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Role of Mineral Nutrients in Cultivation of Medicinal Legumes

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ABSTRACT

Legumes (Fabaceae family) produce primary and secondary metabolites and other phytochemicals such as nutraceuticals, pharmaceuticals, pesticides and other industrial products. The medicinal legumes are potential sources of glycosides (aloe-emodin, chrysophenol, emodin, rhein, etc.), antibiotics, flavonoids, alkaloids and phytochemicals, which are used in drug manufacturing by the pharmaceutical industries. Thus, escalation of yield and quality of the medicinal legumes is of paramount importance. The various ways to improve yield and quality of medicinal legumes essentially include the supply of mineral nutrients as per the soil demand. In fact, balanced nutrition of crop plants plays a vital role in sustaining the yield and quality of medicinal plants together with maintaining the fertility status of soils on long-term basis. Among the macro-nutrients, phosphorus (P) is a major component of metabolic molecules involved in storage and utilization mechanism of energy that affects the growth and metabolism of plants significantly. Another element of macro-importance is calcium (Ca) that plays important structural and physiological roles in plants. It is essential for maintaining the stability of the membranes and walls of the cells and maintains the cell integrity. Above all, Ca is a second messenger and, thereby, controls the growth and differentiation of plants. In this review article, we have gathered important information about the individual effects of P and Ca on selected medicinal legumes. This review also covers the general description and therapeutic uses of medicinal legumes. The authors have themselves carried out a considerable work to evaluate the effect of P and Ca on selected medicinally important leguminous plants including hyacinth bean (*Lablab purpureus* L.), coffee senna (*Senna occidentalis* L.), senna sophera (*Cassia sophera* L.) and *Cassia tora* L. (*Cassia obtusifolia* L.).

Keywords: calcium, medicinal legumes, mineral nutrition, nutraceuticals, phosphorus

CONTENTS

INTRODUCTION

Medicinal herbs are used to combat illness and support the body's own defense to regain good health. However, the supply of these medicines lags behind their demand in the market. For the cultivation of plants, the role of mineral nutrition is of paramount importance. In fact, yields of most crop plants increase linearly within limits with the amount of fertilizer that they absorb (Franz 1983; Loomis and Conner 1992). Using balanced mineral nutrients, the plant's maximum genetic potential can be realized successfully (Wallace and Wallace 2003). The scientific cultivation may improve the yield and quality of medicinally important leguminous plants, particularly through application of optimal fertilizer amounts and, thus, can help meet the increasing demands of these plants. This would augment the yield and quality of these herbs ensuring their steady supply in the market.

Medicinal herbs are the most important source of therapeutic agents used in modern as well as traditional systems of medicine and constitute the important natural wealth of the country. The alternative systems of medicine have provided a large variety of potent drugs to alleviate suffering from diseases. With easier and safer transportation, medicinal plants continued to play an extraordinary significant role in the health care of humankind far and wide and it is

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Invited Review

no wonder that presently six hundred million people depend directly or indirectly on plant-derived drugs for their health-care needs. World Health Organization (WHO) has estimated that about 80% of the populations of developing countries depend on plant-based traditional systems of medicine to meet their health-care needs. The demand for medicinal plants is increasing in both developing and developed countries due to growing recognition of natural products, being generally non-narcotic, having no or little side-effects and easy availability at affordable costs (Bent and Ko 2004; Dubey *et al.* 2004).

According to Schippmann *et al.* (2002), the number of species used medicinally worldwide and in India is 52,885 and 3,000, respectively. However, WHO's report contains a list of only 20,000 medicinal plants used in different parts of the globe (Purohit and Vyas 2004). Arguably, being the largest producer of medicinal herbs, India is appropriately called the botanical garden of the world and the treasure house of biodiversity (Ahmedullah and Nayar 1999).

India is known to possess a rich repository of medicinal plants. Around 70% of India's medicinal plants are found in tropical areas, mostly in forests spread across the Western and Eastern Ghats, the Vindhyas, the Chota Nagpur plateau, the Aravalis and the Himalayas. This leaves only 30% of the medicinal plants in temperate and Alpine areas and on higher altitudes (Purohit and Vyas 2004; Seth and Sharma 2004). Arguably, being the largest producer of medicinal herbs, India is appropriately called the botanical garden of the world and the treasure house of biodiversity (Ahmedullah and Nayar 1999). Two of the largest users of medicinal plants are China and India. Scientists, physicians and pharmaceutical companies will be looking in the future also mainly towards these countries for their requirements, as they have the largest number of medicinal plant species and are among the top exporters of the commodity (Wakdikar 2004).

According to WHO, the international market of herbal products is US$ 62 billion which is expected to reach US$ 5 trillion by the year 2050. Surprisingly, India although being one of the largest producers of medicinal plants, has presently less than 0.5% share in the global export market of medicinal plants and their products (Bhattacharjee 2004; Purohit and Vyas 2004).

The majority of these medicinal plants belong to angiospermic families of which the legume family (Fabaceae) is the third largest, with approximately 650 genera and 20,000 species (Doyle 1994). A handsome number of medicinal legumes are potential sources of glycosides (aloe-emodin, chrysophenol, emodin, and rhein, etc.), antibiotics, flavonoids, alkaloids and phytochemicals, which are used in drug manufacturing by the pharmaceutical industries (Tyler *et al.* 1976; Morris 1996, 1997, 1999, 2003). Legumes produce primary and secondary metabolites and other phytochemicals such as nutraceuticals, pharmaceuticals, pesticides, and industrial products. Bio-functional legumes have provided healthy food constituents to be used as nutraceuticals, pharmaceuticals, and pesticidals, thus, they can increase healthy food resources worldwide. The natural products of leguminous plant have been and will continue to be important sources and models of forage, gums, insecticides, phytochemicals and other industrial, medicinal and agricultural raw materials. Many legumes have been used in folk medicine too (Duke 1992).

It is true that due to awareness concerning herbal remedies and some meticulous results in laboratory and clinical trials, the market and public demand of herbal drugs has shown a quantum jump, resulting in increased their collection. Moreover, increasing urbanization threatens many medicinal plants to the extent of extinction as well as loss of genetic diversity, resulting in acute shortage. Also, the current trend towards increased commercialization has resulted in over-harvesting of some important medicinal plants, many of which have become threatened. Additionally, 22% of threatened medicinal plant species of Indian Himalayas are reported to be critically endangered, 16% endangered, and 27% vulnerable. Of these, 32 threatened medicinal plant species are endemic (Kala 2005).

There is thus an urgency to give special emphasis and to clearly define the policies to regulate medicinal plant conservation, cultivation, quality control standards, processing and preservation, marketing and export. Out of these useful steps and policies regarding medicinal plants sustenance, the cultivation of medicinal plants on scientific lines appears to be extraordinarily effective to obtain authentic, standard and fresh herbal materials. This would be a safeguard against unauthentic, spurious, denatured, fake and soiled drugs.

At Aligarh (India), Khan and Mohammad (2006), Naeem (2007), Naeem *et al.* (2009a-e, 2010a, 2010b, 2011) carried out in-depth studies on the mineral nutritional requirements of a number of medicinal plants, including *Anethum*, *Artemisia*, *Carum*, *Cassia*, *Cichorium*, *Curcuma*, *Cymbopogon*, *Datura*, *Foeniculum*, *Lablab*, *Lallemantia*, *Linum*, *Mentha*, *Nigella*, *Plantago*, *Senna*, *Solanum*, *Trigonella*, *Withania* and *Zingiber*. However, little work has been done so far regarding the fertilizer requirements on the useful medicinal legumes.

In view of this requirement above, the survey of literature regarding individual effect of phosphorus (P) and calcium (Ca) nutrients on medicinally important leguminous plants has been reviewed in this article. Work done at Aligarh, other places of India and abroad has been compiled in the pages that follow.

BLACK GRAM (*VIGNA MUNGO* L.)

Black gram (*Vigna mungo* L.) cv. 'Hepper' is a highly valued pulse in India. It is very nutritious and is recommended for diabetics, as are the other pulses. It is an anti-diabetic food. Germinated seeds taken with half a cup of fresh bitter gourd juice, forms and effective remedy for treating mild types of diabetes. In severe diabetes, regular use of this combination is an effective complement to other treatments. It is also a useful health food for preventing complications due to malnutrition in diabetes (www.alternative-healthguide.com).

Singh and Sudhakar (1991) conducted a field experiment at Hyderabad (Andhra Pradesh) on black gram cultivars 'T 9' and 'PDU 3' in a sandy loam soil with three levels of P (0, 20 and 40 kg P/ha) with and without inoculation. Application of 40 kg P/ha with inoculation recorded significantly higher values for dry matter accumulation compare to other combination of P and inoculation separately. It significantly increased seed yield and percent of nitrogen (N) and P content (stems, leaves and seeds) compared to the control.

Reddy and Swamy (2000) conducted a field experiment on black gram at Hyderabad. They applied three levels of P (0, 13.1 and 26.2 kg/ha), two levels of farmyard manure (0 and 10 tons/ha) and two levels of phosphate-solubilizing bacteria (PSB) (inoculated and uninoculated). Application of 26.2 kg P/ha increased growth and yield attributes. With increase in P levels from 0 to 26.2 kg P/ha yield attributes like number of pods/plant, number of seeds/pod and seed yield increased by 53.5, 15.3 and 50.6%, respectively over the control.

Singh and Sharma (2001) studied the response of black gram to P fertilization and *Rhizobium* inoculation in the hill soils of Assam, India. Four levels of P, viz. 0, 25, 35 and 45 kg P_2O_5 (equivalent to 0, 10.9 15.3 and 19.6 kg P, respectively)/ha were applied through single superphosphate (SSP) ($Ca(H_2PO_4)_2$) with and without *Rhizobium* inoculation of seeds. Application of 45 kg P_2O_5/ha produced the highest grain and straw yield and was at par with that of 25 and 35 kg P_2O_5/ha. Application of P at 25 to 45 kg P_2O_5 increased the N and P uptake as well as grain yield of the crop from 20 to 30 kg/ha. Number of nodules and mass of nodules/plant increased with increasing levels of P application up to 35 kg P_2O_5/ha.

Shrivastava *et al.* (2003) conducted an experiment

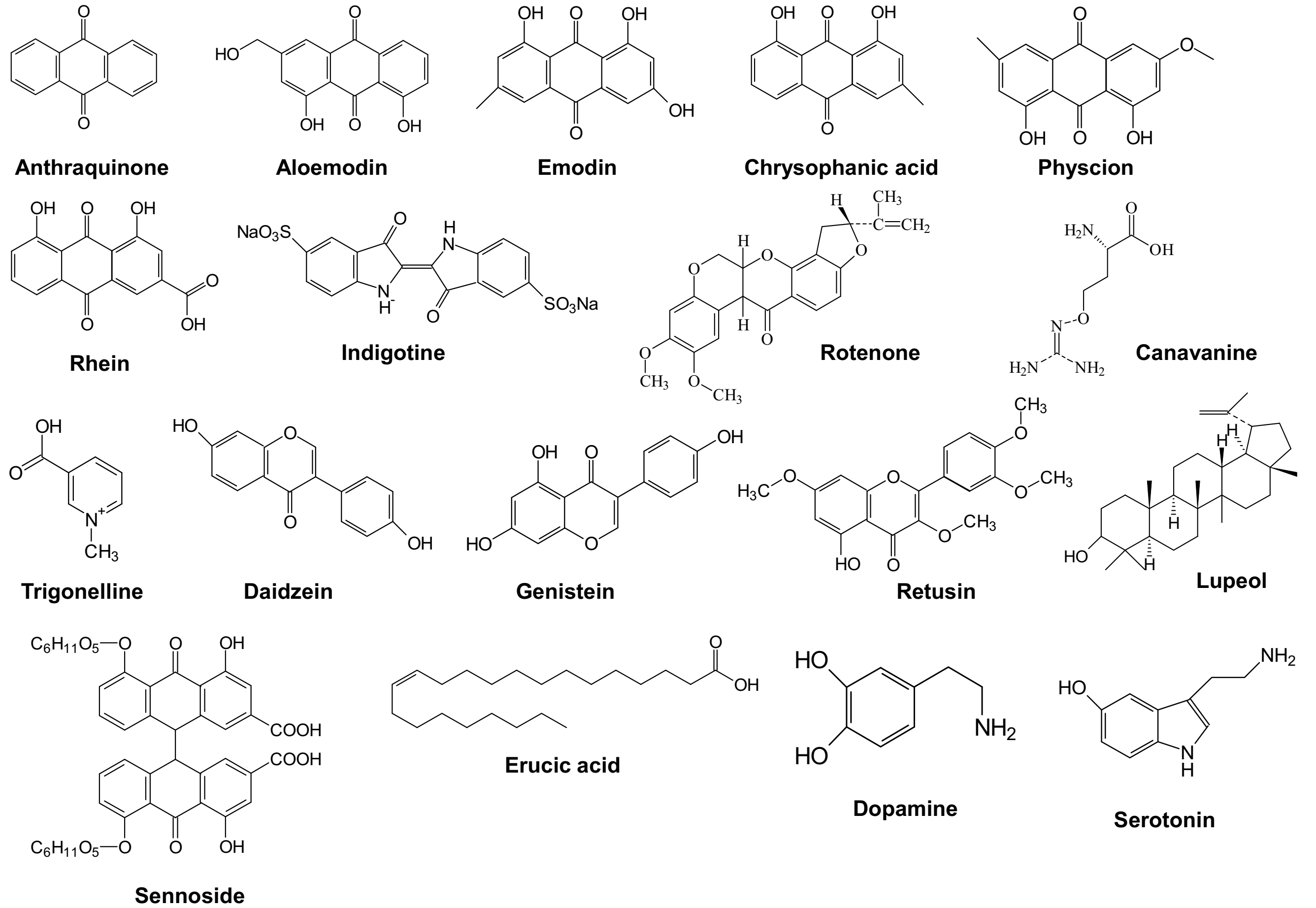

Fig. 1 Structural formulae of various active constituents present in the medicinal leguminous plants.

during the *rabi* (winter) and *kharif* (summer) seasons of 1997-2000 at Raipur, to study the effect of different levels of farmyard manure (FYM), P and zinc (Zn) on the productivity of 'RU 9401-2'. The treatments consisted of 2 levels of FYM (with and without 5 tonnes of FYM), 3 levels of P (0, 8.6 and 17.2 kg P/ha) and 2 levels of Zn (0 and 15 kg $ZnSO_4$/ha). Application of 5 tonnes FYM/ha resulted the higher yield (599 kg/ha) than without FYM. Among the P levels, 17.2 kg P/ha resulted in significantly highest yield (628 kg/ha), and the maximum net return (9 334 Rs/ha). However, Zn levels did not show a significant effect on black gram yield.

Javaid *et al.* (2006) studied growth, nodulation and yield response of black gram to seed-inoculation by two strains of *Bradyrhizobium japonicum* viz., TAL-102 and MN-S, in different soil amendment systems. Soil was used either in amended or un-amended form along with FYM, *Trifolium alexandrinum* green manure (GM) or NPK fertilizers. Un-amended and NPK-amended soils with inoculation resulted in a significant increase in number and biomass of nodules. Effect of inoculation was more pronounced in NPK-amended soil than in un-amended soil. In un-amended and FYM-amended soils, inoculation failed to induce any significant change in shoot biomass and grain yield. In NPK-amended soil with inoculation, the nodulation was enhanced with a subsequent increase in shoot biomass and grain yield. Grain yield was positively correlated with nodule biomass in FYM- and NPK-amended soils.

Javaid (2009) investigated the effect of application of EM (effective microorganisms; a commercial biofertilizer mainly consisting of photosynthetic and lactic acid bacteria, yeast, actinomycetes and two strains of nitrogen-fixing bacterium *Bradyrhizobium japonicum*, viz. TAL- 102 and MN-S) on plant growth, nodulation and yield of crop in different soil amendment systems including unamended soil and amended soils with FYM (5 g/100 g), *Trifolium alexandrinum* green manure (GM) (4 g 100/g) and recommended dose of NPK fertilizers. Nodule number was significantly enhanced by inoculation with either of the two *B. japonicum* strains in NPK-amended and unamended soils. A marked increase in nodule biomass was also recorded due to *B. japonicum* inoculation in these soils. Grain yield was increased by 46% due to either of the two strains of *B. japonicum* in NPK-amended soil. EM application markedly enhanced nodule number in FYM-amended soil. Conversely, EM application in combination with either of the two *B. japonicum* strains resulted in a pronounced reduction both in number and biomass of nodules in NPK-amended soil. EM application alone significantly enhanced grain yield by 48% in NPK-amended soil.

Hussain *et al.* (2011) carried out an experiment during the 2009 *kharif* season on black gram var. 'PU-19' with different levels of N and P viz., N_0 P_0, N_{15} P_{40}, N_{15} P_{60}, N_{30} P_{40} and N_{30} P_{60} kg/ha at Share-e-Kashmir University of Agriculture Science and Technology, Srinagar (J and K), India. They applied a basal dose consisting of entire P and one half of N as per treatment along with K at 20 kg/ha in the form of single super phosphate, urea and muriate of potassium before sowing of seeds. The remaining half of the N was top dressed treatment wise 30 days after sowing (DAS). Their study revealed that application of N and P at 30 Kg N + 60 Kg P_2O_5/ha proved beneficial for boosting seed yield, plant height, branches, number of seeds/pod, harvest index (HI), dry matter, 1000-seed weight and number and weight of nodules respectively under Kashmir temperate conditions.

CASSIA TORA (*CASSIA OBTUSIFOLIA* L.)

Cassia tora (*Cassia obtusifolia* L.), locally known as "Chakunda", is distributed in wastelands throughout the country and belongs to the family Fabaceae. The leaves and seeds contain anthraquinone compounds (**Fig. 1**) that are famous for their laxative action, antiseptic antifungal, anti-inflammatory and anticancer properties and have been used as drug to treat the skin diseases for a long time (Thomson 1971; Gritsanapan *et al*. 2005). The leaves are used in the treatment of tuberculosis and ring worms. The roots are crushed and mixed with lime juice to treat ringworms infection. The pods are used in dysentery and ophthalmic diseases (Singh and Premanath 1992). The seeds not only contain considerable amount of gum but also carry chrysophanic acid, which is used in the treatment of skin diseases like ringworms, scabies and eczema (Dastur 1977; Kirtikar and Basu 1987; The Wealth of India 1992). The leaves and pods of this plant possess a group of anthracene derivatives collectively known as sennosides (**Fig. 1**), which are important sources of organic laxatives. It has a worldwide demand in pharmacopoeia preparations and in modern as well as traditional systems of medicine.

Naeem and Khan (2005) investigated whether P application could augment the growth, physiology and seed yield of *Cassia tora*. Out of five levels of P , viz. 0, 0.1, 0.2, 0.3 and 0.4 g P/kg soil (P_0, P_1, P_2, P_3 and P_4, respectively), 0.3 g P/kg soil (P_3) significantly enhanced fresh and dry weights of plant, number of leaves, leaf area/plant, total chlorophyll content, leaf-N, -P and -K content, leaf-nitrate reductase (NR) activity, pod length, number of pods, pod weight/plant, seed weight/pod, seed yield, seed yield-merit and seed-protein content. However, number of seed/pod, 100-seed weight and HI were not affected by different levels of P. P_3 enhanced seed yield and seed yield merit by 30.3 and 34.2%, respectively. P_3 also proved to be the best P level for most of the parameters studied.

Naeem and Khan (2006) studied the influence of calcium (Ca) application on growth, yield and quality attributes of *C. tora*. Calcium chloride ($CaCl_2$) was applied to provide 0 (control), 40, 80, 120 and 160 mg Ca/kg soil (Ca_0, Ca_1, Ca_2, Ca_3 and Ca_4, respectively). The plant fresh and dry weights, number of leaves and leaf area were estimated. Yield attributes including, HI, number of seeds, seed weight, 100-seed weight, pod yield and seed quality were recorded at harvest. The leaves were analyzed for inorganic nutrient elements (N, P, K and Ca) as well as for chlorophyll (Chl) content and NR activity. The protein, total anthraquinone glycosides (in seeds) and total sennoside contents (in pods) were also estimated. The results showed that Ca significantly enhanced all the attributes except number of seeds/pod and HI. Ca applied at 0.3 g P/kg soil (Ca_3) proved optimum and gave maximum value for all attributes over their respective controls. This treatment enhanced the seed yield, seed yield merit and seed protein content by 31.6, 33.1 and 10.3%, respectively over the controls. It is reported that soil-applied Ca stimulated the production of anthraquinone and sennoside contents responsible for the therapeutic property of the plant.

Another experiment was conducted by Naeem *et al.* (2009a). They reported that the plants of *C. tora* were grown in pots containing soil, supplied with five levels of P: 0 (control), 0.1, 0.2, 0.3 and 0.4 g P/kg soil. The fresh and dry weights, number of leaves and leaf area/plant were recorded. The leaves were analyzed for inorganic elements, such as N, P, K and Ca. Physiological and biochemical attributes including Chl and carotenoid content, NR activity, carbonic anhydrase (CA) activity, net photosynthetic rate (P_N), stomatal conductance (*g*s) and transpiration rate were determined. Yield attributes including number of pods, number of seeds/pod, 100-seed weight, and seed yield/plant were recorded. In addition, protein, total anthraquinone glycosides (in seeds) and total sennoside content (in pods) were also estimated. The results showed that P at 0.3 g/kg soil was optimum and significantly enhanced most of the attributes studied.

CLUSTER BEAN (*CYAMOPSIS TETRAGONOLOBA* L. TAUB.)

The seed powder of cluster bean (*Cyamopsis tetragonoloba* L. Taub.) is used as an emulsifier, thickener and stabilizer in a wide range of foods. Its seeds are potential source of additional phytochemicals such as flavonoids that include daidzein, genistein, quercetin and kaempferol (Morris and Wang 2007).

Garg *et al.* (1997) studied the effect of sodium chloride (NaCl) on cluster bean cv. 'HF G-182'. They observed that the increasing NaCl concentration (0, 50, 100 and 150 mM) progressively decreased growth and seed yield of cluster bean, which was associated with decreased concentration of K and Ca and increased concentration of sodium (Na) in the shoots. Supplemental application of Ca (0, 2.5 and 5.0 mM) significantly ameliorated the adverse effects of NaCl due to enhanced uptake of Ca and K and reduced uptake of Na. Ca also alleviated the negative effects of NaCl regarding activities of N metabolism enzymes and contents of soluble protein and free amino acids.

Shubhra *et al.* (2004) studied the influence of three levels of P (75, 150 and 300 mg/pot) on plant water relation parameters (relative water content, leaf water potential and osmotic potential), contents of total Chl, Chl *a*, Chl *b*, and soluble sugars and gum of seed (seed quality). Under water stress, leaf water-potential, osmotic potential, total leaf-Chl and seed-gum contents decreased, while the seed-sugar content increased. P application increased Chl content and sugar content in control plants, ameliorating the negative effects of water stress.

Burman *et al.* (2007) conducted a two-year field study on cluster bean cv. 'RGC-936' under rainfed conditions, using three levels of P (0, 20, and 40 kg/ha) and two levels of N (0 and 20 kg/ha) with and without thiourea application (seed treatment with 500 mg/kg followed by two foliar sprays of 1000 mg/kg each at 25 and 40 days after sowing). N and P, applied alone or in combination with thiourea, resulted in significantly higher P_N and contents of Chl, starch, soluble protein, and total free amino acids in addition to increased NR activity compared to the control both at vegetative and flowering stage. However, the magnitude of favorable changes in the parameters studied varied with soil moisture due to varying rainfall. The effects of N, P, and thiourea were generally more pronounced at the vegetative stage. Seed yield, dry-matter production, HI, and water-use efficiency (WUE) were significantly enhanced by the treatments mentioned above. Favorable effects of the treatments were realized through significant improvements of metabolic efficiency and maintenance of higher photosynthesis and NR activity for more efficient N utilization. It was concluded that elevating N and P status of the arid-zone soils coupled with thiourea application might significantly improve the yield of cluster bean under rainfed conditions, the potential gains might be varying with the soil-moisture availability.

Sammauria *et al.* (2009) performed a field experiment to assess the effect of *Rhizobium* and PSB alone and in combination with different levels of recommended N and P fertilizers, i.e. recommended dose of fertilizers (RDF) (20–17.4 kg N-P/ha) on the performance of rain-fed cluster bean. Increasing N and P levels resulted in significant improvement in plant growth, yield attributes and crop yield. The increase in seed yield was significant up to 50% RDF in 2004 (1.01 t/ha) and up to 75% RDF in 2005 (1.15 t/ha). However, the mean biological yield (4.66 t/ha) increased significantly up to 75% RDF during both years. The control recorded the lowest seed and biomass yields. However, P uptake increased significantly up to 100% RDF, while N and K uptake and B:C ratio increased up to 75% RDF. The growth, yield attributes and crop yield increased significantly due to inoculation of cluster bean seeds with biofertilizers. Combined inoculation of *Rhizobium* and PSB was more promising from a productivity and profitability point of view compared to carrying out the seed inoculation with either of the bacteria. Integrated use of 75% RDF with *Rhizobium* + PSB inoculation was the best for cluster bean.

COFFEE SENNA (*SENNA OCCIDENTALIS* L.)

Coffee senna (*Senna occidentalis* L.) is the substitute for coffee. Leaf powder is used as an analgesic, antibacterial, anti-hepatotoxic, antifungal, anti-inflammatory, antiseptic, antiparasitic, antiviral, carminative, laxative, purgative and vermifuge medication (The Wealth of India 1992). The volatile oil obtained from leaves, roots and seeds contains antibacterial and antifungal activity (Chopra *et al.* 1958; Kirtikar and Basu 1987). Seeds are useful in cough and whooping cough, convulsions and in heart diseases. The roots are bitter in taste and considered as tonic, purgative, anthelmintic and diuretic (The Wealth of India 1992). The plant parts are used to cure sore eyes, haematuria, rheumatism, typhoid, asthma, leprosy, ringworm and disorders of hemoglobin. A decoction of the plant is used in hysteria, dysentery, itching, inflammation of the rectum and scorpion sting. The herb is reported to be used as condiment and aroma ingredient in perfumery (The Wealth of India 1992).

Coffee senna plants were subjected to five P levels: 0, 25, 50, 75 and 100 mg P /kg soil (P_0, P_1, P_2, P_3 and P_4, respectively). Naeem and Khan (2009) conducted a pot culture experiment in a net house, AMU, Aligarh, India, under P-deficient soil. The present data indicates that soil-applied P significantly ameliorates most of the attributes studied. Out of five P levels, 75 mg P/kg soil (P_3) proved best and enhanced fresh and dry weights, total Chl and carotenoid content, NR activity and leaf-N, P, K and Ca content, analyzed at 120, 270 and 300 DAS. The number of pods, seed yield/plant and seed-protein content (330 DAS) were significantly enhanced by the P_3 level, except the number of seeds/pod, 100-seed weight and total anthraquinone glycosides content, respectively. Transpiration rate, *g*s and P_N were also enhanced by this treatment.

Furthermore, Naeem *et al.* (2010a) stated that plant biological yield appears to be comparatively low in Ca-deficient soil of Aligarh, western Uttar Pradesh, India. Ca deficiency poses a serious yield and quality limitation for several crops, including medicinal herbs, in this region of India. In view of the importance of coffee senna as a medicinal legume, it was hypothesized that Ca application through soil could enhance crop productivity, photosynthetic efficiency, enzymatic activities and nutraceuticals. Plants were grown in pots containing soil supplied with five levels of Ca, viz. 0, 40, 80, 120 and 160 mg Ca /kg soil (Ca_0, Ca1, Ca_2, Ca_3 and Ca_4, respectively) applied as $CaCl_2$. The performance of the crop was assessed in terms of various growth, physiological, biochemical, yield and quality attributes at 120, 270 and 300 days after sowing. Ca application effectively increased most of the parameters studied. Of the five Ca levels, Ca_3 stimulated most of the attributes studied at the three growth stages (120, 270 and 300 DAS). In fact, Ca_3 increased seed yield and seed-protein content by 27.6 and 10.6%, respectively, compared to control plants.

FENUGREEK (*TRIGONELLA FOENUM-GRAECUM* L.)

Fenugreek (*Trigonella foenum-graecum* L.), an annual plant, is one of the oldest medicinal plants, originating in India and Northern Africa. It grows to an average height of two feet. The leaves and seeds are used to separate extracts or powders for medicinal use. The medicinal use of fenugreek was documented in ancient Egypt in curing incense human behavior and embalming mummies. In the modern Egypt, fenugreek is still used as a supplement in wheat and maize flour for bread-making. In India, fenugreek is commonly consumed as a condiment and is also used medicinally as lactation stimulant in mothers. It is also used as tonic and for curing ailments such as allergies, coughs, colds, flu, inflammations, fevers, dyspepsia, emphysema, flatulence, headaches, toothache, menstrual cramps, intestinal inflammations, cystitis, hydrocele of the testicle, pellagra, stomachic ulcers, lungs, bronchitis, dropsy, infections of mucous membranes, and as tea for sore throat gargle. There are numerous other folkloric uses of fenugreek, including the treatment of indigestion and baldness. Seeds are also used in ameliorating the bad effects of diabetes and rickets (Kirtikar and Basu 1975; Chevallier 1996).

Maliwal and Gupta (1989) studied the effect of P on yield and yield attributes of fenugreek cv. 'Lagour Local'. P treatments consisted of 0 and 40 kg P_2O_5 (equivalent to 0 and 17.5 kg P respectively)/ha. Application of P at 17.5 kg P/ha increased number of pods/plant, straw yield and seed yield over the control. However, 1,000-seed weight and number of seeds/pod were not affected by P application.

Rathore and Manohar (1989) reported the effect of two levels of N and four levels of P on growth and yield of fenugreek cv. 'Nagour Local' at Jobner (Rajasthan). N was applied at 0 and 20 kg N/ha and P at 0, 25, 50 and 75 kg P_2O_5 (equivalent to 0, 10.9, 21.8 and 32.8 kg P, respectively)/ha. Application of N at 20 kg N/ha and P at 21.8 kg P/ha proved the best for most of the growth and yield parameters, including number of branches, dry matter, number of pods and seed yield/plant. In another communication, they further reported the beneficial effect of N and P on dry weight of nodules at 75 days after sowing and on the percent content of N and P in straw and seeds at harvest (Rathore and Manohar 1990).

Patel *et al.* (1991) conducted a field experiment to study the effect of different levels of N, P and K on yield and yield attributes of 'IC 9955' cultivar of fenugreek. They applied three levels N, viz. 0, 10 and 20 kg N/ha, three levels of P, viz. 0, 20 and 40 kg P_2O_5 (equivalent to 0, 8.7 and 17.5 kg P, respectively)/ha and two levels of K, viz. 0 and 20 kg K_2O (equivalent to 0 and 16.6 kg K, respectively)/ha. However, the applied levels of N, P and K did not affect the yield and yield attributes of fenugreek.

Verma *et al.* (1991) studied the effect of N and P on fenugreek (cultivar not mentioned). They applied four levels of N (0, 20, 40 and 60 kg N/ha) and four levels of P, viz. 0, 20, 40 and 60 kg P_2O_5 (equivalent to 0, 8.7, 17.5 and 26.2 kg P, respectively)/ha. Seed yield increased with increasing level of N up to 20 kg/ha. However, increasing levels of P enhanced seed yield linearly.

Bhati (1993) studied the effect of P application on fenugreek cv. 'Prabha'. P was applied at 0, 20, 40 and 60 kg P_2O_5 (equivalent to 0, 8.7, 17.5 and 26.2 kg P)/ha along with a uniform dose of 30 kg N/ha. The application of P at 8.7 kg P/ha increased the pods/plant, 1000-seed weight, straw yield, HI and WUE over the control. Seed and biological yields increased significantly up to 17.5 kg P/ha. However, P application did not affect the plant height, seeds/pod and pod length.

Banafar *et al.* (1995) conducted a field trial to study the effect of N and P on fenugreek cv. 'Plume 55'. N was applied at 0, 20, 40 and 80 kg N/ha and P at 0, 15, 30 and 45 kg P_2O_5 (equivalent to 0, 6.6, 13.1 and 19.7 kg P respectively)/ha. Application of 80 kg N and 19.7 kg P/ha proved the best for seed yield and vegetable leaf yield.

Detroja *et al.* (1995) studied the effect of three levels each of N, P and two levels of K on seed yield of IC 9955 cultivar of the fenugreek. They applied 0, 30 and 60 kg N/ha, 0, 60 and 120 kg P_2O_5 (equivalent to 0, 26.2 and 52.4 kg P respectively)/ha and 0 and 30 kg K_2O (0 and 24.9 kg K respectively)/ha. Application of 30 kg N, 26.2 kg P and 24.9 kg K/ha proved best for seed yield.

Singh and Bishnoi (1996) conducted a pot experiment to study the response of fenugreek cv. 'ML 150' to P application in the soils differing in available P status (low, medium and high). They applied five levels of P, viz. 0, 10, 20, 30 and 40 mg P_2O_5 (equivalent to 0, 4.4, 8.7, 13.1 and 17.5 mg P respectively)/kg soil along with a uniform dose of 10 mg N and 10 mg K/kg soil. The dry matter and yield increased significantly up to 17.5 mg P/kg soil in low P soil. In medium and high P soil, a significant increase in dry matter yield was observed up to 4.4 mg P/kg soil.

Kamal and Mehra (1997) studied the effect of soil-applied fertilizers and foliar spray of naphthalene acetic acid (NAA) on the yield of fenugreek cv. 'NLM' (Prabha).

They applied three levels of N (0, 20 and 40 kg N/ha), four levels of P (0, 30, 60 and 90 kg P/ha) and two foliar sprays consisting of 0 (water) and 10 ppm 1-naphthaleneacetic acid (NAA). Higher seed yield resulted from the combination of 40 kg N/ha + 90 kg P/ha + NAA spray.

Dayanand *et al.* (1998) studied the effect of four levels of P on the growth and yield attributes of fenugreek cv. 'RMT 1'. P was applied at 0, 20, 40 and 60 kg P_2O_5 (equivalent 0, 8.7, 17.5 and 26.2 kg P, respectively)/ha along with a uniform basal dose of 25 kg N/ha. Application of 40 kg P_2O_5/ha increased the plant height, dry mater accumulation, number of branches/plant, number of pods/plant and number of seeds/pod over its preceding doses. However, test weight was not affected by P application.

Gogoi *et al.* (1998) conducted an experiment to study the effect of P fertilization on fenugreek cv. 'Pusa Early Bunching'. Six levels of P, viz. 0, 10, 20, 30, 40 and 50 kg P_2O_5 (equivalent to 0, 4.4, 8.7, 13.1, 17.5 and 21.8 kg P respectively)/ha were applied. The plant height and number of branches/plant did not show any significant change with increasing levels of P. Plants applied with 50 kg P_2O_5/ha took maximum time to flower. It was concluded that to obtain the higher seed yield, 30 kg P_2O_5/ha should be applied to the soils of north blank planes of Assam for optimum fenugreek production.

Halesh *et al.* (1998) performed a field trail to study the response of fenugreek cv. 'CO1' to N and P application. The treatment comprised of four levels of N, viz. 0, 30, 60 and 90 kg N/ha and four levels of P, viz. 0, 30, 60 and 90 kg P_2O_5 (equivalent to 0, 13.1, 26.2 and 39.3 kg P, respectively)/ha, with a uniform dose of 50 kg K_2O (41.45 kg K)/ha. Higher plant growth and seed production were achieved by the application of 60 kg N and 39.3 kg P/ha. A higher dose of N delayed the flowering and prolonged the crop duration.

Jat *et al.* (1998) studied the effect of two levels of P, viz. 20 and 40 kg P_2O_5 (equivalent to 8.7 and 17.5 kg P respectively)/ha on the yield attributes, crop yield and nutrient content of fenugreek cv. 'RMT 1'. Application of P at 40 kg P_2O_5/ha increased the number of pods/plant, number of seeds/pod, seed yield and straw yield. P at 40 kg P_2O_5/ha also increased N and P content in the seeds and straw.

Kumawat *et al.* (1998) studied the effect of P application on fenugreek cv. 'RMT 1'. Three levels of P, viz. 20, 40 and 60 kg P_2O_5 (equivalent to 8.7, 17.5 and 26.2 kg P, respectively)/ha were applied along with a uniform basal dose of 25 kg N/ha. Application of 40 kg P_2O_5/ha proved the best for plant height, number of branches/plant, number of pods/plant, number of seeds/pod, test weight, seed yield and straw yield. N content in the seed and P content both in the seed and straw were also maximum with 40 kg P_2O_5/ha.

Chaudhary (1999a) studied the response of fenugreek cv. 'RMT 1' to N and P application. Three levels of N, viz. 0, 20 and 40 kg N/ha and two levels of P, viz. 20 and 40 kg P_2O_5 (equivalent to 8.7 and 17.5 kg P respectively)/ha were applied to the soil. Application of 40 kg N and 40 kg P_2O_5/ha proved the best for number of branches/plant, number of pods/plant, test weight, seed yield and straw yield.

Chaudhary (1999b) studied the effect of six combinations of N and P on fenugreek cv. 'RMT 1'. The six combinations of N (kg N/ha) + P (kg P_2O_5/ha) included 0+0, 20+20, 20+40, 20+60, 40+40 and 40+60, respectively. Application of 40 kg N + 40 kg P_2O_5/ha proved the best for number of pods/plant, test weight and seed yield. However, these combinations did not affect the plant height, number of branches/plant, pod length and number of seeds/pod.

Sheoran *et al.* (1999) studied the effect of four levels P, viz. 0, 30, 60 and 90 kg P_2O_5 (equivalent to 0, 13.1 26.2 and 39.3 kg P respectively)/ha at three sowing dates (16 November, 1 December and 16 December) on two fenugreek genotypes, namely 'HM 65' and 'T 8'. P was applied in the form of SSP and a basal dose of 20 kg N/ha was applied as urea. Application of P (60 kg P/ha) significantly increased the seed yield and productivity of the crop. Based on the pooled data, an increase in the seed yield up to 19.4, 27.6 and 28.8% was recorded as a result of the application of 30, 60 and 90 kg P_2O_5/ha, respectively.

Ram and Verma (2001) conducted a field experiment to study the effect of four levels of P (0, 26.4, 52.8 and 79.2 kg P/ha) on the seed yield of fenugreek cv. 'Pusa Early Bunching'. The P, applied at 52.8 kg/ha, gave significantly higher seed yield (2.1 ton/ha), number of seeds/plant (1158), weight of seeds/plant (10.2 g), test weight of 100-seeds (1.18 g), number of seeds/pod (14.1), weight of seeds/pod (0.123 g), weight of pods/plant (16.4 g) and fresh weight of the whole plant (35.1 g). Thus, 52.8 kg P/ha was optimum dose for growing crop of fenugreek for seed.

Khiriya and Singh (2003) conducted a field experiment to study the effects of four levels of farmyard manure, viz. 0, 5, 10 and 15 tons/ha and four levels of P , viz. 0, 20, 40 and 60 kg P_2O_5 (equivalent to 0, 8.6, 17.2 and 25.8 kg P, respectively)/ha on two cultivars of fenugreek, namely 'HM 65 and NLM'. Cultivar 'NLM' was significantly superior to 'HM 65' in terms of number of branches/plant, number of pods/plant and number of seeds/pod. Increasing the levels of P up to 40 kg P_2O_5/ha significantly increased the yield attributing characters as well as seed yield and quality parameter.

Azam (2002) conducted a pot and a field experiment on this fenugreek plant to confirm whether the results of pot experiment tally with those obtained in the field experiment. Six P levels, viz. P_0, P_{10}, P_{20}, P_{30}, P_{40} and P_{50} (i.e. 10, 20, 30, 40 and 50 kg P, respectively)/ha were applied at the time of sowing. The performance of the crop was adjudged in terms of growth and photosynthetic parameters, yield and quality parameters and leaf-N, -P and -K content. Treatment P_{10} proved the best for most of the parameters. In a yet another study conducted in this regard, it was reported that if a foliar spray of gibberellic acid was applied at 200 ppm at the flowering stage along with a basal dose of 50 kg N and 25 kg P/ha as supplement, the productivity as well as the biochemical attributes of the plant could be augmented to a considerable extent (Azam 2002).

Khan *et al.* (2005) studied the effect of different P levels (0, 30, 45 and 60 kg P_2O_5/ha) and spatial arrangement of row spacing (1.8 × 6 m, 2.4 × 6 m and 3 × 6 m for row spacing 30, 40, and 50 cm, respectively) on growth and yield of fenugreek during 2003-2004. Spatial arrangement only affected fenugreek plant population per unit area. The effect of P and spatial arrangement was non-significant on growth and yield of fenugreek. P application improved the performance of fenugreek plants regarding number of seeds/plant, 1000-seed weight, biological yield, seed yield and HI. However, P application did not affect the number of branches/ and pods/plant. Application of P at 60 kg P_2O_5/ha increased seed yield of fenugreek (1358.29 kg/ha) significantly, being statistically at par with 45 kg P_2O_5/ha (1326.47 kg/ha). It was concluded that optimum dose of P for fenugreek crop was 45 kg P_2O_5/ha.

Basu *et al.* (2008) conducted a field experiments on fenugreek cv. 'Tristar' to determine appropriate cultural practices for maximizing forage and seed production of this crop. Increasing rates of phosphate fertilizer (0, 30, 40, 50 and 60 kg/ha) had a significant effect on forage and seed yield. They reported that phosphate application at 40 to 50 kg/ha was effective for seed yield, while high forage yield was obtained when 50 to 60 kg/ha of phosphate fertilizer was applied. It was concluded that the use of appropriate agronomic practices is necessary to maximize the forage and seed production of 'Tristar' of this crop in dark brown soil zones of the Canadian prairies.

Sammauria and Yadav (2008) conducted a field experiment during *rabi* and *kharif* seasons of 2003-04 and 2004-05 to study the effect of P and Zn application on seed yield and yield attributes of fenugreek. The residual effect of P and Zn application was also investigated on the yield of succeeding pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] crop. On pooled basis, significant improvements were recorded in the number of branches/plant, number of pods/plant, test weight, seed, straw and biological yield up to 40 kg P_2O_5/ha, whereas number of seeds/pod increased only up to 20 kg P_2O_5/ha. Effect of 40 kg P_2O_5/ha significantly enhanced the number of effective tillers/plant of the succeeding pearl millet crop, whereas ear length and test weight was improved only up to 20 kg P_2O_5/ha. Seed, stover and biological yields as well as HI of pearl millet increased up to 60 kg P_2O_5/ha.

Sammauria and Yadav (2010) performed a field experiment using split plot design with three replications during winter and rainy seasons of 2003 to 2005 at Bikaner. They studied the effect of P levels (0, 8.7, 17.5 and 26.2 kg/ha) and zinc (Zn) (0, 2.5, 5.0 and 7.5 kg soil application; 0.25 or 0.5% $ZnSO_4$ foliar spray once (45 DAS) twice (45 and 60 DAS) applied to fenugreek, on the performance of fenugreek (*Trigonella foenum-graecum*)-pearl millet (*Pennisetum glaucum*) cropping system. They reported that application of 17.5 kg P/ha and 5.0 kg Zn/ha resulted in 24.7 and 14.7% higher seed yield of fenugreek than the control (0.77 and 0.85 t/ha). Application of 26.2 kg P/ha and 7.5 kg Zn/ha to fenugreek significantly increased the content and uptake of P and Zn in fenugreek and pearl millet. However, increasing the levels of either of these two nutrients depressed the content and uptake of other nutrients by fenugreek. They concluded that the combined application of 26.2 kg P/ha +7.5 kg Zn/ha resulted in the highest yields of both crops. The net returns and benefit: cost (B:C) ratios were also highest when 26.2 P and 7.5 kg Zn were applied.

Mehta *et al.* (2010) carried out a field experiment to find the optimum levels of N and P with suitable bio-fertilizer on fenugreek. Application of 20 kg N and 40 kg P_2O_5/ha resulted in more number of nodules/plant and higher dry weight/plant over 10 kg N and 20 kg P_2O_5/ha, at 40 and 60 DAS, respectively. Similarly, nodules/plant and their dry weight also significantly increased with increasing level of N and P. Further, they also reported combined inoculation of seed with *Rhizobium* and PSB produced the highest number of nodules/plant and dry weight over their sole application and control. Thus, better nodulation at 40 and 60 DAS and higher Chl content at 75 DAS could be obtained by application of 20 kg N and 40 kg P_2O_5/ha with seed inoculation by *Rhizobium* and PSB.

FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

Various parts of the plant (*Phaseolus vulgaris* L.) are extensively used in Ayurvedic and Unani systems of medicine in the Indian subcontinent for the treatment of diabetes mellitus (Chopra *et al.* 1958). The green pods are mildly diuretic and contain a substance that reduces the blood sugar level (Duke and Ayensu 1985). The dried mature pod is used in the treatment of diabetes. The seed is diuretic, hypoglycaemic and hypertensive (Roman-Ramos *et al.* 1995). It is used externally in the treatment of ulcers. The seed is also used in the treatment of blood cancer. The root is dangerously narcotic. A homoeopathic remedy is prepared from the entire fresh herb. It is used in the treatment of rheumatism, arthritis, and the disorders of the urinary tract (Duke and Ayensu 1985).

Ssali (1981) studied the effect of various levels of $CaCO_3$, inoculation and lime pelleting on nodulation, dry matter yield and N content of the bean plant (*Phaseolus vulgaris* cv. Candian wander) using five acid soils in green house condition. The soil pH represented a range of 3.89 to 5.1 with exchangeable Al from 0.0 to 4 mg/100 g, exchangeable Mn from 0.35 to 2.32 mg/100 g and percent carbon from 6.69 to 5.60 mg/100 g. Application of $CaCO_3$ increased the soil pH and exchangeable Ca in all the soils, but exchangeable Al and Mn decreased with increasing amount of $CaCO_3$. Inoculation increased the nodule weight, dry matter yield and percent N particularly at the low pH level. However, when the seeds were not inoculated, the soil pH increased the nodule weight and dry matter yield. At low organic matter content and with substantial amounts of Al and/or manganese (Mn), liming increased the nodule weight and dry matter yield and decreased exchangeable aluminium and/or Mn. However, low lime rates had little effects on exchangeable aluminium (Al) and Ca as well as dry matter yield, but higher lime rates decreased the exchangeable Al and dry matter yield but increased the exchangeable Ca.

Parmar *et al.* (1999) conducted a field experiment in cold desert area of Himachal Pradesh, to study the effect of three levels of N, viz. 0, 15 and 30 kg N/ha, and four levels of P, viz. 0, 30, 60 and 90 kg P_2O_5 (equivalent to 0, 13.1, 26.2 and 39.3 kg P, respectively)/ha on growth, yield and nutrients uptake in French bean. Plant height, number of nodules/plant, number of pods/plant, number of seeds/pod and seed yield increased significantly up to 15 kg N and 60 kg P_2O_5/ha. The uptake of N and P significantly increased up to 60 kg P_2O_5/ha. N and P-use efficiently was, however, the highest at 15 kg N and 30 kg P_2O_5, respectively.

Singh and Verma (2002) conducted two field experiments using five N (0, 30, 60, 90 and 120 kg/ha) and three P (0, 30 and 60 kg P/ha) levels to study the impact of the N and P levels on growth and yield attributes, seed yield and economics of French bean grown under late-sown condition in the plains of Eastern Uttar Pradesh, India. Higher doses of N (120 kg/ha) and P (60 kg/ha) resulted in higher yield along with high profit. Kumar and Puri (2002) studied the response of two varieties of French bean to four P levels, viz. 0, 25 and 50 kg P_2O_5 (equivalent to 0, 10.9 and 21.8 kg P respectively)/ha and two levels of FYM (0 and 10 tons/ha) under rainfed condition. Application of 50 kg P_2O_5/ha with 10 t of FYM/ha resulted in the maximum plant height, number of pods/plant, number of seeds/pod and 1000-seed weight, leading to the improved yield of the crop.

Moniruzzaman *et al.* (2008) conducted a field experiment on French bean cultivar 'BARI Jhar Shim-2' with five levels of N (0, 40, 80, 120 and 160 kg N/ha) and four levels each of P (0, 40, 80 and 120 kg P_2O_5/ha), K (0, 30, 60 and 90 kg K_2O/ha) and sulfur (S) (0, 10, 20 and 30 kg S/ha), three levels each of Zn (0, 4 and 8 kg Zn/ha) and B (0, 1 and 1.5 kg B/ha) at Raikhali, Rangamati Hill District during *rabi* seasons of 2005-2006 and 2006-2007. Yield and yield components were significantly influenced by different fertilizer treatments containing macro and micronutrients. There was a significant effect of the fertilizer levels applied on plant height, number of branches/plant and leaves/plant, pod length, number of green pods, pod weight/plant and green pod yield during both years. The highest pod yield of 23.14 t/ha (average of 2005-2006 and 2006-2007) was obtained with 120-120-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo/ha along with 10 tons cow dung (CD) manure/ha that was closely followed by 120-80-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo/ha along with 10 tons CD/ha. The response equations indicated an optimum level of 138.6 kg N, 131.5 kg P_2O_5, 63.4 kg K_2O and 17.4 kg S/ha for higher green fruit yield of the bean. The economic dose of the nutrients applied came out to be 135.8-123.3-60-17.4 kg of N-P_2O_5-K_2O-S/ha. It was concluded that application of 136-123-60-17-4-1 kg N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo/ha along with 10 tons CD manure/ha might be considered as profitable dose for growing the French bean in South-Eastern hilly region of Bangladesh.

Sulieman and Hago (2009) conducted a field experiment in order to study the response of common bean to P application in combination with farmyard manure (FYM). The treatments consisted of two rates of FYM (0 and 2.5 ton/ha) and five levels of P (0, 50, 100, 150 and 200 kg P_2O_5/ha). Triple superphosphate (48% P_2O_5) was used as a source of P in the experiment. As a basic treatment, the seeds of common bean (cv. 'Shendi') were inoculated with *Rhizobium phaseoli* strain USDA 2669. Application of P and FYM increased all the values of parameters but the increase was not significant. P effects were sometimes erratic and inconsistent. In addition, there was a significant effect of the interaction between P and FYM on the shoot dry weight after 10 weeks from sowing.

HYACINTH BEAN (*LABLAB PURPUREUS* L.)

Hyacinth bean (*Lablab purpureus* L.) is one of the important leguminous crops widely cultivated in many regions of the tropics and subtropics. Its seeds and pods contain as much as 20-28% protein and, thus, it serve as a good source of vegetable proteins in human diets. The plant residue is used as a green manure. The crop yield is not high, and the low yield of the beans is attributed to the low levels of Ca available in the soils. Hyacinth bean, originating in India (Deka and Sarkar 1990), was introduced to Africa from Southeast Asia during the 8th century (Kay 1979).

Hyacinth bean is used in the treatment of cholera, vomiting, diarrhoea, leucorrhoea, gonorrhoea, edema, alcohol intoxication and globefish poisoning. The seeds are used as laxative, diuretic, anthelmintic, antispasmodic, aphrodisiac, anaphrodisiac, digestive, carminative, febrifuge and stomachic source in medication (Chopra *et al.* 1986; Kirtikar and Basu 1995). Hyacinth bean contains tyrosinase enzyme, which has potential use for the treatment of hypertension. Hyacinth bean fibre is known to prevent cancer, diabetes, heart disease, obesity, and is used as a laxative (Beckstrom-Sternberg and Duke 1994). The potential breast cancer fighting chemical known as Kievitone, a flavonoid, is found in hyacinth bean (Hoffman 1995). The flavonoid, genistein may play a role in prevention of carcinogenesis (Kobayashi *et al.* 2002) and as a chemotherapeutic and/or chemopreventive agent for head and neck cancer (Alhasan *et al.* 2001)

Verma (1975) carried out an experiment to study the effect of four levels of P , viz. 0, 20, 40 and 80 kg P_2O_5 (0, 8.7, 17.5 and 43.9 kg P, respectively)/ha on *L. purpureus* var. 'Lignosus'. Application of P (40 and 80 kg P_2O_5/ha) increased the seed yield (23.3 and 39.8%, respectively) over the control.

Sawant *et al.* (1987) carried out field trials, to study the effect of spacing and N and P application on *L. purpureus*. Application of 0, 30 and 60 kg P_2O_5 (equivalent to 0, 13.1 and 26.2 kg P, respectively)/ha gave average yields of 0.47, 0.52 and 0.58 tons/ha respectively. The highest yield of 0.75 ton/ha was given by the crop grown at a spacing of 30×20 cm and fertilized with 30 kg N and 60 kg P_2O_5/ha.

Noor *et al.* (1992) conducted a field experiment on *L. purpureus* cv. 'line HCOOLO' to study the effect of different combinations of 0, 30 or 60 kg P_2O_5 (equivalent to 0, 13.1 or 26.2 kg P, respectively)/ha, 0, 50, 100 or 150 kg K_2O (equivalent to 0, 41.5, 83.0 or 124.5 kg K, respectively)/ha, 0 or 20 kg S, 0 or 5 kg Zn and 5 or 10 ton FYM/ha, using controls with no fertilization application. Application of 60 kg P_2O_5 + 100 kg K_2O + 20 kg S + 5 kg Zn + 5 tons FYM/ha gave maximum pod yield.

Patel *et al.* (1994a) conducted a field experiment to study the effect of different row spacings (30, 45 or 60 cm), three levels of N (15, 25 or 35 kg N) and three levels of P, viz. 30, 50 or 70 kg P_2O_5 (equivalent to 13.1, 21.8 or 30.6 P, respectively)/ha on growth of Indian butter bean var. 'Typicus'. Dry matter production/plant, number of seeds/pod, number of pods/plant and 1000-seed weight increased to the highest extent with 25 kg N and 50 kg P_2O_5.

Patel *et al.* (1994b) also worked out the yield and quality of the same crop with different row spacings (30, 40 or 60 cm), three levels of N (15, 25 and 35 kg N) and three levels of P, viz. 30, 50 and 70 kg P_2O_5 (equivalent to 13.1, 21.8 and 30.6 kg P, respectively)/ha. Application of 25 kg N and 50 kg P_2O_5 gave maximum seed yield and seed protein content compared with that of 15 or 35 kg N and 30 or 70 kg P_2O_5.

Patel *et al.* (1995) conducted a field trial to study the effect of different row spacing (30, 45 or 60 cm), three levels of N (15, 25 or 35 kg N/ha) and three levels of P, viz. 30, 50 or 70 kg P_2O_5 (equivalent to 0, 13.1, 21.8 or 30.6 kg P, respectively)/ha on the same crop . Seed yield and uptake of N and P in seeds attained the highest level with 45 cm row spacing and application of 25 kg N and 50 kg P_2O_5/ha.

Arya *et al.* (1997) conducted an experiment during 3 seasons of 1992, 1993 and 1994 to study the effect of three N levels (20, 30 and 60 kg N/ha) and two P levels, viz. 20 and 40 kg P_2O_5 (equivalent to 8.7 and 17.5 kg P, respectively)/ha on the productivity of grain sorghum (*Sorghum bicolor*) and *Dolichos* intercropping systems. The higher grain and stover yields were obtained in pure crop of sorghum with 60 kg N + 40 kg P_2O_5/ha compared to the other intercropping systems with different fertilizer schedules. The productivity of grain of both crop with 60 kg N + 20 kg P_2O_5/ha (4.21 ton/ha) was more than that of grain sorghum + cowpea [*Vigna unguculata* (L.) Moench.] with 60 kg N + 40 kg P_2O_5/ha (4.16 ton/ha). The minimum sorghum gram-equivalent yield was obtained in pure crops of sorghum and dolichos.

Santhaguru and Hariram (1998) studied the effect of *Glomus mosseae* and *Rhizobium* on growth, nodulation and nitrogen-fixation in *L. purpureus* cv. 'Sweet' under different P regimes (0 and 150 mg/kg soil). The nodule activity, viz. the number and dry weight of nodules, leghemoglobin content and N content, was higher with dual inoculation using *Glomus mosseae* and *Rhizobium* as compared to the single inoculation with *Rhizobium* alone. The nodule activity was a function of the supplemental P application in both the dual inoculated and *Rhizobium* inoculated plants. Accumulation of plant biomass and total N and P content were higher with dual inoculation than with single inoculation using either *Rhizobium* or *Glomus mosseae* alone.

Khan *et al.* (2005) studied the effect of Ca application on growth and other physiological attributes, seed yield and quality attributes of hyacinth bean. Ca was applied at five levels, viz., 0, 0.2, 0.4, 0.6 and 0.8 g/pot. The plant dry weight, leaf-N, P, K and Ca content, total Chl content, total carotenoids contents, leaf-NR activity, number of nodules, nodule dry weight, nodule-N and leghemoglobin content were analyzed at two growth stages. Yield attributes, viz. number of pods, number of seeds/pod, 100-seed weight and seed yield and seed-protein content were recorded at harvest. Ca application at 0.6 g/pot produced the best results, in general. This treatment also enhanced the seed yield and seed-protein content by 30.3 and 11.6% over the respective control. Ca application also increased the pH of the soil that presumably enhanced the nodulation. The present study also showed that addition of Ca enhanced the nodulation of the bean and significantly increased the NR activity in the leaves.

Naeem *et al.* (2009b) evaluated the performance of hyacinth bean accessions [EC-497617 (Australia), EC-497616 (China), EC-497615 (Egypt), EC-497619 (Iran), and EC-497618 (Kenya), respectively] of different origins received from USDA, ARS, Plant Genetic Resources Conservation Unit, Griffin, GA, U.S.A. in terms of agrobotanical attributes, enzyme activities, nutraceuticals and quality in Ca deficient soil of Aligarh, Western Uttar Pradesh, India. Hyacinth bean accessions originated from different countries are denoted as A_1, A_2, A_3, A_4 and A_5. Fresh and dry weights/plant, leaf area, number and dry weight of nodules/plant, P_N, *gs* and transpiration rate, total Chl and carotenoid content, activities of NR and CA , leaf-N, -P, -K and -Ca contents and nodule-N and leghemoglobin content, respectively were analyzed at 60, 90 and 120 DAS. Photosynthesis was measured only at 90 DAS. Yield attributes including number of pods/plant, number of seeds/pod, 100-seed weight and seed yield/plant were recorded at harvest (150 DAS). Protein and carbohydrate content as well as tyrosinase activity in hyacinth bean seeds were also determined. Among the five accessions, EC-497619 (A_4) showed superior performance over the rest of the accessions. Accession A_4 showed the highest values for growth, yield, physiological, biochemical and quality attributes in comparison to the other accessions. P_N, *gs* and transpiration rate were found maximum in the A_4 accession. Chl and carotenoid content were also reported higher in accession A_4. Accession A_4 showed higher NR and CA activities than the other accessions. Nodule-N and leghemoglobin content ranged from 5.267-5.314% and 0.110-0.130 mM, respectively. Mineral profiles, viz. N, P, K and Ca content varied from 3.610-3.643, 0.338-0.356, 3.020-3.124 and 1.764-1.804%, respectively. Seed-protein of all accessions varied from 24.70-25.06%. Carbohydrate content ranged from 50.83-53.16% across all accessions tested. Accession A_4 produced the highest tyrosinase activity in the seeds.

Keeping the importance for hyacinth bean as a bio-functional medicinal legume, Naeem *et al.* (2009c), designed another pot experiment to determine whether Ca application through soil could enhance hyacinth bean production, nitrogen fixation, photosynthesis, enzymatic activities, nutraceuticals and quality attributes for this legume. The plants were grown in pots containing soil and supplied with five levels of Ca, viz. 0, 40, 80, 120 and 160 mg Ca/kg soil applied as $CaCl_2$. The performance of the crop was assessed in terms of various growth, physiological, biochemical, yield and quality attributes at 60, 90, 120 and 150 DAS. Ca application proved to be significantly effective on most of the parameters studied. Of the five levels, Ca at 120 mg/kg soil showed the best results, significantly stimulating most of the attributes studied at 60, 90, 120 and 150 DAS. In fact, this level of Ca increased seed yield, seed-protein content and tyrosinase activity by 30.3, 16.6 and 20.3%, respectively, compared to control plants. Thus, it was concluded that this need for Ca by hyacinth bean should be included as a fertilizer recommendation for this region.

P deficiency causes a serious yield and quality constraint of beans at Aligarh, Western Uttar Pradesh, India. To address the problem, Naeem *et al.* (2010b) conducted a pot experiment to study the effect of basal P application on the agricultural performance of this medicinal legume. The plants were grown in pots containing soil supplied with five levels of P viz. 0, 25, 50, 75 and 100 mg P/kg soil as potassium dihydrogen orthophosphate (KH_2PO_4). The growth and other physiological attributes, leaf nutrient contents, nodule-N and leghemoglobin content were studied at 60, 90 and 120 DAS, photosynthesis and other related parameters were measured at 90 DAS and yield and quality attributes were recorded at harvest (150 DAS). NR and CA activities, leaf-N, -P, -K and -Ca contents and nodule-N and leghemoglobin contents reached the maximum extent at 60 DAS. At 90 and 120 DAS, the values decreased significantly. Chl content, carotenoids content, and photosynthesis were at maximum level at 90 DAS. At various growth stages, P application at 75 mg P/kg soil resulted in maximum amelioration of most of the parameters studied. It increased the seed yield by 38.3%, seed-protein content by 14.9% and seed-carbohydrate content by 5.0%, relative to the control. It was concluded that there was a hidden hunger of hyacinth bean for P owing to soil-P deficiency that was ameliorated effectively by its basal dressing at 75 mg P/kg soil.

HORSE GRAM (*MACROTYLOMA UNIFLORUM* SYN. *DOLICHOS BIFLORUS* L.)

The seeds of horse gram (*Macrotyloma uniflorum* syn. *Dolichos biflorus* L.) contain *myo*-inositol, which is used in potential panic disorder treatment. It is also used as a vegetable in India and is known as the poor man's pulse crop in southern India. It also possesses slow digestible starch, which is considered to have low postprandial glucose response when consumed by diabetic patients (Bravo *et al.* 1998). In addition to that, the cooking liquor of the horse gram seeds with spices is considered to be a potential remedy for the common cold, throat infection and fever and the soup made from the seeds of this plant is said to generate heat and help dilute renal stones. It contains isoflavone diglycoside (Mitra *et al.* 1983). Its seeds are increasingly consumed as human food, the beneficial effects of its bioactive compounds yet remaining unexplored (Morris 2003, 2008).

Choudhary and Singh (1994) studied the effect of N, P and Zn on yield of horse gram. The treatments comprised of three levels each of N (0, 10 and 20 kg/ha) and P (0, 8.8 and 17.6 kg/ha) and 2 levels of Zn (0 and 4.1 kg/ha). Application of P up to 8.8 kg/ha increased the seed yield significantly. Number of pods/plant, pod length and number of seeds/pod showed a similar trend. The maturity of crop decreased significantly by 5-6 days at 17.6 kg P/ha compared with the control.

KASONDI (*CASSIA OCCIDENTALIS* L.)

Kasondi (*Cassia occidentalis* L.) is a diffused shrub and serves as a good green manure. Its roots, leaves, flowers, and seeds have been employed in herbal medicine around the world. Its root bark serves as a quinine substitute and is used to treat gonorrhoea. The crushed leaves are used in a poultice as an anti-inflammatory agent, and the crushed fresh leaves are taken internally to expel intestinal worms and parasites (The Wealth of India 1992). In many countries around the world, the fresh and/or dried leaves are crushed or brewed into a tea and applied externally for skin disorders, wounds, skin fungus, parasitic skin diseases, abscesses, and as a topical analgesic and anti-inflammatory natural medicine. Undried seeds are considered poisonous, purgative and are used to treat ringworm (Duke 1986; Panda 2004).

Wasiuddin *et al.* (1982) conducted a field experiment to study the effect of four levels of basal N, viz. 0, 10, 20 and 30 kg N/ha and four levels of P, viz. 0, 20, 30 and 40 kg P_2O_5 (equivalent to 0, 8.7, 13.1 and 17.5 kg P, respectively)/ha on the root growth, shoot growth and seed yield of the medicinal crop. Application of 30 kg each of N and P was optimum for the improved growth and yield of this important medicinal plant.

Hussein (2003) investigated the effect of N, P and K fertilizers, using various fertilizer-ratios, viz. 1:1:1 (6% N – 6% P_2O_5 – 6% K_2O), 2:1:1 (12% N – 6% P_2O_5 – 6% K_2O) or 3:1:1 (18% N – 6% P_2O_5 – 6% K_2O) along with five soil amendment strategies (taffla, clay, composted sewage sludge, cattle manure or Agrosil) on the growth and chemical composition of the medicinal herb. The total amount of fertilizers was applied at 5 g/plant/month. All the fertilizer treatments significantly increased the plant vegetative growth (plant height, stem diameter, number of branches and leaves/plant, fresh and dry weight of leaves and stems and roots/plant). N, P and K fertilizers applied at 3:1:1 fertilizer-ratio gave the best results. In general, the application of amendments to the soil significantly improved the plant growth parameters. The N, P and K fertilizer treatments along with soil amendments increased the contents of total Chl, total carbohydrates and N, P and K in the leaves. Raising the N level in the fertilizer-ratio increased the contents of total Chl, total carbohydrates and N with a concomitant decrease in the percent contents of P and K. The P percentage was different in respect with soil amendments in the 2 seasons. It was concluded that for the best vegetative growth of the crop, growing in a sandy soil, the soil should be amended with clay and the plant should be supplied with 5 g of fertilizer/plant/month in the fertilizer-ratio of 3:1:1 (N: P: K).

LUCERNE (*MEDICAGO SATIVA* L.)

Leaves of lucerne (*Medicago sativa* L.), either fresh or dried, have traditionally been used as a nutritive tonic to stimulate the appetite and promote the weight gain (Foster and Duke 1990). The plant has an oestrogenic action and could prove useful in treating problems related to menstruation and menopause (Chevallier 1996). It is used as antiscorbutic, aperient, diuretic, oxytocic, haemostatic, nutritive, stimulant and tonic (Duke and Ayensu 1985). The plant is taken internally for debility in convalescence or anaemia, haemorrhage, menopausal complaints, pre-menstrual tension, fibroids, etc. The leaves can be used fresh or dried (Bown 1996). The leaves are rich in vitamin K which is used medicinally to encourage the clotting of blood. The plant is grown commercially as a source of chlorophyll and carotene, both of which have proven health benefits. The leaves also contain the anti-oxidant tricin. The root is febrifuge and is prescribed as remedy in the cases of highly coloured urine (Duke and Ayensu 1985).

Pijnenborg *et al.* (1990) conducted an experiment on *Medicago sativa* cv. 'Resis' to study the effect of Ca on the nodulation using EGTA, a specific calcium chelator used at Wageningen (The Netherlands). It was observed that Ca, given at 0.2 mM in the form of $CaCl_2$, improved the number of nodules. In the absence of Ca, the number of nodules decreased by 70%. A similar decrease in nodule number was observed with the application of 0.2 mM Ca along with 0.2 mM EGTA. However, nodulation was restored by the addition of a higher dose of Ca, i.e. 0.8 M $CaCl_2$ to the 0.2 mM Ca solution containing 0.4 EGTA. It was concluded that the depletion of soil Ca could depress nodulation only during the first day after inoculation and that Ca had different modes of action in the symbiotic process during the initiation and formation of the nodules.

Pijnenborg and Lie (1990) studied the effect of lime pelleting on the nodulation of lucerne in an acid soil. This comparative study was carried out in the field, in pots and in rhizotrons at Wageningen (The Netherlands). The seeds were either inoculated with *Rhizobium meliloti* (R) or inoculated and pelleted with lime (RP). It was observed that in the field conditions, lime-pelleting (PR) was superior to inoculation (R) with regard to seedling establishment and N yield. The number of seedlings, carrying crown nodules, increased from 18% (R) to 56% (PR) at 26 days after sowing. Like that in the field conditions, in pots and rhizotrons also, lime-pelleting increased crown nodulation. In pots, the increase ranged from 32% (R) to 60% (PR) and in rhizotrons from 5% (R) to 90% (PR). It was concluded that crown nodulation might be used to quantify the benefits of lime-pelleting.

Grewal and Williams (2003) conducted a field experiment in Australia to investigate the cultivar variation in lucerne with respect to soil acidity and lime application. Ten cultivars of lucerne (Hunter River, Hunter field, Seeptre, Aurora, Genesis, Aquarius, Venus, PL 90, PL 55 and Breeding Line Y 8804) were tested at two levels of lime (0 and 2 tons/ha). Lime application significantly increased the root growth, nodulation, leaf retention, leaf to stem ratio, herbage yield, crude protein content and element composition of lucerne shoots. Liming also improved the Ca concentrations of shoots, while there was a little effect of liming on P and Zn concentration of alfalfa shoots. The effect of lime application was greater on 'Y 8804' and 'Aurora' cultivars; however their yield increased by 32 and 31%, respectively. The yield increase was 11-22% in the case of other cultivars.

Patel and Kotecha (2006) conducted a field experiment in well-drained sandy loam soil during the winter, summer and rainy seasons of 2003-04, to study the nutritional requirement of major nutrients (P and K) for lucerne varieties 'GAUL 1' and 'AL 3'. Application of 75 kg P_2O_5/ha along with 300 kg K_2O/ha to lucerne variety 'AL 3' recorded the highest dry-matter yield and maximum uptake of N, P and K; whereas, the highest crude-protein yield and the maximum uptake of N and K were obtained with combined application of 75 kg P_2O_5/ha and 300 kg K_2O/ha in variety 'GAUL 1'. Application of 50 kg P_2O_5 + 300 kg K_2O/ha to 'GAUL 1' showed the maximum net return and net incremental cost: benefit ratio, followed by the application of 75 kg P_2O_5/ha + 300 kg K_2O/ha to var. 'AL 3'.

MUNG BEAN (*VIGNA RADIATA* L.)

Mung bean (*Vigna radiata* L.) is used medicinally in the form of a decoction in the treatment of dysentery, diarrhoea, cystitis, paralysis, piles, rheumatism and affections of the liver and nervous system. Externally, a poultice of the seeds is applied in gastritis, dysentery and rheumatism. It possesses detoxicant, heat dispersing, diuretic and hypolipemic properties. The most common traditional uses of mung bean include heat rash, prickly heat, summer heat syndrome (restlessness, irritability, thirst, etc.), heatstroke, food and drug poisoning and "toxic" conditions (erysipelas, carbuncles, boils, swellings, sores, etc.). Although mung bean is a common food in China, it is often consumed with therapeutic intentions (Duke 1981; Phillips 1993).

Tariq *et al.* (2001) determined the effect of P and K application on growth and yield of mung bean in a sandy clay loam soil under irrigated conditions of Faisalabad. Application of P and K significantly increased the plant height, number of branches/plant, number of pods/plant, number of seeds/pod, 1000-seed weight and grain yield. Application of P_2O_5 and K_2O each at 70 kg/ha along with N application at 30 kg/ha produced the highest grain yield of 876.32 kg /ha.

Naeem *et al.* (2005) conducted a pot experiment to study the effect of four levels of Ca (0, 15, 30 and 45 kg Ca/ha) on *Vigna radiata* L. Wilczek. Observations were recorded on fresh and dry weights/plant, number and dry weight of nodules/plant, nodule-N content and total Chl and carotenoids contents. Among the four levels of Ca, 45 kg Ca/ha proved the best for all the parameters studied. The application of Ca (45 kg Ca/ha) significantly enhanced fresh and dry weights, number and dry weight of nodules/ plant, nodule-N content, total Chl content and total carotenoids content over the respective controls.

Shah *et al.* (2006) evaluated a field experiment to compare the relative efficacy of broadcast, banding and fertigation technique using four levels of P (0, 40, 80 and 120 kg P_2O_5/ha) for improving P use efficiency in mung bean. They reported that the response to P applied through fertigation was more pronounced as compared to broadcast and banding method. They recorded significant highest mung bean yield, P uptake, P recoveries and agronomic efficiency with fertigation and the lowest with broadcast method. The low rate of P application resulted in a relatively higher P recovery and agronomic efficiency compared to higher rate of P application by either method.

Bhuiyan *et al.* (2008) conducted a pot experiment during *kharif*, 2005 at the Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. There were four levels of P (0, 20, 40, 60 kg/ha) and 2 levels of molybdenum (Mo) (1.0 and 1.5 kg/ha) having a common *Rhizobium* inoculant, one control with no *Rhizobium* or fertilization and a *Rhizobium* inoculation only were applied. The performance of *Rhizobium* inoculant alone was superior to control in almost all parameters of the crop studied. They reported that *Rhizobium* inoculation along with P and Mo significantly increased the growth of plants, number of nodules, dry matter production as well as grain yield of mung bean significantly compared to uninoculated control. Nodulation (nodule number/plant) was the highest with 20 kg P/ha and 1.0 kg Mo/ha. However, P and Mo application at the rate of 40 kg P/ha and 1.0 kg Mo/ha progressively and significantly increased dry matter content of shoot and root of mung bean. Seed yield/plant was positively correlated (R^2 = 0.651) with the number of nodules/ plant.

Ali *et al.* (2010) conducted field experiments under Adaptive Research Station at Mianwali, to evaluate the influence of three levels of phosphatic fertilizer on mung bean for two consecutive *kharif* seasons i.e. 2007 and 2008. The experiment comprised of four treatments viz., control, phosphatic fertilizer at 30 kg/ha with started dose of N, phosphatic fertilizer at 57 kg/ha and phosphatic fertilizer at 84 kg/ha. Their results revealed that all the levels of phosphatic fertilizer showed significant impact on mung bean compared to that of control plots. However, treatment of phosphatic fertilizer at 84 kg/ha out yielded rest of the treatments giving the maximum yield components and grain yield during both years.

Sadeghipour *et al.* (2010) conducted a field experiment in Iran in 2009 to investigate the effect of different N and P levels on seed yield and yield components of mung bean var. 'Partowa'. Five levels of N (0, 30, 60, 90 and 120 kg N/ha) and six levels of P (0, 30, 60, 90, 120 and 150 kg P_2O_5/ha) were the treatment variables. Application of N and P fertilizers significantly increased the seed yield. The maximum seed yield (224.2 g m^{-2}) was obtained when 90 kg N and

120 kg P_2O_5/ha was applied. It was reported that the sustained increase in seed yield was mainly due to higher number of pods/plant, number of seeds/pod and 1000-seed weight. Thus, application of 90 kg N and 120 kg P_2O_5/ha appeared to be the optimum N and P levels for harvesting the highest yield of mung bean.

SENNA (*CASSIA ANGUSTIFOLIA* VAHL.)

Cassia angustifolia Vahl. (syn. *C. medicinalis* Bisch, *C. lanceolata* Wall.), commonly also known as sennai, is commercially employed in various tonic and laxative preparations (Agarwal 1986). The plant is useful in constipation, loss of appetite, liver complaints, abdominal troubles, jaundice, anemia, leprosy and tumours (Kirtikar and Basu 1987; The Wealth of India 1992).

Kalyanasundram (1981) studied the effect of four levels of N (0, 25, 50 and 75 kg N)/ha and four levels of P, viz. 0, 50, 100 and 150 kg P_2O_5 (equivalent to 0, 21.8, 43.6 and 65.5 kg P, respectively)/ha on Tinnevelly senna. Half of the N and entire P were given as the basal doses and the remaining half dose of N was top dressed prior to flower initiation i.e., 30 days after sowing. The parameters, studied were green yield of leaflets, dry yield of leaflets, sennoside percentage and total yield. Application of 50 kg N/ha increased the dry yield of leaflets by 50% and sennoside yield by 44% compared with the control. Application of P, however, had a slight beneficial effect on sennoside yield only. The interaction effect between N and P was non-significant for all the parameters studied.

Pareek *et al.* (1983) conducted three field experiments to study the effect of different levels of plant densities, N (0, 50, 100 and 150 kg/ha) and P (0, 50, 100, 150 and 200 kg/ha) on senna. An increase in N level from 50 to 100 kg/ha resulted in 9.2, 3.9, 13.9, 4.2 and 5.4% increase in plant height, number of branches, number of pods/plant, leaf yield and pod yield, respectively. A slight improvement in sennosides content of leaves and pods was noted at all the levels of N. P exerted significant effect on plant height, number of pods/plant and dry leaves of the plant. However, P showed a slight improvement on sennoside content of leaves and pods, with the results being non-significant. In another experiment, Ilangovan *et al.* (1990) reported that similar effect of three levels of spacing, N and P on growth parameters of this medicinal crop.

Ramamoorthy *et al.* (2003) conducted an experiment with senna cv. 'Tirunelvely Local' during the *rabi* seasons of 1997 and 1998 under irrigated condition. The main plot treatments included a control and farmyard manure (FYM) application at 12.5 tonnes/ha. The subplot treatments comprised of 3 fertilizer levels, viz. 35:25:40, 50:25:40 and 65:25:40 kg N:P:K/ha. Within the subplots, spacing treatments (35×30, 45×30 and 60×30 cm) were introduced. Application of FYM in combination with a fertilizer level of 60:25:40 kg N:P:K/ha and a spacing of 45×30 cm was recommended for enhanced herbage yield, pod-yield, seed yield, and germination percentage.

Arshi *et al.* (2005) conducted pot experiments to study the growth, photosynthetic capacity, sennoside concentration and yield attributes of senna under the individual as well as combined influence of NaCl and $CaCl_2$. Six treatments, viz. 80 and 160 mM of NaCl, 5 and 10 mM of $CaCl_2$ alone and a combination of NaCl + $CaCl_2$ (80 + 10 and 160 + 10 mM) were given to the growing senna plants at pre-flowering (45 DAS), flowering (75 DAS) and post-flowering (90 DAS) stages. As a result of NaCl treatments, significant reductions were observed in pod biomass, leaf area, P_N, *g*s, sennoside concentration and seed yield. On the contrary, individual $CaCl_2$ treatments showed the favourable effect. Under the effect of combination treatments, although these parameters were reduced, the extent of reduction was much less than the one caused by NaCl treatments without $CaCl_2$. The combined treatments thus mitigated the adverse effects caused by NaCl.

SENNA SOPHERA (*CASSIA SOPHERA* L.)

Senna sophera (*Cassia sophera* L.) is used as expectorant, depurative and alterative; its decoction is used as an expectorant in acute bronchitis. The leaves possess purgative properties. An application of paste of leaves and root bark is a useful in skin diseases like ringworm, ulcers etc. (The Wealth of India 1992). The cathartic seeds of crop are used as a febrifuge; they are administered in diabetes too (Dastur 1977; Kirtikar and Basu 1987). The roots are considered diuretic. A paste of the roots is sometimes a substituted for the leaf-juice in ringworm. The bark, like the leaves and seeds is cathartic in action. Its infusion is considered useful in diabetes, its juice is used in asthma and its honey is administered in diabetes. A paste made of the seeds with S is applied in skin diseases (The Wealth of India 1992).

Naeem *et al.* (2009d) conducted a pot experiment according to simple randomised design, to find out the performance of senna sophera under five basal levels of P (0, 25, 50, 75 and 100 mg P/kg soil). The basal dressing of P proved beneficial for most of the parameters studied at 120, 150, 180 and 210 DAS, with 75 mg P/kg soil proving best. Application of this treatment, for example, gave 20.4% higher P_N at 150 DAS, 16.7% higher CA activity and 15.6% higher NR activity at 120 DAS, and 24.5% higher seed yield and 13.6 % higher seed-protein content at 210 DAS than the no P control.

In view of the medicinal importance of the crop a hypothesis was designed to determine whether Ca application through soil could enhance the photosynthetic efficiency, enzymatic activities, N assimilation, yield and quality attributes (Naeem *et al.* 2009e). The plants were grown in pots containing soil supplied with five levels of Ca, viz. 0, 40, 80, 120 and 160 mg Ca/kg soil (Ca_0, Ca_1, Ca_2, Ca_3 and Ca_4, respectively) applied as $CaCl_2$. The performance of the crop was assessed in terms of various growth, physiological, biochemical, yield and quality attributes at 120, 150, 180 and 210 DAS. Ca application proved significantly effective on most of the attributes studied. Of the five Ca levels, Ca_3 showed the best results that significantly stimulated most of the attributes studied at the three growth stages.

SOYBEAN (*GLYCINE MAX* L.)

Soybean (*Glycine max* L.) is used in the treatment of colds, fevers and headaches, insomnia, irritability and in a stuffy sensation in the chest (Yeung 1985). The bruised leaves are applied to snakebite (Duke and Ayensu 1985). The flowers are used in the treatment of blindness and opacity of the cornea. The ashes of the stems are applied to granular haemorrhoids or fungus growths on the anus. The immature seedpods are chewed to a pulp and applied to corneal and smallpox ulcers. The seed is antidote and is considered to be specific for the healthy functioning of bowels, heart, kidney, liver and stomach (Duke 1983; Duke and Ayensu 1985). The seed sprouts are constructive, laxative and resolvent. They are used in the treatment of edema, dysuria, chest fullness, decreased perspiration, the initial stages of flu and arthralgia. A decoction of the bark or root is astringent. Commercial grades of natural lecithin, which are often derived from soybean, are reported as a lipotropic agent (Duke 1983). Isoflavones from soybeans have more recently been suggested to reduce the risks of cancer and to lower serum cholesterol (Kennedy 1995; Molteni *et al.* 1995). Soybean and soyfood phytoestrogens have been suggested as possible alternatives to hormone replacement therapy for postmenopausal women.

Dadson and Acquaah (1984) conducted an experiment to study the effect of 3 levels of N (40, 80 and 160 kg N/ha), 3 levels of P (30, 60 and 90 kg P/ha) and seed inoculation on nodulation, symbiotic nitrogen fixation and yield of soybean. N and P were applied in the form of urea and triple superphosphate. Application of N and P significantly increased plant height, number of nodules and number of pods/plant, leaf area index, total dry matter/plant, grain yield and seed weight. Low rates of N and medium to high rates of P promoted nodule number, dry weight and leg-haemoglobin content.

Bell *et al.* (1989) studied the effect of Ca on five tropical food legumes, *viz*. peanut (*Arachis hypogea* (L) cv. 'Red Spanish'), pigeonpea (*Cajanus cajan* (L). Millsp. cv. 'Royes'), guar (*Cyamopsis tetragonoloba* (L.) Taub. cv. 'Brooks'), soybean (*Glycine max* (L.) Merr. cv. 'Fitzroy') and cowpea (*Vigna unguiculata* (L.) Walp. cv. 'Vita 4' and 'CPI 28215'). They applied six levels of Ca (2, 12, 50, 100, 500 and 2500 μM) in the flowing solution culture at pH 5.5 ± 0.1 with adequate inorganic N and controlled-based nutrient concentrations. Increase in solution of Ca concentration from 2 to 12 μM generally increased the rate of absorption of N, P and K. Further increases in Ca concentration from 12 to 2500 μM generally had no effect on K absorption rate, but it further increased the absorption rates of N (by 20-130%) and P (by 90-500%). The increases in nutrient absorption and transport rates were associated with the alleviation of severe Ca deficiency. Further increases in solution Ca concentration from 12 to 2500 microM generally had no effect on K absorption rate, but increased absorption rates of N (by 20-130%), and P (by 90-500%), and decreased those of Mn and Zn; it also decreased rates of transport of Fe and Mg to plant tops. Ca was too low to maintain adequate concentrations of P in plant tops for maximum growth.

Keiser and Mullen (1993) studied the response of soybean to Ca and relative humidity. Plants were grown in solution culture in a controlled environment growth chamber applying various Ca concentrations (0, 0.6, 1.2 and 2.5 mM) to the root medium from beginning seed growth stage (R_5) to beginning seed maturity stage (R_7). Seed-Ca concentration increased with increased Ca supply to the plant. Relative humidity had no effect on either seed Ca concentration or germination. A decrease in the percentage of normal stand of seedlings from 96.7 to 41.8% coincided with a decrease in seed-Ca content from 2.37 to 0.87 mg/g. Reduced Ca-supply to the plant reduced the seed-Ca concentration in addition to altering other seed nutrients. Reduced Ca concentration was associated with poorer seed germination. It was concluded that further studies were needed to clarify the role of Ca and other nutrients in the germination of seed and seedling establishment.

Sharma *et al.* (2002) carried out a field experiment on soybean to study the effect of three P levels, viz. 30, 60 and 90 kg P_2O_5 (equivalent to 13.1, 17.5 and 21.8 kg P, respectively)/ha in combination with or without FYM. P application significantly enhanced growth determinants and seed yield of the crop. Application of 60 kg P_2O_5/ha significantly improved the number of nodules/plant, weight of nodules/plant, dry matter accumulation (DMA)/plant and seed yield over the control.

Gautum *et al.* (2003) conducted a field experiment to study the effect of P rates (13.2, 19.8 and 26.4 kg P/ha), seed inoculation with *Pseudomonas* sp. and *Bradyrhizobium* and farmyard manure (1 ton/ha) on the seed yield and yield attributes of soybean. The yield attributes, viz. number of seeds/plant, pod length, number of pods and pod dry weight, differed significantly due to different treatments. Seed yield also increased (22.2-34.2%) significantly owing to variation in applied P treatments.

Fatima *et al.* (2006) conducted a pot experiment to evaluate the effect of three strains of *Rhizobium leguminosarum* (TAL-377, TAL-379 and TAL-102) alone and in combination with P on soybean. The parameters studied were survival of *Rhizobium* at pod filling stage and after harvesting, and root/shoot dry and fresh weight of soybean under natural condition. Surface sterilized soybean seeds var. NARC-4 were sown in earthen pots filled with a mixture of soil and sand 1:3. P (8 g/pot) was applied to the soil as SSP at the time of sowing. Soybean seeds were inoculated with the *Rhizobium* strains as seed-coating just before sowing. The combined effect of *Rhizobium* inoculums and P on was highly significant on plant growth resulting into an increase in root/shoot dry and fresh weight of plant. Among the three *Rhizobium* strains, TAL-102 performed better as compared to TAL-377 and TAL-379. It was concluded that a mixture of effective *Rhizobium* strains with P application is promising for enhancing the growth of soybean.

Lone *et al.* (2009) performed a field experiment at Shalimar Campus during *kharif* season of 2004 and 2005 in a silty clay loam soil, medium in available N and K and low in available P, to study the response of soybean to seed rate, row spacing and fertility (N:P:K) levels under temperate conditions. There were 27 treatment combinations viz., 3 levels each of seed rate (40, 60 and 80 kg/ha), row spacing (30, 45 and 60 cm) and fertility (40: 60: 40, 60: 90: 60 and 80: 120: 80 of N: P_2O_5: K_2O kg/ha). Application of N: P: K at 80: 120: 80 significantly improved the growth parameters viz., plant height, leaf are index, number of nodules/plant, fresh nodule weight and dry matter accumulation. Uptake of both N and P were increased with increase in fertility levels. The highest fertility level of N: P: K (80: 120: 80) gave significantly more protein and oil content than the control.

CONCLUSION

The genetic makeup of a plant is primarily responsible for its growth, development and yield. The productivity as well as quality of a crop is, however, also controlled by environmental factors. Of which, the uptake and utilization of mineral nutrients from the soil, or by the fertilizers applied to the plants, is of prime importance. Over the last 30 years, additional nutrients applied as fertilizers have been responsible for 55% increase in the yield in the developing countries (FAO 1998). There is thus an urgency to give special emphasis and clearly the policies in order to ensure the conservation, cultivation, processing, preservation and maintenance of quality control standards of the medicinal plants for their smooth rise in the national and international markets. Out of these useful steps and policies regarding sustenance of medicinal plants, their cultivation on scientific lines appears to be extraordinarily effective so as to obtain authentic, standard and fresh herbal materials. This would be a safeguard against unauthentic, spurious, denatured, fake and soiled products of these plants.

Generally legumes require high amount of P and Ca for their growth, nodule formation and N_2-fixation. Hence, intensive research efforts should be expanded for maximizing the yield of potentially useful leguminous medicinal plants particularly through optimal supply of required fertilizers, since natural the products of medicinally important leguminous plan have been and will continue to be important sources and models of forage, gums, insecticides, phytochemicals, and other industrial, medicinal, and agricultural raw materials.

Additionally, the efficient absorption and utilization of the nutrients is also highly desirable to ensure the full exploitation of the genetic potential of these plants. Understandably, this has proved a highly successful technique for profitable cultivation of a number of crop plants.

Each essential nutrient element plays a specific role in the metabolism of the organisms. Major essential elements, viz. N, P, K and Ca, are considered and especially in this regard as they are removed by most of the crops in relatively much larger quantities. In most of the studies, the macronutrients have been shown to ameliorate the growth and productivity of various medicinal plants, recommending their optimum dose for maximum production of the medicinal crops. This indicates that bumper agricultural yields of these crops depend strongly on the adequate application of the mineral nutrients.

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