REVIEW OF LITERATURE

For boosting crop production, nutrient balance in the soil is the key component. Agriculturists have been focusing their attention towards the efficient and judicious utilization of available resources to increase the total productivity and profitability per unit area to meet out the food and other demands of ever increasing population. The exploitative agriculture for centuries in our country has brought down the fertility status of the soil to a level that even the application of fertilizers at higher rates is not able to sustain the productivity of soil. Therefore, in order to sustain the productivity and promote the health of the soil combined use of organic and chemical fertilizers is imperative, that's why, it is well experienced and documented now particularly under intensive cultivation. There is hardly any soil on earth provided so adequately with nutrients, that high yield can be obtained over prolonged period without any fertilization. It is, therefore, necessary to replenish the soil with balanced fertilization. Chemical fertilizers play a major role to increase crop yields. On one hand chemical fertilizers alone do not provide all the nutrients in balanced quantities needed by the plants and on the other hand encourage depletion of soil organic matter content, adversely effect biological and physical properties of soil, also their increasing prices, soil health deterioration, sustainability and pollution consideration in general have led to renewed interest in the use of organic manures. Use of organic manure not only helps to sustain crop yields but also plays a key role by exhibiting both direct as well as indirect influence on the
nutrient availability in soil by improving the physical, chemical and biological properties of soil and also improve the use efficiency of applied fertilizers (Singh and Biswas, 2000). Organic manures though have all the essential elements present, but are in small quantities. They are bulky in nature and release nutrients slowly. During decomposition, organic manures also release some growth promoting substances, which bring about favourable changes in soil ecosystem. In coming decades, a major issue in designing sustainable agricultural system will be the management of soil organic matter and the rational use of organic inputs such as animal manures, crop residues, green manures, sewage, sludge and food industry wastes. These organic manures being slow in release of nutrients, assume greater significance in a cropping sequence than individual crops and their usefulness needs to be investigated. Interaction of nutrients in soil, with organic manure and plant is an important factor in determining the yield of various crops. However, it is not possible to supply all the nutrient requirements of crops wholly through organic manures. Since organic manures cannot meet the total nutrient needs of the modern agriculture, integrated use of nutrients from fertilizers and organic sources seems to be need of the time.

Soil contains an array of microorganism, some of them are beneficial like nitrogen fixers, phosphate solublizers, plant growth promoting rhizobacteria etc and some are harmful to plant growth like cyanide producing DRMO (Deleterious rhizosphere microorganism) and other disease causing microorganisms. The beneficial effects of microorganisms such as Rhizobium are clearly recognized and these organisms are extensively used as plant inoculants (Saxena and Tilak, 1994). The legume-Rhizobium symbiosis is now the most
widely managed agricultural system for biological nitrogen fixation. Inoculation of legumes with exotic strains of *rhizobia* is a common agricultural practice intended to promote nitrogen fixation and increase crop yield (Jensen, 1987). Nitrogen fertilizers with *Rhizobium* inoculation have the direct impact on various growth and yield attributes in pea.

The basic concept underlying the INM, nevertheless is the maintaince and improvement of soil fertility for sustained crop productivity on long term basis and also to reduce fertilizer input cost. Tandon (1994) stated that different components of INM possesses great diversity in terms of chemical and physical properties and nutrient release patterns which can effectively be made use to meet the nutrient needs of agriculture. The degradation of soil fertility owing to over-mining of nutrients and inadequate replenishment through fertilizers can only be curbed through adoption of INM (Paroda, 1998).

So by taking into consideration the above facts, integrated plant nutrient management system has been developed in relation to garden pea based cropping system. Thus, an attempt has been made to review the present literature both from India and abroad associated with the research investigation on “Studies on integrated nutrient management (INM) in garden pea based cropping systems under dry temperate high hill conditions” in this chapter under the following heads:

2.1 Effect of organic manures on

2.1.1 Growth, yield attributes and yield

2.1.2 Soil physical and chemical properties

2.1.3 Nutrient accumulation and nutrient uptake
2.1.4 Quality parameters
2.1.5 Economics/Cost benefit analysis

2.2 Effect of chemical fertilizers on
2.2.1 Growth, yield attributes and yield
2.2.2 Soil physical and chemical properties
2.2.3 Nutrient accumulation and nutrient uptake
2.2.4 Quality parameters
2.2.5 Economics/Cost benefit analysis

2.3 Combined effect of organic manures and chemical fertilizers on
2.3.1 Growth, yield attributes and yield
2.3.2 Soil physical and chemical properties
2.3.3 Nutrient accumulation and nutrient uptake
2.3.4 Quality parameters
2.3.5 Economics/Cost benefit analysis

2.4 Residual effects of organic manures and chemical fertilizers

2.1 Effect of organic manures

2.1.1 Growth, yield attributes and yield

According to the study conducted by Kanaujia et al. (1997) at Nauni (H.P.) pea seed inoculation with Rhizobium culture attributed to higher number of nodules/plant at all the stages (45, 90 and 135 days after sowing) of plant growth, and this increase in nodulation and nitrogen fixation due to the inoculation led to significantly more plant height, days taken to flowering, higher green pod yield and dry matter over uninoculated control.
Patel and Meisheri (1997) conducted a field experiment at Anand (Gujarat) and concluded that FYM application @ 10 and 20 tonnes/ha significantly increased the plant height, secondary branches/plant, siliquae/plant, seeds/siliquae, 1000-seed weight seed and stover yields and these were higher under F_{20} followed by F_{10} as compared to control F_0.

Patel and Shelke (1998) while working with Indian mustard (*Brassica juncea*) at Parbhani (Maharashtra) observed that farmyard manure had a significant effect on the growth and yield components.

Salroo *et al.* (2002) carried out a field experiment at Jammu and Kashmir on brown sarson and found that crop residue incorporation with application of additional 10 kg N ha^{-1} had beneficial effect on seed yield of the crop.

The pea plant inoculated with *rhizobium leguminosarum* were superior in terms of plant height, number of pods/plant, number of grains/pod and yield than the non-inoculated plants (Asghar *et al.*, 2003).

Similarly, Bahadur *et al.* (2006) observed a significant increase in number of nodule/plant in pea crop, when organic amendments and bio-fertilizers are applied in combination.

Negi *et al.* (2006) evaluated the effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea *var. Lincoln* in acidic soils of Garhwal hills. The results revealed that the composite inoculation of *rhizobium leguminosarum* and *pseudomonas striata* significantly increased plant height by 71.43 per cent, nodules/plant, number of pods/plant, pod length by 20.27 per cent and green pod yield by 52.04 per cent over no inoculation.
Rana et al. (2006) assessed the effect of *rhizobium* culture in combination with organic and chemical fertilizers on rajmash (*Phaseolus vulgaris*) under dry temperate conditions of Himachal Pradesh and observed taller plants, higher number of pods/plant, more grains/pod, more nodules/plant and higher straw yield in rajmash at 1t FYM/ha and it was statistically at par with 5t FYM/ha. They also indicated that *rhizobium* inoculation resulted in taller plants, higher pods/plant, grains/pod, nodules/plant and straw yield over no inoculation.

2.1.2 Soil physical and chemical properties

Jarecki (1991) studied the interaction between organic and mineral fertilizers and its influence on yield quantity and quality and chemical properties of light soil recorded substantial increase in C and N with the application of FYM on potatoes, spring barley, winter rape and winter wheat.

Mankotia and Sharma (1998) at Palampur (H.P.) studied the response of gobhi sarson (*Brassica napus* subsp. *Oleifera* var. annua) + toria (*B. campestris* var. toria) to fertilizer and manure and their residual effect on maize (*Zea mays*) and observed no change in available N, while available P had increased by 5.2 kg/ha and available K by 5.4 kg/ha.

Thiyageshwari et al. (2000) during their study on changes in available phosphorus and grain yield of blackgram (*Vigna mungo*) under integrated nutrient management in inceptisol observed that due to conjunctive use of rock phosphate, vermicompost and phosphobacteria the available phosphorus was higher during the vegetative stage and then decreased at harvest due to P utilization by blackgram.
Tolanur and Badanur (2003) studied the effect of integrated use of organic manure and fertilizer N on the productivity of chickpea in vertisol of Bijapur. They concluded that integration of fertilizer N with different organics i.e. FYM, vermicompost sustains the productivity of chickpea and significantly improves the organic carbon, available N, P and K status of vertisol after harvest.

2.1.3 **Nutrient accumulation and nutrient uptake**

Rana *et al.* (2006) studied the effect of *rhizobium* culture in combination with organic and chemical fertilizers on rajmash (*Phaseolus vulgaris*) under dry temperate conditions of Himachal Pradesh and found significant increase in N, P and K uptake by grain and straw of rajmash with the increase in FYM levels from 0 to 10 tonnes/ha. Similarly, *rhizobium* inoculation treatment was found better and recorded more N, P and K uptake than no inoculation.

2.1.4 **Quality parameters**

Kanaujia *et al.* (1997) in their study at Nauni (H.P.) observed that inoculation of pea seeds with *rhizobium* increased the protein content of pea seeds.

Results of the field experiment conducted by Bahadur *et al.* (2006) on garden pea cv. Azad pea-3 in Varanasi revealed that organic amendments and bio-fertilizers significantly influenced the vitamin content and ascorbic acid (vitamin C) in pea.

2.1.5 **Economics/Cost benefit analysis**

Kanaujia *et al.* (1999) studied the response of phosphorus, potassium and *rhizobium* inoculation on pod yield and economics of pea and reported that green pod yield was significantly influenced with the application of P, K and
rhizobium inoculation during both the years. An application of 60 kg each of $P_2O_5$ and $K_2O$ along with rhizobium inoculation gave the highest yield. This treatment combination gave maximum profit of Rs. 52,657/ha.

### 2.2 Effect of chemical fertilizers

#### 2.2.1 Growth, yield attributes and yield

Taylor and White (1950) reported that the supply of nitrogen was necessary on less fertile soils. They recommended a dose of 24 lb N and 48 lb $P_2O_5$/acre (1 lb=0.4536 kg and 1 acre=0.4047 hectare).

Barak (1952) reported that the application of nitrogen increased the yield of buckwheat. Sirasawa (1953) also studied the effect of phosphorus and potash on growth and fruiting of buckwheat. He noticed increase in the height of the plant by the increase in the amount of phosphorus supply.

Leguminous crops are, generally, cultivated without the application of fertilizers especially nitrogenous, however during initial growth stages these plants depend upon the available soil nitrogen, till the symbiotic fixation system becomes efficient to meet their nitrogen requirement. Hence, an initial starter dose of 10-15 kg N/ha is considered useful, especially in soils, which are poor in nitrogen content (Mann, 1968 and Chowdhury et al., 1972).

Sokolov et al. (1971) studied the influence of N, P and K on grain yield and quality of buckwheat on a chernozem soil of low humus content. They concluded that the application of 20 to 60 kg N, 30 to 60 kg $P_2O_5$ and 30 to 60 kg $K_2O$/ha in various combinations increased the average grain yield from 1.64 to 1.95 t/ha.
Khlobnikov (1973) conducted an experiment on the effect of mineral fertilizers on buckwheat. It was observed that 45 kg N + 45 kg P₂O₅/ha combination was superior over all other combinations as it gave the highest values of leaf area index at flowering stage, grain yield and dry matter at harvest.

Mustafaev (1976) in a trial on buckwheat under rainfed conditions reported that application of 20 to 60 kg P₂O₅/ha increased the seed yield from 680 kg/ha and without phosphorus the increase was from 130 to 170 kg respectively.

Whereas, Riznichenko (1976) observed that 45 kg N + 40 kg P₂O₅ + 45 kg K₂O/ha increased the grain yield of buckwheat from 1.19 to 1.41 t/ha under rainfed conditions and upto 2.01 t/ha under irrigated conditions.

Demidenko and Nakonachnyi (1978) recorded the highest seed yield of buckwheat with 45 kg N + 60 kg P₂O₅ + 60 kg K₂O/ha and found this to be the best combination as compared to several others. However, Kusiorska (1978) found no effect on grain yield with the increase in the level of applied nitrogen from 30 kg to 90 kg/ha.

Bahadur and Singh (1990) in their study on yield and growth response of garden pea (Pisum sativum L.) to N and P₂O₅ application at Faizabad (U.P.) indicated that plant height at 30 and 45 DAS was increased significantly with increasing level of N and at 80 kg P₂O₅. Number of nodules per plant was significantly superior at 45 kg N. Application of 80 kg P₂O₅ brought tremendous increase towards nodulation. Highest dose of N significantly delayed 50% flowering. Early flowering was also observed due to highest level of phosphorus.
application. They also observed that increasing levels of nitrogen and phosphorus also caused favourable increase towards yield parameters such as number of pods/plant, length of pod, number of seeds/pod and green pod yield and maximum values of these recorded at 45 kg N/ha and with 80 kg P$_2$O$_5$.

Shekhar and Sharma (1991) during their studies on pea at Kukumseri (H.P.) observed delay in time taken for 75% flowering with increase in the level of chemical fertilizers. At the same they found increase in pod length, grains/pod, pods/plant and green pod yield with increasing dose of NPK up to N$_{60}$P$_{69.9}$K$_{66.4}$ kg/ha.

According to Negi (1992) the application of 20 kg N/ha increased pea yield up to 1.66 t/ha in 1989 to 3.32 t/ha in 1990 compared with control yields of 1.18 and 1.24 t/ha but further increment of 40 kg N/ha had no effect on yield. He further observed that nitrogen application @ 20 kg/ha significantly increased all the yield contributing characters viz. number of pods/plant and green-pod yield. Response of P was observed up to 60 kg/ha during 1989 and up to 120 kg/ha during 1990.

Kukrash et al. (1994) conducted experiment on derno-podzolcic light loam soil on buckwheat and tested combinations of 0-80 kg N, 0-90 kg P2O5 and 0-210 kg K2O/ha. The optimum rate found for buckwheat was 30 kg N + 60 kg P2O5 + 120 kg K2O/ha; this increased yield from 2.00 to 2.14 t/ha.

Das and Das (1995) conducted an experiment in the soils of Shillongani in Assam on toria (Brassica campestris) with four levels of N (0, 30, 60 and 90). They observed that application of N @ 90 kg/ha significantly
increased the plant height, primary and secondary branches/plant, siliquae/plant, seeds/siliquae, 1000-seed weight and seed yield. The magnitude of increase at 90 kg N/ha compared with 0, 30 and 60 kg N/ha was 46.9, 19.9 and 9.3% for seed yield.

Sharma (1995) conducted a field trial during 1990-91 and 1991-92 on Chinese sarson (Brassica chinensis) grown on a sandy loam soil with P levels at 30, 60 or 90 kg P₂O₅/ha and K at 30, 60 or 90 kg K₂O/ha and found that seed yield per plant and per hectare was highest with 30 kg P₂O₅ + 60 kg K₂O/ha (57.42 g and 21.34 q/ha, respectively). Phosphorus significantly improved plant height, pods/plant, seeds/pod, pod length compared with no P (Rathi et al., 1995).

Saini and Thakur (1996) in their field study during summer season of 1990 and 1991 at Leo (H.P.) concluded that an application of 30 kg N/ha and 39.6 kg P/ha significantly increased plant height, pods/plant, grains/pod and green-pod yield of pea plants compared with no N and P in both the seasons.

Ali and Zaman (1997) during their study on rapeseed (Brassica campestris) at Dhaka indicated that nitrogen application @ 120 kg N/ha gave the highest dry-matter yield.

Gurmani et al. (1997) in their studies with Sarson on different types of soil conducted at Dera Ismail Khan District found that application of 90 kg N + 40 kg P₂O₅ + 100 kg K₂O/ha was suitable for this crop.

In an experiment conducted by Kanaujia et al. (1997) at Nauni (H.P.) reported that phosphorus at 90 kg/ha to pea crop excelled plant height, days taken to first flowering nodules/plant at all the stages (45, 90 and 135 days after
sowing). But the maximum green pod yield, dry matter was obtained with the application of 60 kg P$_2$O$_5$/ha. Similarly, potassium showed pronounced effect on plant height, number of nodules/plant and maximum values were recorded at 90 kg K$_2$O/ha. Green pod yield and dry matter was increased by potassium application and the highest values were recorded with 60 kg K$_2$O/ha. Patel and Meisher (1997) at Anand (Gujarat) observed the similar findings with the application of 75 kg N/ha.

The work of Sharma et al. (1997) at Hisar on brassica species advocated that *azotobacter* inoculation and varying levels of N increased the fruiting, branches/plant, siliquae/plant, seeds/siliquae, 1000-seed weight and seed yield, and the response was found up to 60 kg N/ha for seed yield.

Patel and Shelke (1998) during their work on Indian mustard (*Brassica juncea*) at Parbhani (Maharashtra) found that phosphorus application significantly increased the plant height, branches/plant, siliquae/plant, total dry matter/plant, seeds/siliquae, 1000-seed weight up to 120 kg P$_2$O$_5$/ha.

Patel and Thakur (1998) studied the effect of N and P levels on growth, yield and quality of toria (*Brassica campestris*) under irrigated conditions at Raigarh (M.P.) and reported that application of N up to 80 kg/ha significantly increased the plant height only, whereas, branches/plant, siliquae/plant, 1000-seed weight and seed yield were recorded significantly higher at 60 kg N/ha. They also observed that 40 kg P$_2$O$_5$/ha significantly increased the siliquae/plant, 1000-seed weight and seed yield over 20 kg P$_2$O$_5$/ha.

In another study under dry temperate conditions of Himachal Pradesh Saini and Negi (1998) worked out on buckwheat crop at Leo (H.P.) and observed that 60 kg N/ha found to be the optimum dose in buckwheat.
Buttar and Aulakh (1999) also found similar effects on Indian mustard with application of N from 75 to 125 kg/ha at Bathinda, Punjab. These results are also in conformity with the findings of Baburkova et al. (1999) at Ceske Budejovice (Czech Republic).

Dubey et al. (1999) carried out a field experiment at Kukumseri in Lahaul Valley of Himachal Pradesh during summer of 1993 and 1994 on pea crop and reported that plant height, yield attributes viz. pods/plant and green pod yield of pea increased with an increase in P level up to 80 kg P$_2$O$_5$/ha.

Thakur (1999) at Kangra (H.P.) also reported a significant increase in yield attributes of Indian mustard (Brassica juncea) up to 60 kg N/ha. However, fertilizer rates exceeding the starter nitrogen dose generally inhibit nodulation and N-fixation (Zahran, 1999).

Bali et al. (2000) conducted a field experiment at Srinagar (J&K) with three levels each of N (30, 60 and 90 kg/ha) and P (30, 45 and 60 kg/ha) on brown sarson (Brassica campestris) and observed that N up to 60 kg/ha significantly increased primary and secondary branches/plant, siliquae/plant, seeds/siliquae, 1000-seed weight and seed yield, while application of P at various levels did not produce significant variation in yield and yield attributes of brown sarson. However, application of 60 kg P$_2$O$_5$/ha resulted in maximum values.

Sharma (2000) during his study at Sangla (H.P.) reported that application of nitrogen to buckwheat from 0 to 60 kg increased plant height, branches per plant, number of grains per plant, 1000-grain weight and grain yield
significantly and 40 kg P$_2$O$_5$/ha was optimum dose for buckwheat grain yield. On
an average 40 kg P$_2$O$_5$/ha registered 36.8 and 10.2 per cent higher grain yield
over 0 and 20 kg P$_2$O$_5$/ha.

Thakuria and Gogoi (2000) carried out a field experiment at Jorhat
(Assam) with buckwheat and indicated that all the growth, yield attributes and
yield increased significantly at 20, 10 and 10 kg N, P$_2$O$_5$ and K$_2$O/ha. The
increase in seed and straw yields was 29.3 and 35.7%, respectively over the
control. However, the harvest index decreased with the increasing levels of
fertilizer NPK.

Results of the field experiment conducted by Sinha et al. (2000) on pea
crop revealed that each incremental dose of phosphorus (from 45 to 75 kg/ha)
significantly increased plant height, reduce the number and days to 50%
flowering. They also observed that yield attributing traits viz. pod length,
pods/plant, seed/pod, 100-seed weight and straw yield/ha showed a remarkable
increase with the application of moderate level of P (60 kg/ha).

Bhatt et al. (2002) in temperate conditions of Kashmir, studied the
response of four levels of phosphorus (0, 30, 60 and 90 kg P$_2$O$_5$/ha) on field pea.
The results showed that application of 60 kg P$_2$O$_5$/ha enhanced the nutrient
uptake significantly.

A field experiment carried by Lapa and Tarasenko (2002) on
buckwheat at Grodno (Belarus) showed that the best results (yield of 2.35 t
buckwheat seeds/ha) were obtained using N$_{80}$P$_{60}$K$_{135}$. 
Omidbaigi and Zakizadeh (2002) evaluated the effect of three fertilizer levels on yield and growth parameters of buckwheat at Tehran (Iran). The results revealed that maximum seeds/plant (132) and grain yield (1390 kg/ha) were obtained from the plants that received 100 kg N/ha. The plant receiving 100 kg N/ha showed 97 and 124% increase in seeds/plant and grain yield /plot respectively.

Shah and Hoult (2002) while working on the yield response of buckwheat to the application of major nutrients at New South Wales, Australia accentuated that when major nutrients (N, P, K, and S) were applied at a rate of 50, 40, 50 and 50 kg/ha, respectively to buckwheat, addition of 50 kg N/ha resulted an increase of 136% in grain yield over the control. The application of K was not beneficial except when applied in combination with N and P.

Sharma and Harnam (2002) evaluated the effect of three fertilizer levels on yield and plant growth parameters of pea at Solan. The results revealed that fertilizer treatments 25 kg N + 60 kg P₂O₅ + 40 kg K₂O/ha recorded the maximum pea seed yield (11.5 q/ha), plant height, number of pods/plant, pod length and number of seeds/pod.

The effect of seed rate and NPK fertilizers on green pod production of pea cultivar Arkel at Solan (H.P.) was studied by Sharma and Singh (2002). They observed an increase in green pod yield of pea up to 45kg N/ha+90 kg P₂O₅/ha+60 kg K₂O/ha and thereafter the yield decreased.

Datt et al. (2003) carried out a study in Kukumseri (H.P.) on pea and reported that the value of growth parameters such as plant height, nodules/plant increased with the addition of NPK up to 150% of recommended dose.
In a field trial in sandy loam soil of Faizabad (U.P.) Singh and Singh (2003) studied the response of seed yield of garden pea (*Pisum sativum* var. hortense) to various seed rates and fertility levels. They reported a significant response of fertility level on plant height. More height of plants and delay in 50% flowering and test weight during both years (17.31 and 17.67) were recorded with 45:90:60 kg NPK/ha. They also recorded more number of pods/plant, length of pod, number of seeds/pod with medium fertility level (35:75:50 kg NPK/ha).

Chadda et al. (2004) conducted a study at Lari (H.P.) on pea and reported that pod yield increased with increasing level of nutrients (N40P60K30) applied and this was ascribed to increase in pods/plant and seeds/pod.

Rana et al. (2004) conducted a field experiment on sandy loam soil at Sangla (H.P.) for buckwheat and found that recommended dose of fertilizers nutrient (N40P40) recorded significantly higher plant height, grains per plant, 1000-grain weight and number of branches per plant as compared to farmer’s practice (N15P15K15). They also observed that recommended dose of fertilizers (N40P40) increased the grain yield significantly by 22.6 and 24.2 per cent during 1997 and 1998, respectively compared to farmer’s practice (N15P15K15). Straw yield also increased significantly with recommended dose of fertilizers.

Sugimoto (2004) studied the effects of nitrogen application on the growth and yield of summer buckwheat in Western Japan and advocated that dry weight and seed yield increased with increasing rates of N up to 4 g/m2.

Dass et al. (2005) conducted a field experiment at Koraput (Orissa) on pea crop with four levels of phosphorus (0, 25, 50 and 75 kg P2O5/ha) and
observed that increasing phosphorus level from 0 to 75 kg/ha consistently and significantly increased growth characters like plant height and yield attributes, viz. pods/plant and seeds/pod, and green pod yield and straw yield.

Mondal *et al.* (2005) also conducted some trials at different temperate regions of Himachal Pradesh and concluded that at fertility level of 40:40:20 (N:P:K kg/ha), grain yield was significantly increased (28.08 q/ha=2.808 t/ha) in all genotypes under study.

Rana *et al.* (2005) while working on buckwheat crop in sandy loam soils of Sangla (H.P.) reported that application of N @ 60 kg/ha, P\textsubscript{2}O\textsubscript{5} @ 40 kg/ka and K\textsubscript{2}O @ 20 kg/ha significantly increase plant height, branches per plant, plant population per meter row length, grains/plant, 1000-grain weight, grain yield and straw yield/ha over farmer’s practice (N\textsubscript{15}P\textsubscript{15}K\textsubscript{15}) and recommended fertility levels (N\textsubscript{40}P\textsubscript{40}).

In a field experiment conducted by Kumar *et al.* (2006) on the productivity of pea under Lahaul valley conditions of Himachal Pradesh reported that an application of 20 kg N, 60 kg P\textsubscript{2}O\textsubscript{5} and 30 kg K\textsubscript{2}O/ha resulted in significantly higher seed yield, growth and yield contributing traits. This study corroborated with the study conducted by Rana *et al.* (2006) as they also observed significantly highest straw yield at 100% of recommended fertility levels.

Reager *et al.* (2006) carried out an experiment at Bikaner (Rajasthan) during the winter season of 2002-03 and 2003-04 on Indian mustard (*Brassica juncea*) and stated that application of nitrogen from 40 to 100 kg/ha significantly
enhanced siliquae/plant, seeds/siliquae, test weight and seed yield of Indian mustard. The magnitude of increase was 30.17, 16.11, and 7.00% in siliquae/plant 30.37, 16.08, and 6.03% in seed/siliquae 27.67, 15.67, and 5.37% in test weight and 36.48, 14.67 and 5.40% in seed yield in 100 kg N/ha compared to 40, 60 and 80 kg N/ha respectively. However, stover yield, biological yield and harvest index showed a significant increase up to 120 kg N/ha.

2.2.2 Soil physical and chemical properties

Kumar et al. (2005) while studying the response of rajmash (*Phaseolus vulgaris* L.) to integrated nutrient management in dry temperate region of Himachal Pradesh observed that pH, organic carbon (OC) and available NPK were maximum at recommended dose of NPK (40, 60 and 30 kg NPK/ha) along with *Rhizobium* + *Phosphate solublising* bacteria treatment.

Varalaxmi et al. (2005) conducted an experiment at farmers’ field on Alfisol of Bangalore to study the effect of integrated use of organic manure and inorganic fertilizers on change in organic carbon, available N, P and K status of the soil in groundnut-finger millet cropping system. The study indicated that application of recommended NPK along with 7.5 t FYM/ha not only improved the productivity of groundnut but also significantly improved the organic carbon, available N, P and K contents of soil.

2.2.3 Nutrient accumulation and nutrient uptake

Kukrash et al. (1994) in an experiment on dernopodzolic light loam soil found a significant increase in N, P and K contents and uptake of grain and straw with 30 kg N + 60 kg P2O5 + 120 kg K2O/ha in buckwheat.
Verma and Bhandari (1996) conducted an experiment at Solan in Himachal Pradesh with four levels of each N (0, 15, 30, 45 kg/ha) and P$_2$O$_5$ (0, 30, 60, 90 kg/ha). They found that mineral concentration in seed generally increased with the application of 15 kg N and 60 kg P$_2$O$_5$/ha.

Ali and Zaman (1997) in their study on rapeseed (Brassica campestris) at Dhaka observed an increase in N uptake with 120 kg N/ha. Similarly, Patel and Thakur (1998) at Raigarh (M.P.) found that application of 60 kg N and 40 kg P$_2$O$_5$/ha to toria (Brassica campestris) showed a significant increase in N and P uptake.

Dubey et al. (1999) carried out a field experiment at Lahaul Valley of Himachal Pradesh on pea crop and stated that among different P levels, 80 kg/ha showed maximum uptake of N, P and K.

Bali et al. (2000) in their study at Srinagar (J&K) with three levels each of N (30, 60 and 90 kg/ha) and P (30, 45 and 60 kg/ha) on brown sarson (Brassica campestris) found that application of N up to 60 kg/ha significantly improved N and P uptake.

Podlesna (2006) in a pot experiment stated that the highest total uptake of all mineral nutrients was found in buckwheat plants supplied with the highest level of N. He also observed higher concentration and accumulation of K in all organs of buckwheat plant which were supplied with higher level of K.

Rana et al. (2006) studied the effect of rhizobium culture in combination with organic and chemical fertilizers on rajmash (Phaseolus vulgaris) under dry temperate conditions of Himachal Pradesh and found that
among fertilizer levels, 100% of recommended fertilizer proved better than 50% recommended fertilizer in case of N, P and K uptake in grain and straw of rajmash.

Reager et al. (2006) in an experiment at Bikaner (Rajasthan) on Indian mustard (Brassica juncea) observed that total uptake of N, P and K increased significantly with the application of graded levels of nitrogen from 40 to 100 kg/ha.

2.2.4 Quality parameters

Sokolov et al. (1971) during their study on the influence of nitrogen, phosphorus and potash on grain yield and quality of buckwheat on a chernozem soil of low humus content found increase in the protein content in grains from 12.5 to 13.8 per cent as compared to 1.58 t/ha and 11.8 per cent, respectively on the plots given no fertilizer. For protein content in buckwheat the best combination was 60 kg N + 30 kg P₂O₅ + 30 kg K₂O/ha.

Kanaujia et al. (1997) in their study at Nauni (H.P.) observed that protein content in pea increased with an application of 60 kg P₂O₅/ha. They also observed an increase in protein content with 60 kg K₂O/ha.

In an experiment in Bangladesh, Shamima and Farid (2003) evaluated the effect of N, P, K and S on yield and protein content of pea. The results revealed that highest protein content was obtained in treatment combination of 30 kg N + 50 kg P₂O₅ + 40 kg K₂O + 20 kg S/ha.

2.2.5 Economics/Cost benefit analysis

Shukla and Kohli (1992) during their research at Kalpa (H.P.) on pea crop also observed that 64.98 kg P₂O₅/ha was the optimum dose of P in terms of yield and net income/ha.
Patel and Meisheri (1997) at Anand (Gujarat) also observed the highest net returns with 75 kg N/ha. Patel and Shelke (1998) during their work on Indian mustard (Brassica juncea) at Parbhani (Maharashtra) reported that the mean net return was significantly more in 80 kg P$_2$O$_5$/ha.

Bali et al. (2000) during their study at Srinagar (J&K) on brown sarson (Brassica campestris) concluded that among different N and P levels, N @ 60 kg/ha and P$_2$O$_5$ @ 45 kg/ha gave highest net returns and benefit cost ratio.

Chadda et al. (2004) in a study at Lari (H.P.) on pea observed that N$_40$P$_60$K$_30$ was economically viable because it resulted in significant increase in net return and B:C ratio. Similar results were observed by Sugimoto (2004) that nitrogen absorption increased with increasing rates of N.

Dass et al. (2005) in their study on pea in Koraput (Orissa) with four levels of phosphorus (0, 25, 50 and 75 kg P$_2$O$_5$/ha) concluded that significant increase in green pod yield and straw yield owing to phosphorus, in turn, led to significantly higher net returns and benefit : cost ratio. They showed that increasing dose of P from 0 to 75 kg P$_2$O$_5$ consistently and significantly increased net returns of pea crop.

Rana et al. (2005) in their investigation on buckwheat crop at Sangla (H.P.) depicts that 60 kg N, 40 kg P and 20 kg K/ha, obtained maximum net returns and B:C ratio.

Kumar et al. (2006) while working on sandy loam soils of Kukumseri in Lahaul valley of Himachal Pradesh showed that application of 20 kg N, 60 kg P$_2$O$_5$ and 30 kg K$_2$O/ha resulted in highest seed yield, net return (Rs. 1,40,849) and B:C ratio value of 6.25.
Reager et al. (2006) in a study during the winter season of 2002-03 and 2003-04 on Indian mustard (*Brassica juncea*) at Bikaner (Rajasthan) found that the net returns increased significantly with the increase in the level of N up to 100 kg/ha. However, further increase in N up to 120 kg/ha did not show any significant increase in net returns over 100 kg N/ha.

### 2.3 Combined effect of organic manures and chemical fertilizers

#### 2.3.1 Growth, yield attributes and yield

In an experiment Sharma and Rana (1993) studied the nutrient management of pea crop and recommended 15 t FYM, 30 kg N, 60 kg P$_2$O$_5$ and 40 kg K$_2$O/ha for achieving optimum yield of pea of good quality. They further reported that neither the chemical fertilizers alone nor organic manure exclusively sustain productivity of pea but a judicious combination of both and their efficient management is a potential tool of sustaining the productivity.

Mankotia and Sharma (1998) in their field study during 1992-93 and 1993-94 at Palampur, Himachal Pradesh on yield attributes and yield of gobhi sarson (*Brassica napus* ssp. *oleifera*) and toria (*B.rapa*) reported that branches/plant, siliquae/plant, seeds/siliquae, 1000-seed weight and seed yield of gobhi sarson and toria increased with increasing supply of N, P and FYM up to 160 kg/ha, 35 kg/ha and 5 t/ha respectively.

Parmar et al. (1998) while studying the effect of integrated nutrient supply system for ‘DPP 68’ vegetable pea (*Pisum sativum* var. arvense) in dry temperate zone of Himachal Pradesh during summer 1995 and 1996 reported that the green-pea yield of pea, nodules/plant, plant height and pods/plant
increased substantially and significantly with increasing level of NPK up to 100% of the recommended dose (N\text{20}P_{60}K_{30}) both in presence and absence of FYM (10 t/ha) compared with the control (N_0P_0K_0+ no farmyard manure).

A field experiment conducted at Indore in Madhaya Pradesh, Patel et al. (1998) showed that application of \textit{rhizobium} culture and phosphate solubilizing bacteria in combination with 50% of N&P significantly increased plant height, pods/plant, grains/pod and ultimately pod yield over control and chemical fertilizers alone.

Reddy et al. (1998) conducted a field trial during kharif 1995 at Attibele, Karnataka, on peas and reported that plant height at harvest (84.25 cm), days to initial flowering, number of pods/plant (51.01), number of seeds/pod (6.20), hundred fresh seed weight (35.50g) and pod yield (8828 kg/ha) were highest with 10 tonnes of vermicompost + 100% recommended NPK (37.5:60:50 kg/ha).

Vimala and Natarajan (1999) in a study with pea on effect of \textit{Rhizobium}, N and P and reported that plant height increased with increasing rates of N and P. The number of days taken for 50% flowering increased with increasing rates of N. The treatment combination of 120 kg N/ha + 80 kg P/ha + 2 kg \textit{Rhizobium}/ha + 2 kg phospho-bacteria/ha produced the highest yield for both seasons (44.1 q ha^{-1}) and (44.0 q ha^{-1}).

Zakarackas (1999) in a study on buckwheat crop at Lithuania concluded that with increasing N rates, 1000-grain weight, grain yield and straw yield slightly increased. The N fertilizers gave an effective yield increase and the best treatment was 60 kg N/ha + 60 kg P/ha + 90 kg K/ha + 40 t FYM/ha.
Vimala and Natarajan (2000) conducted a field experiment at Udhagamandalam (Tamil Nadu) on pea (*Pisum sativum* L. spp. hortense) and reported that the pod length was maximum with treatment combination $N_{120}P_{80}B_{1}$ ($B_{1} = \textit{rhizobium} \text{ and } \textit{phosphobacteria}$), while the highest number of pods (23.7) was observed at $N_{90}P_{160}B_{1}$. The highest yield of (44.0 q/ha) was however, noticed in the treatment with $N_{120}P_{80}B_{1}$.

Shakya and Upreti (2001) conducted a study under Hill Crops Research Program (HCRP), Kabre (1740 masl) on buckwheat crop and found that the highest yield and 1000-grain weight was obtained with the application of 30:30:0 kg NPK/ha which was at par with 45:30:0 kg NPK/ha and 30 kg N/ha but significantly higher than most of the treatments including 10 t FYM/ha and absolute control.

Shankar et al. (2002) during a study at Faizabad (U.P.) on Indian mustard recorded the highest seed and stover yield under the treatment receiving 100% NPK along with 10 t FYM/ha and *azotobacter* inoculation.

Bhattarai et al. (2003) while studying the effect of integrated nutrient management on yield attributes and economics of pea (*Pisum sativum*) in Imphal (Manipur) reported that the application of *rhizobium* or FYM in combination with full recommended nutrient dose increased the yield attributes but the best treatment found was poultry manure with full recommended nutrient dose.

Datt et al. (2003) carried out a study in Kukumseri (H.P.) on vegetable pea and observed that successive addition of NPK in combination with farmyard manure further increased the nodulation and other yield attributing parameters. The green pea yield increased significantly and substantially with increasing levels of NPK fertilizers up to 150% recommended dose in the presence of FYM.
Similar results were reported by Kuldeep (2003) at Solan (H.P.). Maximum values with respect to green pod yield, plant height, number of green pods/plant, number of seeds/pod and 100-seed weight were recorded with the application of 20 t FYM/ha + 25 kg N + 65 kg P₂O₅ + 97.5 kg K₂O/ha.

Rajput and Pandey (2004) found that under Madhya Pradesh conditions application of FYM @ 12.5 t/ha and NPK at 50 per cent of the recommended rate was equivalent in effectiveness compared to NPK at 100 per cent on the yield of pea.

Negi et al. (2006) in their study on the effect of biofertilizers, nutrient sources and lime on growth and yield of garden pea var. Lincoln in acidic soils of Garhwal hills concluded that the combined application of FYM + NPK (50:50 of the recommended doses i.e. FYM = 20 t/ha and NPK = 25:25:25 kg/ha) were much superior to the individual ones in terms of plant height, nodules/plant, number of pods/plant, pod length and green pod yield/ha.

Rana et al. (2006) assessed the effect of rhizobium culture in combination with organic and chemical fertilizers on rajmash (Phaselous vulgaris) under dry temperate conditions of Himachal Pradesh and stated that 100% of recommended dose resulted in taller plants than 50% of the recommended dose.

The weight of 100 pea seeds, depending on cultivars ranged from 209.4 to 280.4 g (Zdunczyk et al., 1997), whereas, 100 seed weight in yellow field peas ranged between 19.1 to 26.9 g (Wang et al., 2003).
2.3.2 Soil physical and chemical properties

Parmar et al. (1998) in a field experiment on pea crop in dry temperate zone of Himachal Pradesh concluded that the effect of NPK fertilizers (N_{20}P_{60}K_{30}) on soil organic carbon was non-significant. However, its content in soil increased with addition of farmyard manure along with NPK as compared with control (N_{0}P_{0}K_{0}+ no farmyard manure). They also observed that NPK fertilizers in the absence of FYM though improved the build up of soil available N, P and K content but, further improvement was also only due to addition of FYM @ 10 t/ha in the presence of NPK fertilizers.

Shankar et al. (2002) conducted a study at Faizabad (U.P.) on Indian mustard and observed that application of farmyard manure along with inorganic fertilizers improved the physio-chemical properties of the soil.

Datt et al. (2003) while carrying out a study at Kukumseri (H.P.) on vegetable pea concluded that the organic carbon content increased with the addition of NPK and farmyard manure in comparison to control.

2.3.3 Nutrient accumulation and nutrient uptake

Parmar et al. (1998) in an experiment on pea crop in dry temperate zone of Himachal Pradesh observed that the total N, P and K uptake increased significantly with successive increase in their doses with and without farmyard manure compared to control (N_{0}P_{0}K_{0}+ no farmyard manure).

Shankar et al. (2002) in an experiment at Faizabad (U.P.) on Indian mustard stated an increase in N, P and K uptake with 100% NPK along with 10 tonnes FYM/ha and *azotobacter* inoculation.
Datt et al. (2003) during their study on effect of supplementary use of farmyard manure along with chemical fertilizers on pea in Lahaul valley of Himachal Pradesh found that total N, P and K uptake increased significantly in different treatments in comparison to control. They also observed that successive increment of NPK fertilizers in the presence of FYM increased N, P and K uptake significantly.

2.3.4 Quality parameters

Vimala and Natarajan (2000) at Udhagamandalam (Tamil Nadu) on pea observed that the TSS content in pea was significantly higher in treatments with biofertilizers in addition to nitrogen and phosphorus. Protein content was also improved with the application of nutrients. According to authors, considering the pod characters, yield and quality, a combination of N 120 kg, P 80 kg, *Rhizobium* 2 kg and *phosphobacteria* 2 kg per hectare was found optimum.

Brick et al. (2004) in their study observed that highest protein content of pea was from treatment combination comprising 40 kg N/ha + *rhizobium*.

2.3.5 Economics/Cost benefit analysis

Bhattarai et al. (2003) in their study on pea at Imphal (Manipur) reported an increase in the net returns by applying organic manures in combination with full recommended dose of nutrient to pea crop. However, due to higher cost of organic manures, the treatments where organic manures were applied, returns/rupee invested were slightly lower but higher in treatments receiving biofertilizer.
Rana et al. (2004) assessed the influence of fertility levels in common buckwheat at sangla (H.P.) and reported that recommended dose of fertilizers (N\textsubscript{40}P\textsubscript{40}) increased net returns by 37 per cent compared to farmer’s practice (N\textsubscript{15}P\textsubscript{15}K\textsubscript{15}).

### 2.4 Residual effect of organic manures and chemical fertilizers

Sharma et al. (1999) conducted an experiment on nutrient management in soybean (Glycine max) – mustard (Brassica juncea) crop sequence and observed that the residual effect of different levels of fertility applied to soybean, showed significant variation in seed yield of mustard. The highest yield of 2,109 kg/ha was observed when N40 (½N through urea + ½N through FYM) was applied to soybean.

Sharma et al. (1999) in another experiment on nutrient management in soybean (Glycine max) – mustard (Brassica juncea) crop sequence inferred that during rabi season, maximum uptake of NPK nutrients was recorded where mustard crop received recommended dose (80:40:20) of fertilizers, preceded by the treatment receiving 50% through inorganic sources applied to kharif season crop (soybean).

Thakur et al. (1999) while studying the response of french bean (Phaseolus vulgaris) varieties to fertilizer levels, rhizobium inoculation and their residual effect on onion (Allium cepa) in mid-hills of north-western Himalayas at Palampur (H.P.) concluded that rhizobium inoculation in french bean registered a significant residual effect and resulted in higher onion bulb yield.
Trivedi and Singh (1999) during their study on response of blackgram (*Phaseolus mungo*) – Indian mustard (*Brassica juncea*) cropping sequence to fertilizer application at Gwalior (M.P.) observed that Indian mustard responded significantly up to 45 kg N/ha, beyond which there was no significant increase in the yield. Possibly this may be due to better built-up of N in the soil by the preceding blackgram crop and regular use of nitrogenous fertilizer.

Singh *et al.* (2001) while studying the response of brown sarson (*Brassica campestris* subsp. *oleifera* var. brown sarson) to residual effect of organic manure, nitrogen and transplanting dates of rice (*Oryza sativa*) at Kashmir observed that the number of siliquae per plant and seed yield increased with increasing N rates. The value for 1000-grain weight was highest at 100 and 150 kg N/ha. Siliquae per plant was highest with FYM application. They further observed that P uptake increased with increasing residual N rates from 100 to 150 kg N/ha whereas N and K uptake increased only up to 100 kg N/ha.

Mahala *et al.* (2006) carried out a field experiment at Udaipur (Rajasthan) to study the direct and residual effects of sources and levels of phosphorus and farmyard manure in maize (*Zea mays*) – mustard (*Brassicca juncea*) cropping sequence and reported that the seed and straw yield of mustard were significantly increased due to residual effect of P levels up to 80 kg P$_2$O$_5$/ha applied to maize. The residual effect of 80 kg P$_2$O$_5$/ha increased the seed yield of mustard by 5.16 and 6.89% over 60 kg P$_2$O$_5$/ha and 11.47 and 13.00% over 40 kg P$_2$O$_5$/ha. It was further observed that N and P uptake and available N and P in soil increased significantly due to residual effect of increasing P levels. Authors
also observed that the residual effect of FYM 10 t/ha significantly improved the seed and straw yields of mustard and uptake of N and P over no FYM application.

Rana et al. (2007) while working on direct and cumulative residual effect of phosphorus and sulphur on Indian mustard (*Brassica juncea*) – sunflower (*Helianthus annuus*) – urdbean (*Vigna mungo*) cropping system observed the positive response of residual P applied to sunflower on the yield and yield attributes of urdbean. The increase in seed yields of urdbean and other crops owing to residual effect of applied P and S to preceding crops were also reported by Jain and Dahama (2006).