorus, viz. 40, 60, 80 and 100 kg P$_2$O$_5$/ha. A uniform basal dose of nitrogen (20 kg N/ha) and potassium (24 kg K$_2$O/ha) was also applied at the time of sowing. The sources of phosphorus, nitrogen and potassium were single superphosphate, urea and potassium sulphate respectively. The design of the experiment was randomised block and each treatment was replicated four times. The acetylene reduction assay of the excised nodulated roots of plants as a measure of nitrogenase activity was determined at preflowering stage. However, they did not find any significant effect of phosphorus on nitrogenase activity. They concluded it might be due to the fact that acetylene reduction assay, being a rapid and most sensitive technique to measure an instantaneous nitrogenase activity was often affected by technical, environmental factors including physiological conditions of plant growth.