Chapter II

REVIEW OF LITERATURE

The literature on the "Studies on the Effect of Integrated Nutrient Management on Soil Properties, Yield and Quality of Mustard and its Residual effect on Summer Moong" viz. Organic and inorganic sources of nutrients and their uptake and physico-chemical and microbial properties of soil etc, the subject of present investigation is so extensive that it is difficult to present the review in detail. Therefore, an attempt has been made to give the salient features of the research findings on the subject under review. For convenience of presentation, the review and literature on relevant aspect is reviewed Mustard and Moong accordingly.

The modern agriculture technologies emphasized wide spread use of chemical fertilizers as a source of nutrients. Infact, chemical fertilizers have a significant contribution in providing nutrients for intensive crop production. However, increase in usage of chemical fertilizers alone create problems such as diminishing soil productivity and multiple nutrient deficiencies and disorders (Bhardwaj, 1983).

Increasing cost of fertilizers, enhancing incidence of multiple nutrient deficiencies and deterioration in physical properties of soil were known to be responsible for lower yields in the areas having high fertility of soils. It has been found that application of the nutrients through organics and biological or with other like FYM, Azotobacter etc, enhances the soil fertility as compared to mineral fertilizers alone. Also the productivity of
the system could be sustained through the application of organics in conjunction with chemical fertilizers.

Indian mustard (Brassica juncea, L.) occupies a key place in the agriculture scenario of the Country, as it contributes a substantial amount to the national GNP as well shares more than 25% of total oil production and consumption. However, the crop has not been given due attention in the past. The crop is normally cultivated either as a mixed crop or on marginally poor soils without caring its nutrient and water needs. Now the time has come to take care of it to augment its productivity in order to cater the oil needs of growing population of human & animals. A lot of work have also been in the past, however the systematic knowledge is still lacking. Herewith, an approach has been made to review the research works, pertaining to the subject, under following heads:

- **Studies on Mustard**
  
  ✓ Effect of N & S on yield and quality of Mustard.
  ✓ Effect of N & P on yield and quality of Mustard
  ✓ Effect of N, P & K on yield and quality of Mustard
  ✓ Effect of N, P, K & S on yield and quality of Mustard
  ✓ Effect of combined use of inorganic & organics on yield and quality of Mustard
  ✓ Effect of INM on plant nutrients content and uptake in Mustard
  ✓ Effect of INM on oil content & oil yield

- **Studies on Moong (Succeeding Crop)**
  
  ✓ Effect of INM on yield and yield attributes of Moong
  ✓ Effect of INM on nutrient composition and their uptake by Moong
• **Studies on soil properties**

✓ Influence of INM on soil Properties

2.1. **STUDIES ON MUSTARD**

2.1.1. **Effect of N & S on yield and quality of Mustard**

**Singh and Singh (1977)** reported that application of upto 90 ppm. S led to seed yield but with 120 ppm. it decreased. Application of up to 90 and 30 ppm. S increased plant N and P contents respectively. Despite the increase in S uptake with increase in S rate, the degree of S utilization decreased.

**Singh and Singh (1978)** conducted a pot trial on B. juncea and given 0, 15, 30, 60, 90 and 120 ppm. S. The free S-amino acid content of shoot increased with increasing S application to 120 ppm., whereas the bound S-amino acid content increase to 90 ppm. And declined thereafter. Methionine content was the highest followed by cystine and cysteine. Free acid formed <10% of the total S-amino acids. S-amino acid content was positively correlated.

**Pathak & Tripathi (1979)** found the seed oil content increased with increasing S rates and decrease with increasing N-rates. Methionine content was increased by applied S and reduced by applied N. There were positive correlation between seed and oil yields and between content and protein yield and a negative correlation between protein and oil content.

**Verma & reddy (1985)** observed that when 60 kg N and 60 kg S ha\(^{-1}\) gave the highest values for yield components, seed and oil yields. S increased the seed oil content, N had no effect. S as gypsum was much superior to element S.
Singh & Sahu (1986) stated that the requirement and availability of Sulphur and its critical level in soils and plants are considered. Response are reviewed for mustard and the effect of oil content and quality is considered with reference to sesame. Sawarkar et al. (1987) reported that increasing rates of applied S from 0 to 60 kg increased the available oil content in seeds from 40.46 to 45.05%, decreased an protein content from 18.84 to 17.48 and also decreased S content from 0.28 to 0.26%.

Rathore & Manohar (1989) stated that the application of 80 to 400 kg elemental S and 30 to 180 kg N ha\textsuperscript{-1}, increased the D.M. production and leaf chlorophyll contents compared with untreated control, the effect increased with increasing S and N rates. Rathore & Manohar (1989) observed in a 2 years trial with mustard (B. juncea) given 0 – 180 kg N ha\textsuperscript{-1}, seed yield increased significantly as N rates increased upto 120 kg ha\textsuperscript{-1} and S rates upto 160 kg ha\textsuperscript{-1}. 1000 seed wt increased with upto 80 kg S ha\textsuperscript{-1} and 160 kg S ha\textsuperscript{-1} in 2 trials respectively but was not affected by N rates. Rathore & Manohar (1989) found the oil content increased with 80 kg S ha\textsuperscript{-1} compared with the control. Increase in N rates in the range 90-180 kg ha\textsuperscript{-1}. Increased oil yields compared with lower N rates and no nitrogen. Oil contents increased with increasing rates of both S and N.

Chaudhary et al. (1992) observed seed yield increased from 0.80 to 1.44 t ha\textsuperscript{-1} with increase in N rate (20-80) and from 1.04 to 1.19 ton with increase in S rate (0-50). Seed oil content was unaffected by N rate and increased from 41.05 to 43.49% with increase in S rate. Mohan & Sharma (1992) reported that seed yield increased with upto 75 kg N and 50 kg S. A further increment of 25 kg N and 25 kg S decreased seed yield. Oil yield followed a similar pattern to seed yield statistical analysis
indicated that the optimum n and S rates for B. juncea at the site were 73.81 and 43.96 kg respectively.

Rathore & Manohar (1992) found in a field experiment that, Indian mustard B. juncea cv. T-59 was given 0,80,160,240,320 and 400 kg S and 0,30,60,90,120,150 and 180 kg N ha⁻¹. N concentration in whole plants, leaf 2-3, leaf 4-5 and in top one third of the plant increased with increase in applied N and S.

Tripathi and Sharma (1993) found increase in seed yield of mustard with increase in sulphur level. They also found an increase in protein and oil content of mustard by the application of S. Dubey and Khan (1993) observed, seed yield and seed and Plant n contents increased with rate of N application, whereas seed oil content decreased. Seed yield and seed and plant n-contents increased with up to 30 kg S ha⁻¹, whereas oil content increased with up to 40kg S ha⁻¹.

Khanpara et al. (1993) reported that B. juncea given 0, 20, 40 and 60 kg N ha⁻¹ produced mean seed yields of 1-1.5, 1.22, 1.42 and 1.64 t ha⁻¹ respectively. Application of 50, 100, 150, and 200 kg S ha⁻¹ produced seed yields of 1.25, 1.42, 1.43 and 1.43 t ha⁻¹ respectively. Seed yield were similar with application of elemental S. Dubey & Khan (1993) found the seed S content, and total S and N uptakes, increased with upto 90 kg N and upto 40, 50 va nd 20 kg S ha⁻¹ respectively. Seed oil content decreased with increase in N rate and increased with increase in S rate.

Tomar et al, (1996) observed that nitrogen upto 90 kg and sulphur upto 45 kg ha⁻¹ significantly increased the growth and yield components, seed yield and net returns. The highest yield (26.85 q ha⁻¹) and net return was obtained from application of 90 kg N + 45 kg S ha⁻¹.
Singh et al. (1998) stated that yields and yield component values, oil and protein contents and net returns increased with increasing fertilizer rates.

Dekshitulu et al. (1998) reported that seed and oil yields increased with increasing N and S rates. Oil content increased with increasing S rate, but peaked with 100 kg N, then decreased. Anmed et al. (1998) found the application of S and N increased yield components, seed and oil yield, with the highest yield given by 40 kg S and 100 kg N ha\(^{-1}\), respectively. Percentage oil content of seed was highest with 60 kg S and 100 kg ha\(^{-1}\) without any change in applied S, i.e. 60 kg S ha\(^{-1}\), decreased percentage oil content but did not significantly affect seed and oil content. Abraham (1999) observed, that total oil content was highest with 60 kg S + 100 kg N ha\(^{-1}\).

Majumdar & Pingoliya (2000) stated that the highest P and S contents in the seed (0.791 and 0.303% respectively) and stover (19.27, 4.33 and 5.69 kg ha\(^{-1}\)) were recorded upon treatment with gypsum. The highest increase in protein and oil content in seed was recorded upon treatment with gypsum (20.14 and 38.82% respectively) and with 60 kg S ha\(^{-1}\) (20.21 and 39.02% respectively).

Ahmad & Abdin (2000) reported that maximum oil content was from 60 kg S + 100 kg N ha\(^{-1}\). Protein, N and S contents were maximum from 40 kg S + 100 kg N. The results obtained in this study suggest that a balanced N and S supply should be maintained for both quality and quantity of oil.

Abraham (2000) found in Brassica juncea grown at New delhi was given combinations of 40 and 60 kg S and 100 & 150 kg N ha\(^{-1}\).
Chlorophyll and soluble protein content, and rate of photosynthesis, were highest with 60 kg S + 100 kg N ha\(^{-1}\).

**Sharawat et al. (2002)** observed that the yield and oil content generally increased with the increase in N and S rate. N at 120 kg ha\(^{-1}\) resulted in the highest seed yield per plant (368-75gm), seed yield ha\(^{-1}\) (17.33 qt) and oil content (38.39%). The application of 30 kg S ha\(^{-1}\) also gave highest seed yield/plant (337.17 g) and seed yield ha\(^{-1}\) (15.14 qt). The highest oil content with S at 20 (37.89%) and 37.95%). **Prakash and Singh (2002)** found that seed yield, protein and oil contents, and oil yield increased with the increase in sulphur rate upto 40 kg ha\(^{-1}\) only.

**Singh et al. (2004)** found that N application did not influence the oil content in mustard. However, oil yield and chlorophyll content were increased up to 90 kg N ha\(^{-1}\). **Sharma et al. (2005)** observed that S application significantly increased the number of primary branches, number of siliquae plant\(^{-1}\), length of siliquae and 1000-seed weight. Optimum seed yield (14.9 quintal ha\(^{-1}\)) was obtained with the application of 65 kg S ha\(^{-1}\). S application also increased the stover and total dry matter yield.

**Malik et al. (2006)** reported that increasing the N rate up to 80 kg ha\(^{-1}\) increased the crop quality aspects, N content and uptake, protein content, oil and protein yield. However, oil content was negatively correlated with N rate.

**Singh et al. (2007)** reported increase in mean seed yield with N application @ 120 kg over 80, 40, and 0 kg levels was 3.8, 29.2 and 117.6 % respectively. Similarly seed yield (16.4 q ha\(^{-1}\)) was significantly increased with S application @ 90 kg ha\(^{-1}\), but application of 60 kg S ha\(^{-1}\) appeared economically better than other levels of S. A significantly
positive interaction between the two nutrients (S and N) in increasing seed yield was observed, giving the highest seed yield (19.18 q ha$^{-1}$) due to combined application of N 80 kg and S 60 kg ha$^{-1}$. An improvement in oil yield was noticed significantly up to 60 kg S ha$^{-1}$ and appeared a reasonable level of S. Similarly 80 kg N ha$^{-1}$ was noticed quite advantageous for production of oil ha$^{-1}$ mustard. Singh et al. (2007) noticed that 80 kg N ha$^{-1}$ was quite advantageous for production of oil ha$^{-1}$ in mustard.

Mehdi et al. (2007) found that S fertilization significantly increased the growth attributes i.e. plant height, dry matter accumulation, primary and secondary branches and yield as a result of S application up to 40 kg ha$^{-1}$. The siliquae plant$^{-1}$, seed siliqua, test weight of seed and seed yield of mustard also increased up to 40 kg S ha$^{-1}$. Singh and Verma (2007) reviewed that seed yield of Varuna significantly increased with S application @ 90 kg ha$^{-1}$ but application of 60 kg ha$^{-1}$ appeared economically better than other levels.

Kovacs et al. (2009) found changes in the N content of the seed and straw showed a statistically significant increase with increasing N and S fertilization. Highest values in the seed and straw (5.96% and 0.87%, respectively) were observed by applying highest N and S doses. Seed and straw S levels were also observed to increase with increasing N rates and decreasing N-S ratio. Nitrogen doses significantly improved the quantities of essential amino acids.

Dinesh et al. (2010) Studies were conducted to assess the effect of sulphur on growth, yield and uptake of S by the mustard crop during rabi season of 1997-98. Mustard varieties produced significant difference in sulphur uptake by seed. Variety BR-40 showed the highest sulphur uptake by seed (10.95 kg S/ha). The progressive increases in uptake of
sulphur by straw due to different levels (15, 30, 45 kg/ha) were 10.76, 29.18 and 49.52% respectively. Each level of applied sulphur had a significant performance of each of the next lower level of sulphur.

**Singh et al. (2010)** during a study on the effect of different levels of nitrogen (50, 100 and 150 kg N/ha), sulphur (0, 30 and 60 kg S/ha) and zinc (0, 0.5 and 1.0 kg ZnEDTA/ha) on growth, yield attributes, yield, quality and economics of Indian mustard and found the significant increase in oil, protein yield with highest levels of N, S and Zn uptake.

**Brajendra, et al. (2012)** conducted a green house experiment carried out with surface soil samples (0-15 cm). Mustard was taken as a test crop. The dry matter yield and percent relative yield were taken to determine the critical limit of available S in soil for mustard using different extractants. The critical limit of available S for different extractants for mustard were 6.6 mg kg⁻¹(0.001 M HCl), 17.2 mg kg⁻¹(0.25 M HCl), 9.8 mg kg⁻¹( NaOAc+ CH₃COOH), 10.2 mg kg⁻¹(Water soluble),15.6 mg kg⁻¹(NH₄OAc+ CH₃COOH),15.6 mg kg⁻¹(0.15% CaCl₂), 13.2 mg kg⁻¹( 1% NaCl ), 18.2 mg kg⁻¹( Heat soluble),38.6 mg kg⁻¹(CaH₂PO₄), 48.8 mg kg⁻¹(KH₂PO₄).

**Gan et al. (2012)** selected oilseed crops grown on the semiarid northern Great Plains and to determine the effects of N fertilization and environments on the carbon footprint on five oilseed crops, Brassica napus canola, Brassica rapa canola, Brassica juncea canola, B. juncea mustard, and Sinapis alba mustard, were grown under the N rates of 0, 25, 50, 100, 150, 200, and 250 kg N ha⁻¹. Emissions from the production, transportation, storage, and delivery of N fertilizer to farm gates accounted for 42% of the total greenhouse gas emissions, and the direct and indirect emission from the application of N fertilizer in oilseed production, carbon footprint increased substantially for all five oilseed
crops evaluated. Carbon footprint of oilseeds was a function of the rate of N fertilizer, and the intensity of the functionality varied between environments. Key to lower carbon footprint in oilseeds is to improve N management practices.

Parmar and Parmar (2012) conducted a field experiment to study the response of mustard to nitrogen and sulphur application under loamy sand soil of north Gujarat. Three levels each of N (50, 75 and 100 kg N ha\(^{-1}\)) and four levels of S (control, 15, 30 and 45 kg S ha\(^{-1}\)) were tried. Application of nitrogen and sulphur at the rate of 100 kg N ha\(^{-1}\) and 45 kg ha\(^{-1}\) significantly increased protein content, chlorophyll \textquoteleft a\textquoteright, \textquoteleft b\textquoteright and total chlorophyll content over rest of level, respectively. Whereas, the effect of nitrogen was non-significant in case of oil content in mustard seed but the application of 40 kg S ha\(^{-1}\) had significantly increased oil content in mustard seed.

2.1.2. Effect of N & P on yield and quality of mustard

Vir and Verma (1981) conducted a trial on rainfed mustard supplied with 0-90 kg N and 0-60 kg P\(_2\)O\(_5\) ha\(^{-1}\) reported that optimum fertilizer rate were 50.6 kg N and 36.7 kg P\(_2\)O\(_5\) ha\(^{-1}\). The seed oil content was not affected.

Reddy and Sinha (1988) reported that application of N & P increased the seed yield of mustard linearly upto 80 kg N ha\(^{-1}\) and 30 kg P ha\(^{-1}\), respectively. The effect of P was well marked in the presence of nitrogen, application of 80 kg N + 30 kg P ha\(^{-1}\) gave the highest yield (24.7 Q ha\(^{-1}\)) which was 66% more than no fertilizer.

Parihar (1991) while conducting a field experiment in the winter season on B. juncea cv. T59 under irrigated condition and given 30, 60
and 90 kg N ha\(^{-1}\), found that seed yield increase with irrigation and increasing levels of N.

**Jasinska and Kotecki (1994)** observed in a 4 year field experiment that N-fertilization did not expert any pronounced effect on the length of growing period of all the mustard cultivars compared. Increasing N-doses up to 90 kg ha\(^{-1}\) brought about a significant increase in the yields of seeds, fat and total protein.

**Arthamwar et al. (1996)** stated that all yield components increased with increasing N-application, a linear increase in seed yield ha\(^{-1}\) being was also observed from 0 to 100 kg N ha\(^{-1}\). Increasing P application resulted in a significant increase in all yield attributes, seed yield ha\(^{-1}\), oil content and oil yield.

**Shukla & Kumar (1997)** found that N application at rates upto 120 kg ha\(^{-1}\) significantly increased seed yield and nitrogen uptake, whereas a decreasing trends was observed in the case of oil content with an increase in nitrogen fertilization.

**Khafi et al. (1997)** reported that the seed yield of B juncea increased with upto the highest N-rate of 80 kg ha\(^{-1}\) and increased by application of 30 kg P\(_2\)O\(_5\) ha\(^{-1}\). **Singh & Brar (1999)** stated that B. juncea was given 0- 150 kg N and 0-45 kg P ha\(^{-1}\). Seed yield increased upto 100kg N (1.66 t ha\(^{-1}\)) and upto 30 kg P (1.41 t ha\(^{-1}\))

**Kumar et al. (2001)** conducted a field experiment with B. juncea, nutrient which was supplied with varying rates of N ( 0, 30, 60, 90 and 120 kg N ha\(^{-1}\)) and P (0, 12.45, 24.90 and 37.45 kg P ha\(^{-1}\)) and found that oil and seed yield responded significantly upto 90 kg N ha\(^{-1}\) 24.90 kg ha\(^{-1}\). The oil content was significantly decreased with an increased in N rate.
beyond 90 kg ha\(^{-1}\). **Kumar et al. (2001)** stated that total dry matter increased significantly up to 60 kg ha\(^{-1}\). There were non-significant differences in seed yield among Indian mustard genotypes with increasing N levels.

**Singh (2002)** reported that the application of N and P increased the seed yield. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N ha\(^{-1}\) and 30, 45 and 60 kg P ha\(^{-1}\) treatments. The maximum seed yield was recorded from application of 45 kg P ha\(^{-1}\) and 120 kg N ha\(^{-1}\). The oil content also increased with the application of N and P. **Dhaka and Satish (2003) and Jain et al. (2002)** observed that seed and stover yield enhanced with increasing N rates up to 80 kg N ha\(^{-1}\), while integration of P and N produced higher yield compared to 80 kg N ha\(^{-1}\) alone.

**Sah et al. (2006)** observed that plant height and primary branches plant\(^{-1}\) increased significantly up to 80 kg N ha\(^{-1}\), while secondary branches, dry matter plant\(^{-1}\) and leaf chlorophyll content increased up to 120 kg N ha\(^{-1}\). Application of P up to 60 kg ha\(^{-1}\) significantly enhanced dry matter plant\(^{-1}\). On the other hand, plant height, branches plant\(^{-1}\) and leaf chlorophyll content increased significantly only up to 40 kg ha\(^{-1}\) P ha\(^{-1}\). All growth attributes increased significantly only up to 40 kg S ha\(^{-1}\). The result showed that the uptake of NPK and S by both seed and stover increased significantly with successive increase in N level up to 120 kg N ha\(^{-1}\) and levels up to 60 kg S ha\(^{-1}\) and P levels up to 60 kg P ha\(^{-1}\).

**Bhat et al. (2006)** working with three rates of N and P combination i.e.; 60 kg ha\(^{-1}\)+30 kg P ha\(^{-1}\), 80 kg N+40 kg P ha\(^{-1}\) and 100 kg N+50 kg P ha\(^{-1}\) on the growth yield and quality of mustard (B. juncea) cv. Pusa Gold and Kranti found that cultivar Pusa Bold recorded taller plants and high leaf number of primary branches and plant dry weight than cv. Kranti.
Application of 100 kg + 50 kg P ha$^{-1}$ significantly improved all the parameters measured as compare to the other treatment. Higher fertilizer rates also resulted in a significant increase in number of siliqua plant$^{-1}$, length of siliqua and number of seed siliqua$^{-1}$, which consequently result in marked increase in harvest index and seed yield of both cultivars.

**Bhat et al. (2006)** recorded that oil content decreased with increasing N and P rates. Although the extent of decrease in seed oil content was lower than increase in seed yield and thus the total edible oil production was still higher with higher fertilizer rates compared to the normal recommended rates of fertilizer.

**Chaudhary et al. (2007)** recorded the highest seed yield, straw yield, N,P,S as well Zn uptake at both pre-flowering and maturity stages, as well oil content and oil yield with application of 60kg N +30kg P2O5+ 30 kg S + 5kg Zn/ha as compared to other fertility treatments. **Yadav et al. (2010)** recorded higher growth and yield characters, protein & oil yield with application of 125% RDF of NPK fertilizer in Indian mustard.

### 2.1.3. Effect of N, P, & K on yield and quality of mustard

**Lu Jainwei et al. (1996)** studied the effect of K on fertilization and found that best result was obtained where K fertilizer was applied, combined with other elements. **Singh et al. (1999)** reported highest K use efficiency at 9.25 ppm in mustard.

**Bohra et al. (2002)** studied the effect of different levels of NPK (25, 50 and 75% of recommended dose) and S (20 and 50 of recommended dose) however, RDF was 80:40:40:30kg NPK and S ha$^{-1}$ was applied two weeks before sowing in Indian mustard found significant improvement in crop yields and oil content respectively.
Mishra, (2003) observed that oil, protein and total S-amino acid contents increased significantly with the application of S and K. Sulphur and potassium addition also influenced remarkably the fatty acids compositions, oleic and linoleic acid contents increased and erucic acid decreased showing improved quality of mustard oil.

Bhati and Sharma (2006) working with the influence of K and its time of application on leaf area index (LAI) and chlorophyll content of mustard found that application of K @ 60 kg K ha\(^{-1}\) significantly increased LAI by 23.77 and 21.78 % over control at 45 DAS. K also significantly increased chlorophyll content at 45 and 90 DAS.

Grewal et al. (2009) conducted an experiment on mustard crop with potassium application @ 0, 30, 60 and 90 mg K/kg of soil, and found a significant increase in uptake of nitrogen, phosphorus, potassium and sulphur, in mustard seed, oil & crude protein content also increased and a significant effect was noted upto 60gm K/kg soil application. chlorophyll content also increased with K levels.

2.1.4. Effect of N, P, K & S on yield and quality of mustard

Saran & Giri (1990) reported that yields increased with increasing in S rates from 0 -30 and 60 kg ha\(^{-1}\) in the absence of applied NP while crops showed response only to 30 kg S in the presence of NP. Seed oil content increased with 60 kg S ha\(^{-1}\) was not affected by N or P. Sharma & kamath (1991) found, s utilization decreased from 15.6 to 13.2% in B. juncea when S application was increased from 45 to 90 kg ha\(^{-1}\). Interaction between S and P is significant for S utilization by the crop.

Jain et al. (1995) observed the D.M. yield increased with upto 40 kg P\(_2\)O\(_5\) and 50 kg S. Application of P and s increased the uptakes of N, P,
K and S in seed and stover. **Dwivedi and Choubey (1995)** reported that application of N decreased oil content in the linseed. Whereas phosphorus and sulphur increased the oil content of linseed, the highest was at 50 kg ha$^{-1}$ of P$_2$O$_5$ and S respectively.

**Jain et al. (1996)** stated that the seed yield was highest with 17.44 kg (1.69 t ha$^{-1}$) compared with 1.21 t with no P. Increasing S application from 0-75 kg increased seed yield from 1.40 to 1.55 t ha$^{-1}$. Seed oil content increased with upto 50 kg S but was not affected by P application. **Jaggi & Sharma (1997)** reported on a field experiment on B. juncea Cv. Varuna, seed yield increased with increasing S and P rates. The application of 90 kg S + 26.2 kg P produced the highest seed yield of 2.15 t ha$^{-1}$ and the highest uptakes of S and P, S and p had synergistic effect on yield.

**Jaggi (1998)** found, on Indian mustard (B. juncea) Cv Varuna yield was increased by S- application at 60 kg ha$^{-1}$. S application of 30, 60 and 90 kg ha$^{-1}$ increased seed yield by 121, 157 and 176% respectively compared with no S, similar increase in seed yield with P$_2$O$_5$ rates of 30 and 60 kg ha$^{-1}$ were 36 and 82% respectively. The highest seed (21.5 q ha$^{-1}$) and straw (69 q) yields with combined applications of S and P$_2$O$_5$ at their maximum rates.

**Puri et al. (1999)** observed, that the N and P contents in seed, total removal of nutrients (N,P,K), seed yield and oil content were significantly affected by level of fertilization (N,P,K). The highest seed yield (16.8 q ha$^{-1}$) and oil content (39.72%) were noted in the treatment 100:40:20 kg NPK ha$^{-1}$. Significant negative correlation coefficient of oil content with protein content, with yield, seed S content were obtained.
**Jaggi & Sharma (1999)** stated that the oil content was maximum where the highest level of S was used without P and maximum where either no S or P (S₀P₀) was applied or from the highest rates of their application. Significant increased in seed and oil yields remained restricted up to 30 kg S ha⁻¹ and found high residual effect of S and P fertilizers were seen at the end of the experiment.

**Jaggi & Sharma (2000)** reported, that the critical S content for all 4 parameters (D.M., yield, and N, S and P uptake) was 0.31% and those of the N content were 2.9% for dry matter yield and 0.31% and those of N, S and P. Similarly, the critical N:S ratio was 11.0 for dry matter yield and 9.5 for N, S and P uptake by crop. The critical S:P ratio for obtaining N, S and P uptake were 2.75, 2.58 and 2.13 respectively.

**Sharma & Jalali (2001)** found that the oil content increase significantly with increasing levels of S. Application of P decreased the oil content, which ranged between 39.8% at O level of P and 30.33% at 60 kg P ha⁻¹ while oil yield increased significantly. The interaction effect of S and P on oil content was found to be non significant, while oil yield was increased significantly due to combined application of S and P.

**Davaria et al. (2001)** observed in the P treatments seed yield (15.43 q ha⁻¹) stover yield (39.44 q ha⁻¹) were highest with 50 kg P₂O₅ ha⁻¹. S had no significant effects on growth and yield, except for seed yield, which was highest at 50 and 100 kg ha⁻¹ (13.28 and 14.12 q ha⁻¹ respectively). P₂O₅ at 50 kg ha⁻¹ significantly increased leaf chlorophyll content and P and S contents and P and S contents of seed. There were no observed changes in oil, protein contents.

**Chaubey et al. (2001)** stated that phosphorus application increased significantly seed yield over control. Similar sulphur also
increased the seed yield. Seed weight increases significantly with the increasing level of P and S upto 60 kg P\textsubscript{2}O\textsubscript{5} and 30 kg S ha\textsuperscript{-1}. Jaggi & Sharma (2002) reported that dry matter yield and S uptake in control pots were significantly and positive correlated with soil available S, and negatively with available P.

Faujdar et al. (2008) observed the significant increasing in seed and stover yield, oil content and oil yield, protein content, chlorophyll content and S-containing amino acids in seed with the application of both P and S in Indian mustard.

Jain et al. (2009) observed a significant importance in oil content & yield characteristics with the application of foliar spray of P and S @ 2 kg/ha along with 60 kg N/ha and and 28 kg P/ha basal doses in Indian mustard.

Singh et al. (2010) find a significant increase in oil & protein content as well seed yield by various fertility levels of NPK & S upto 100% of RDF and decrease in oil content with increasing in fertility while highest protein content recorded with highest value of 150% of RDF during a field trial, in Indian mustard.

Khambalkar et al. (2012) reviewed during seed inoculants (Azotobactor and PSB), and FYM in combination with chemical fertilizers, positive influx of N, P and K over unfertilized control and other combinations of fertility. The B: C ratio was higher for chemical fertilizer along with Azotobactor and PSB in pearl millet (4.0) due to lesser cost of cultivation compared to other treatments, where as it was highest (4.0) with 100% NPK+FYM (@10t/ha/year) + Azotobactor + PSB in mustard. Thus, INM with organic manure, inoculants and chemical fertilizers not only provided higher productivity but also sustained the soil fertility.
2.1.5. Effect of combined use of inorganics & organics on yield and quality of mustard

Lal & Dravid (1993) reported, that in a green house experiment, application of P and S alone or in combination either with silicate or FYM increased D.M. production and P and S uptake in mustard (B. juncea). FYM was superior to silicate.

Chauhan et al. (1995) reported, that seed inoculation of B. junces cv. RH-30 with Azotobacter or Azospirillum significantly increased seed yield. The higher rate of nitrogen increased values of yield components and seed yield but decreased oil content.

Chauhan et al. (1996) observed highest seed yield of mustard (B. juncea cv. RH-30) by 50 kg S + 60 kg N + Azotobacter inoculation treatment. Seed yield increased with upto 30 kg N in the inoculated crops. Patel et al. (1996) found, that seed yield increased with upto 10 t FYM (2.72 t ha⁻¹) was highest with 75 kg N (2.87 t) and was higher with fertilizer containing (2.80 vs 2.56 t).

Patel et al. (1996) observed, that the P and S uptake and stover yield were significantly higher in treatments where FYM was applied at either rate. N and S contents in seed and stover and N, P and S uptake and seed stover increased with increasing rate. Patel & Shelke (1998) reported, that yields, yield component values and oil and protein contents were greater with than without FYM and generally increased with increasing P and S rates. Net returns were quarter with than without FYM, increased with increasing S rate, but highest with 80 kg P.

Patel et al. (1998) found, that P content in stover S content in seeds and stovers and N uptake, P and S uptake and seed and stover
yields were significantly higher with FYM manure applied at 10 or 20 t ha\(^{-1}\). Increasing N rate progressively raised the N and S contents in both seed and stovers, raised N, p and S uptake and raised seed stover yields.

**Patel & Shelke (1999)** observed, that increased by increasing levels of phosphate and sulphur upto 120 kg P\(_2\)O\(_5\) and 60 kg S ha\(^{-1}\), respectively. Application of FYM gave great absolute growth rate, leaf area index, specific leaf area, biomass duration and crop growth rate as compared to control.

**Patel & Shelke (1999)** stated that FYM significantly increased the yield attributes, seed and stover yields, oil and protein content and net return of mustard compared with controls, parameters, seed stover yields, oil and protein content and net return upto 80 kg P2O5 ha\(^{-1}\). Yield components increased with upto 60 kg S ha\(^{-1}\).

**Ram & Pareek (1999)** reported, that the seed and straw yields were increased by 30 kg P\(_2\)O\(_5\) compared with 15 kg or no P. Application of 60 kg S ha\(^{-1}\) increased seed and straw yields compared with no S seed inoculation with P.S.B. increased by seed & straw yields compared with no inoculation.

**Patel & Shalke (2000)** found, that FYM application increased the mean seed yield, net returns, oil, protein yield and nutrient content. Total N, P and S uptake were also higher in FYM treated vs FYM untreated plants. Sulphur at 30 and 60 kg ha\(^{-1}\) resulted in higher seed and stover yields and higher net returns. Increasing doses of S increased the oil and protein yield N, P and S uptake, as well as the available P and S in poet harvest soil.
**Jat et al. (2000)** observed, that the application of up to 10 t FYM + 30 kg N and 20 kg P$_2$O$_5$ ha$^{-1}$ significantly increased plant height, dry matter and seed yield over the control. Harvest index was not affected significantly by FYM + N and P. **Sachan et. al. (2000)** recorded higher concentration of nitrogen in dry matter at 60 DAS as well as in grain and straw of both maize & wheat crops with use of Azotobacter at all N levels and FYM application, and without N application.

**Singh & Nad (2000)** stated, that mustard seed yield was increased by FYM and P with NPKS + FYM giving the highest yield. N uptake by mustard was increased by N and FYM, whereas S uptake was increased by N, P and FYM, whereas S uptake was increased by N, P and FYM, with half N + P K S + FYM giving the greatest uptake of both elements.

**Shukla et al. (2002)** reported the highest seed yield per plant and seed yield per hectare were obtained with the application of 50 and 100% of the recommended fertilizer rates (120:40:20 kg N:P:K ha$^{-1}$) + FYM (10 t ha$^{-1}$) + S (rate not given) + Zn (25 kg ha$^{-1}$) + B 1 kg ha$^{-1}$) + Azotobacter (10 kg ha$^{-1}$ seed).

**Shankar et al. (2002)** found FYM at 10 t ha$^{-1}$ increased the seed yield significantly at 100% NPK, S, Zn and B and Azotobacter enhanced the seed yield by 15.6, 23.0, 5.0, 26.8 and 31.8% at 100% NPK and 14.1, 26.5.32.4 and 38.2% at 75% NPK respectively. FYM and S significantly increased the oil content. However Zn, B and Azotobacter did not significantly improve the oil content. Generally, seed oil content was less in 75% than 100% NPK plots. FYM, S, Zn, b and Azotobacter for enhanced the seed protein content at both NPK levels.

**Dhaka & Kumar (2003)** observed seed and grain yields increased with increasing N rate up to 80 kg ha$^{-1}$. Integration of P with n produced
higher yield compared to N at 80 kg ha\(^{-1}\) alone. Oil content decreased while oil, protein content and yield increased with increasing N rate. **Vermicompost at 10 t ha\(^{-1}\)** produced significantly higher seed yield compared to **FYM and O.M.** applied, but oil content decreased with increasing organic matter applied.

**Tolanur & badanur (2003)** conducted a field experiment to study the effect of inorganic fertilizers coupled with organic manure and green manure on organic carbon, available N, P and K in inceptisol and then found significantly improved the organic carbon content and available N, P and K were significantly influenced by the use of 50% n through organic manure in conjunction with RFD.

**Vyas et al. (2003)** found, positive balance of available N, P\(_2\)O\(_5\) and K\(_2\)O in soil when soyabean fertilized either with **FYM** alone or along with micronutrients. Seed treatment with na molybdate + **FYM** showed highest build of n (6 kg ha\(^{-1}\)), P\(_2\)O\(_5\) (3 kg ha\(^{-1}\)) and K\(_2\)O (7 kg ha\(^{-1}\)) at the harvest of soyabean.

**Singh & Pathak (2003)** observed, that the content and uptake of N, P, K, S, Mg and Zn were also recorded higher with 40 kg K\(_2\)O + 30 kg Mg + 40 kg S + 5.25 kg Zn along with **azotobacterization** in comparison to other treatments. Integrated application of nutrients along with **azotobacterization** of seeds also caused beneficial and significant effect of protein and starch contents. **Kumar et al. (2007)** recorded highest yield, biological yield and all the quality contents (oil, protein, stover) with combinations of DEPC+FYM and inorganic fertilizers during a two year experiment in Indian mustard.

**Deol et al. (2008)** reported significant increase in plant height, branches, number of siliquae, seed weight, seed yield and oil yield of
mustard with 100% RDF of NPK with FYM & vermicompost along with seed treatment by Azotobacter.

Kumpawat (2010) observed that residual effect of integrated nutrient management practices was also equally effective in improving the yield and nutrient uptake of mustard. Application of FYM 5 tonnes/ha along with Rhizobium+PSB recorded the highest seed yield of mustard (1 642 kg/ha), followed by treatments receiving 25% RDP+vermicompost 1.25 tonnes/ha with Rhizobium+PSB (1 600 kg/ha) and 25% RDF+FYM 2.5 tonnes/ha with Rhizobium+PSB (1 594 kg/ha).

Singh et al. (2010) stated that the mean plant height, total dry matter accumulation, leaf area and seed yield were higher when 100% RDF (120:40:20:40::N:P₂O₅:K₂O:S kg ha⁻¹) were applied with FYM @ 10 t ha⁻¹, ZnSO₄ 25 kg ha⁻¹ and seed treatment with azotobactor & oil content was decreased at higher fertility levels but it improves with application of FYM & Azotobactor, Protein content was increased with higher fertilizers but reduces the glucosinolate content in seed in mustard crop.

Tripathi et al. (2010) conducted a field experiment on Indian mustard & found significant increase in yield with 75% RDF+FYM+S+Zn+B+Azotobacter, while addition of zinc, boron and seed treatment with Azotobacter reduced the glucosinolate content at both RDF and 75% RDF.

Nandi, et al. (2012) conducted An enrichment study on vermicomposting of nutrient supplemented and microbially inoculated mixture of mustard crop residue and farm weeds with fresh cattle dung using Eisenia foetida in pits. Mixture of composting material was supplemented with 0.5 per cent urea, 1.0 percent beneficiated rockphosphate, 0.15 per cent of ferrous and zinc sulphate and inoculated
with lignocellulolytic microorganisms (Trichoderma viride, Cellulomonase fimi and Bacillus sp.), Azotobacter chroococcum, Bacillus megaterium and 500 adult earthworms pit\(^{-1}\) were released according to treatments making seven combinations. During vermicomposting, composting mixtures were analysed for cellulase activity and microbial populations. At harvest, fresh vermicompost yield, earthworm density, C : N ratio, nutrient contents and humus fractions were recorded. Results revealed that combination of both nutrient supplementation and microbial inoculation positively influenced in increasing the macro and micro nutrient content, humus fractions, earthworm density and quality of vermicompost in respect of lower C : N ratio and less fresh vermicompost yield. Cellulase activity and microbial (bacteria, fungi and actinomycetes) populations were higher in enriched vermicomposting pit than control during the process of decomposition.

Khambalkar et al. (2012) reviewed during seed inoculants (Azotobactor and PSB), and FYM in combination with chemical fertilizers, positive influx of N, P and K over unfertilized control and other combinations of fertility. The B: C ratio was higher for chemical fertilizer along with Azotobactor and PSB in pearlmillet (4.0) due to lesser cost of cultivation compared to other treatments, where as it was highest (4.0) with 100% NPK+FYM (@10t/ha/year) + Azotobactor + PSB in mustard. Thus, INM with organic manure, inoculants and chemical fertilizers not only provided higher productivity but also sustained the soil fertility.

2.1.6. Effect of INM on oil Content & oil Yield

Mieth et al. (1983); Murphy and Cummins. (1989) found that oil and protein content is under both genetic and environmental control. Protein content has generally shown an inverse relationship to oil content, however its content being higher and oils content lower when seed is grown under warm dry conditions and vise versa. Three major classes of
proteins have been identified in Brassica oilseeds, albumins, globulins and oleosins. The albumins are water soluble proteins largely responsible for the metabolic activity of the seed. Globulins are salt-soluble protein, which constitute 70 percent of the protein of mature seed. Oleosins are are structural proteins of oil bodies, which can constitute as much as 20 percent of the total seeds protein.

Wither. (1992); Tomer et al. (1992) stated that increase in crude protein content and decrease in oil content with successive increase in NPK fertilization. Zhao et al. (1993) observed S application increased seed protein and methionine content at the expense of aspartic acid at the high N rate. Singh et al. (1994) observed increase in crude protein content and decrease in oil content with successive increase in NPK fertilization.

Kimber and McGragregor. (1995) reported that Brassica oilseed contain 20 to 30 percent proteins on a whole-seed basis, which adds to the value of the seed. The meal by product of oil extraction contains between 36 to 44 percent protein and is generally used as an animal feeds, although some work has explored the preparation of protein isolates and concentrates for human consumption.

Kachroo. (1995) observed increase in seed protein content with increasing N and S rates, while seed oil content increased with increasing S and decreased with N application. Tomar et al. (1996); Thakral et al. (1996) observed increase in crude protein content and decrease in oil content with successive increase in NPK fertilization.

Aulakh and Pasricha. (1998) reported significant increase in protein content with optimum amount of N, N+S and N+S+ green
Khurana et al. (1998) Two percent increase in oil content was found with the combined application of S and Zn.

Sandhya et al. (1999) stated that total and non polar lipids in seeds were highest with 10 or 20 ppm S, while polar lipids like phospholipids and glycolipids were the lowest, on the other hand, at higher doses of S (30 or 60 ppm) a reverse trend was observed at all the stage of seed development. Prasad. (2000) observed slight increase in oil content up to 90:30:15 kg N:P$_2$O$_5$:K$_2$O ha$^{-1}$ and beyond which the oil content decreased.

Kumar. (2001); Kandpal. (2001) reported that successive addition of supplementary nutrients resulted increased oil content and maximum value was recorded when FYM, S, Zn, B and Azotobacter (seed treatment) were applied with 50 percent of the RF level (120:40:20 kg ha$^{-1}$ NPK) in mustard (B. juncea) and Karan Rai ( B. carinata), respectively.

Singh et al. (2010) observed mean seed yield of mustard with 100% recommended fertilizers (120:40:20:40 :: N:P2O5:K2O:S kg ha$^{-1}$) increased by 41.2% over application of recommended fertilizers. More application of fertilizer increased protein content but reduced the glucosinolate content in seed. Oil content decreased at higher inorganic fertility levels but application of FYM and Azotobacter improved it. The recommended fertilizers combined with application of FYM+ZnSO4+seed treatment gave the highest N, P, K, S and Zn content as well as their uptake in seed and stover.

Parmar and Parmar (2012) got result that the increasing levels of nitrogen caused a significant decrease in palmitic, stearic, linolenic and erucic content of oil and its significantly highest value were noted under the lowest level of nitrogen (50 kg N ha$^{-1}$). However, the application of
nitrogen at the rate of 100 kg ha\(^{-1}\) significantly increased oleic and linoleic acid content. Among the different levels of S, application of sulphur at the rate of 45 kg ha\(^{-1}\) significantly increased palmitic, stearic, oleic and linoleic acid content. Similarly, increasing levels of sulphur caused a significant decrease in linolenic and erucic acid contents. The interaction effects showed that application of 100 kg N ha\(^{-1}\) and 45 kg S ha\(^{-1}\) significantly increased chlorophyll ‘a’, ‘b’ and total chlorophyll; oleic and linoleic acid over rest of treatment combination. Whereas, the interaction effect of N x S was non-significant in respect to oil content; stearic acid, oleic and linolenic acid content of oil.

**Foster and Malhi (2013)** conducted a field experiment on a Black Chernozem (Udic Boroll) silty clay soil at Melfort, Saskatchewan, to determine the effects of seeding date on forage dry-matter yield (DMY) and quality [**protein and acid detergent fiber (ADF) contents**] of four annual crops [barley (Hordium vulgare L.), oat (Avena sativa L.), triticale (\(\times\)Triticeae Wittmack L.), and foxtail millet (Setaria italica L. Beauv; hereafter called Golden German millet)] with various maturities as well as different growing-season temperature and moisture requirements. And got the findings suggest that date of seeding of annual forage crops would affect forage yield, and rainfall distribution throughout the growing season also plays a significant role in annual crop forage yields. As long as there is adequate precipitation later in the growing season, late seeding can also result in good forage yields.

2.1.7. Effect of INM on plant Nutrients content and Uptake in Mustard

**Chaudhary. (1978)** found the reduction in fertilizer level produced lower uptake of N, P and K in mustard cv. Varuna. **Holmes. (1980)** reviewed uptake of nitrogen by the R&M crop is large-larger than that of
any other nutrient except potassium. Maximum total uptake (excluding roots) may be over 20 kg ha\(^{-1}\) with a variation between 104 to 257 g ha\(^{-1}\). Most (about 67%) of this variation is associated with difference in dry matter production. He further reported uptake of phosphorus between 30 and 55 kg P ha\(^{-1}\) in winter-rape and between 1 to 10 kg P ha\(^{-1}\) in autumn-rape. A good crop of rape with total dry matter produce of 12 t ha\(^{-1}\).

*Kumar. (1986)* reported the N content and uptake of mustard plant was more at flowering stage (1.42 to 1.76%) than at harvesting stage (1.07 to 1.77%) with increasing in nitrogen levels from 0 - 120 kg N ha\(^{-1}\)

*Rana and Singh. (1991)* reported that the application of nitrogen from 0 to 150 kg ha\(^{-1}\) significantly increased the N content in both seed and stover of mustard. *Krishna and Singh. (1992)* stated the application of Zn increased Zn content and uptake while decreased the content and uptake of P and S in seeds and stover. *Liu at al. (1992)* reported that the application of Zn increased Zn concentration in all plant organs except seeds.

*Zhao et al. (1993)* observed that the total uptake of 80-100 kg S ha\(^{-1}\) was similar in both double low and single low cultivars. Application of 100 kg S ha\(^{-1}\) increased the S uptake by 10-15 Kg, while the application of 300 kg N ha\(^{-1}\) increased S uptake by 29-34 kg ha\(^{-1}\). S distribution within the pods differed significantly.

*Dubey and Khan. (1993)* found the percentage of total plant S presents in the pods were significantly increased by N application and slightly decreased by S application. Application of S stimulates the nitrogen and sulphur content in mustard plant at every crop growth stage. *Yadav et al. (1996)* found while delay in sowing or irrigation significantly increased the N, P and K content if plant tissues at all growth stages. *Lu*
et al. (1998) observed significantly higher P concentration in plant parts without Zn than with Zn application. An increase in P supply had a non-significant effect on Zn concentration but significantly increased the P concentration and P uptake in shoots.

Eriksen and Mortsen. (1999) reviewed the amount of N and S in harvested seed and straw were closely related but N:S ratio decreases when S was applied on the basis of soil and plant analysis they further concluded that the S application was capable of raising S concentration well above critical level.

Yeshpal, et al. (2008) carried out an experiment and got reductions in yield due to application of inorganic fertilizers below the recommended level and also the benefits in yield due to integrated nutrient management (INM) in mustard (Brassica juncea cv. Kranti). The NPK levels applied were 100, 75 and 50% of recommended fertilizer (RF) through inorganic fertilizers alone and in combination. Significant reduction in yield and yield contributing parameters (such as number of branches, number of siliquae and plant height) was recorded with reduction in fertility levels during both years. Similar trend was recorded in uptake of N, P, K, S, Zn and B nutrients. Significantly highest values of plant height, number of branches, number of siliquae, and seed and oil yield were recorded with T6 where complete INM package was applied along with 100% of RF, followed by T12 and T18 where the same INM package was applied along with 75 and 50% of RF level. Significantly higher uptake values of N, P, K, S, Zn, and B were also recorded in these treatments.

Singh et al. (2010) results revealed that quality parameters like oil and protein content in seed and their yield were influenced significantly by various fertility levels. Oil content increased significantly with increasing
fertility level up to 100% RDF (F2) and thereafter decreased with increase in fertility. However, protein content increased with increasing in fertility level and recorded the highest value at 150% RDF (F4). The uptake of N, P, K and S by seed and stover of crop increased concurrently with increasing fertility level and maximum were recorded at the highest fertility level.

Ankit, et al. (2012) reviewed that the uptake of nitrogen by mustard seed showed a significant increase in different treatments as compared to control. Maximum uptake (63.88 kg/ha) obtained in T_{16}, was at par with 100% NPKS + FYM + Azotobacter (T_{15}). Minimum uptake (31.12 kg/ha) was recorded in control. Phosphorus uptake by mustard indicated a significant increase in different treatments except 100% N alone (T_{7}), compared to the control. Maximum P uptake (14.05 kg/ha) in T_{16} was significantly more than all the other treatments except T_{15}, T_{12} and T_{6}. The K-uptake by seed indicated a significant increase due to all the treatments over control. Maximum K-uptake (13.53 kg/ha) was noticed under 100% NPKS + FYM + Azotobacter + PSB (T_{16}), was at par with T_{15} and T_{5}. Sulphur uptake by mustard seed indicated a significant increase in different treatments, as compared to control. Maximum uptake (21.64 kg/ha) observed under T_{16} was at par with 150% NPKS level. The uptake of N, P, K and S was the lowest in the plants which received no fertilizer or manure treatment (T_{1}). The investigation further revealed that straw yield varied from 40.32–76.59 q/ha and increase in straw yield was to the tune of 34.32-89.95% over control.

2.2. STUDIES ON MOONG (SUCCEEDING CROP)

2.2.1. Effect of INM on yield and yield attributes of Moong

Arya and Kalra (1988) found that application of phosphorus had no effect on growth of summer moong, while number of pods per plant, weight of pods per plant, weight of grains per plant, number of grain per
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pod, number of grains per plant, grain yield, dry matter and harvest index were found to be increased with increasing levels of phosphorus from 0 to 50 kg P$_2$O$_5$ ha$^{-1}$.

**Kothari and Sarraf (1990)** reported that increasing P rates from 0 to 13 and 26 kg ha$^{-1}$ increased DM and seed yield. **Meena et al. (1993)** reported that green gram yield increased with increasing N rates applied to preceding wheat crops and was increased by freshly applied P fertilizer. **Tomar et al. (1996)** reported highest index and net returns of vigna radiate with a sowing rate of 40 kg ha$^{-1}$ application of 60 kg P$_2$O$_5$ ha$^{-1}$ and irrigation of 150 mm (cumulative pan evaporation).

**Dudhat et al. (1996)** conducted an experiment by growing wheat in rabi season using 5 mt castor cake or 15 mt FYM and/or the recommended chemical fertilizer rates of 120 kg N + 60 kg P$_2$O$_5$ ha$^{-1}$ or half dose NP rates. Green gram was grown in summer on residual effect of these fertilizers and reported that wheat yield was highest with castor cake plus recommended NP fertilizers, while green gram seed yield was higher from the residual effect of FYM and inorganic fertilizers.

**Rundal et al. (1999)** reported that application of 60 kg P$_2$O$_5$ through phosphocompost significantly increased the growth, dry matter and yield (18.23q ha$^{-1}$ of green gram compared with application of 60 kg P$_2$O$_5$ ha$^{-1}$ through phosphor FYM, phosphor-vermicompost, phosphor-poultry manure, phosphor-pressmud, phosphocity compost and single super phosphate.

**Reddy et al. (2000)** reported that application of FYM @ 10 t ha$^{-1}$ increased dry matter/plant, pods/plant and seed yield of black gram over no FY application, similarly soil inoculation with PSB and different levels of phosphorus increased dry matter, number of pods and seed yield.
Patra (2001), while conducted an experiment to determine the effect of P at 0, 50 and 100 kg ha\(^{-1}\) on several legumes and the residual effect of P on the productivity and N economy of the succeeding crop (wheat cv. Sonalika) N at 0,60 and 120 kg ha\(^{-1}\) was also applied to winter wheat, reported that among legumes (soyabean, mung, black gram and rice bean) Soyabean had the highest yield and was most efficient in terms of residual effect on the succeeding wheat crop. He also reported that P at 50 kg ha\(^{-1}\) produced the highest legume seed or fodder yields, grain yield of wheat increased with increasing levels of P applied to previous arop and with increasing N rates.

Bharat et al. (2003) conducted a study on summer moong and found a significant increased the grain yield with different P levels (0, 30, 60 and 90 kg/ha) with inoculation by PSM. Singh and Pathak (2003) reported that combined seed inoculation in moong bean with rhizobium and PSB recorded the highest values and proved superiority over no inoculation of nodules per plant and nodule dry weight by 19.21 and 15.28% respectively.

Tomar et al. (2003) reported that P application and inoculation of VAM, PSB and phosphorus rates (0, 20 and 40 kg ha\(^{-1}\) increased grain and straw yield, N and P content in black gram. Upadhyay (2003) found that the application of 100% RFD + ZnSO\(_4\) + borax during rainy season and 100% RFD + PSB + azotobacter during winter resulted in the highest grain yield of soyabean and wheat, total straw production by soyabean and wheat and combined yield.

Abraham and Lal (2004) found while conducted an experiment on blackgram-wheat system that plant dry weight values showed no significant difference between 100% and 33% RFD levels. They also
reported that organic manure application showed increased yield over control.

**Shilpa-Dahatonde et al. (2005)** reported while conducted an experiment on wheat- greengram cropping system that 40 kg P2O5 per hectare through DAP along with PSB seed treatments recorded the highest grain yield of green gram.

**Sripriya et al. (2005)** reported a 10% increase in grain yield of moong by applying pressmud, Rhizobium and PSB without chemical fertilizer over control. **Vyas, S.P. (2005)** stated that the spray of antitranspirants(kaolin, methanol, phenylmercury acetate(PMA)) on summer moong(vigna radiate) cv. Pusavasaki, improved the number of branches, number of pods per plant, 1000-seed weight, seed size and drymatter yield significantly, but effect was not significant on plant height although height increased by 15.1% and 12.5% under kaolin and methanol but it decrease with PMA spray.

**Kahlon et al. (2006)** observed highest halum (2942 kg ha⁻¹) and grain yield (2208 kg ha⁻¹) of cowpea by applying 50 kg P + 20 kg S + 10 kg Zn ha⁻¹ + PSB + VAM. **Sripriya et al. (2006)** reported that biofertilizers (PSB & Rhizobium) along with pressmud proved to be beneficial in achieving increase in yield without use of fertilizers (NPK) in green gram.

**Singh et al. (2007)** report the improvement in seed yield and water use efficiency under bed planting over those under flat planting, irrespective of level of phosphorus application. Bed planting system using 33.54 cm water against 51.41 cm used by flat planting system (34.7% saving) recorded 10.48 q/ha seed yield of summer moong against 9.91 q/ha under flat planting.
Mankar and Nawalakhe (2009) found in a study the effect of INM on yield and yield attributes of cotton and greengram and quality parameters of cotton they apply 25 kg N through fertilizer and 25 kg N through FYM+25 kg P2O5 (T7) recorded maximum and significantly more yield parameters and yield of cotton as well as greengram and lint index and seed index of cotton. The ginning per cent remain unaffected. Also the same treatment proved the best in respect of yield of cotton (6.99 q ha-1 pooled mean) as well as greengram (4.36 q ha-1 pooled mean) under cotton+greengram intercropping and was followed by 50 kg N+25 kg P2O5 ha-1 through inorganic fertilizer i.e. 100% RDF (T2).

Juhi et al. (2011) supplies the nutrients through chemical fertilizers along with biofertilizers(Azotobactor, Azospirillum) with different levels of doses but they got highest production with PSB+80 kg N ha\(^{-1}\) in moong crop in an experiment and got The difference in the growth parameters such as plant height, length to branch, no. of pods, pod length and grain yield.

2.2.2. Effect of INM on nutrient composition and their uptake by Moong

Ravankar and Badhe (1975) observed an increase in the test weight of urd and moong with the application of 120 and 80 kg P2O5 ha\(^{-1}\) respectively. They further observed an increase in the N uptake by these crops due to phosphorus application.

Malewar et al. (1990) reported that increasing Zn rates upto 15 kg ha\(^{-1}\) increased seed N, protein, carbohydrates, Zn, Fe, and K contents and decreased Ca and Mg content. Rao and Singh (1991) found that inclusion of moong to maize-wheat rotation increased N availability by 12.6% in control and by 3.7% in the largest wheat yield target.
Singh et al. (1995) reported an increase in seed protein N and P content by applying P and Zn in moong, but decreased the Mg and Ca content. Parveen et al. (2002) reported the highest phosphorus (0.39%) and nitrogen (2.96%) contents in greengram treated with inoculation of phosphate-solubilizers (Bacillus species + Pseudomonas vilgaries).

Ved-ram et al. (2002) reported that moong bean responds significantly to the application of sulphur, Zn and biofertilizers, Nitrogen with Rhizobium and Azotobacter inoculation, Sulphur and Zn significantly increased nutrient uptake compared to their respective control. Phosphorus exhibited a synergistic interaction with sulphur but showed antagonistic interaction with Zn.

Bharat et al. (2003) found in an experiment that P application and PSM inoculation affected the content and uptakes of N, P and K in moong significantly. Parmanik and Singh (2003) recorded significantly higher nitrogen, phosphorus and sulphur uptake by grain and stover with inoculation of PSB + Rhizobium in green gram.

Dhamishkodi et al. (2009) revealed the effect of different sources of sulphur viz. Single superphospate, Gypsum, elemental sulphur and magnesium sulphate on grain yield and quality of black-gram, they found significant increase in protein content and amino acids like methionine and cysteine.

Rather and Sharma (2009) found Significant improvement owing to appropriate combination of NPK, PSB, zinc and FYM was observed for the nutrient uptake by the wheat and the maximum nutrient uptake was noticed due to 100% Rec. NPK+PSB+Zn+FYM and minimum with control. The yield and nutrient uptake of succeeding mung crop grown on residual
fertility showed a significant effect under INM treatments and were highest for treatment T17 comprising of 100% rec. NPK+PSB+Zn+FYM. Soil fertility in terms of available NPK and Zn after the harvest of mung crop had shown a significant effect by adopting INM practices.

**Kumar et al. (2010)** reported that the effect of calcium and sulphur was studied on plant height, no of leaves, leaf area, dry matter and no of pods & yield of seed per plant and 1000 seed weight of mungbean (Vigna radiate L.) & resulted in a significant increase in yield and attributes.

**Patel et al. (2010)** conducted an experiment the result revealed that sulphur levels significantly influenced on quality parameters, Grain yield, Protein content and uptake of Sulphur by summer green-gram.

**Patel et al. (2010)** conducted an experiment the result revealed that sulphur levels significantly influenced on quality parameters, Grain yield, Protein content and uptake of Sulphur by summer green-gram.

**Singh and Singh (2010)** during an experiment effect of application of Sulphur and cobalt on growth, yield and nutrient contents response of mungbean. Sole application of fertilizer at RFD significantly enhanced yields as compared to combination with RFD + sulphur and cobalt produce grain yield (4.45 q/ha) which was at par with the yield 5.25 obtained due to RFD & also increased content & uptake of nutrients.

**Kujar et al. (2010)** evaluate the production potentials of pigeonpea (Cajanus cajan L.) in sole and intercropping with different duration resulted maximum growth and development & nutrient uptake (NPK) and NPK content.
Tabassum et al. (2011) viewed that significant increase in productivity of grain and straw yield and also found significant nutrient uptake by cowpea.

Chesti and Tahir (2012) conducted an experiment on nutrient availability and yield of green-gram as influenced by organic manures, phosphate solubilizers and phosphorus levels, results revealed that application of organic manures significantly increased available N, P and K, grain and straw yield of green–gram.

Quddus et al. (2012) conducted a field experiment on Chickpea-Mungbean-T.Aman cropping pattern at Pulses Research Sub-Station, Madaripur, results revealed that among the treatments the highest seed and stover/straw yields in mungbean (2208 kg/ha and 5121 kg/ha) and T.Aman (5414 kg/ha and 5615 kg/ha) were recorded in treatment T2. After completion of two years’ pattern cycle, the organic matter, total nitrogen, phosphorus, sulphur, zinc, and boron were higher in treatment T2, also found that the soil test based fertilizer dose may be considered as suitable dose for this cropping pattern that ensure higher yield and increase soil fertility.

2.3. INFLUENCE OF INM ON SOIL PROPERTIES

Reddy and Reddi. (1997) found that FYM improves the residual soil fertility because entire amount of nutrients present in FYM is not available immediately. About 30 percent of nitrogen, 60-70 percent phosphorus and 70 percent of potassium are available to first crop.

Lal and Mathur. (1998) reviewed the long term fertility experiment in acidic red loam soil of Ranchi and reported that continuous application of N fertilizer lowered the soil pH by 0.8 units and with NP and NPK by 0.3
units. After 10 years lowered by 0.6, 0.9 and 0.7 with N, NP, and NPK respectively. After 28 years of cropping pH decreased from initial value of 5.5 to 3.8, 3.9 and 4.0 in N, NP and NPK respectively.

Patnaik et al. (1989) found in a number of long term experimental studies, addition of FYM with inorganic fertilizers increased the organic matter content, available P and K of soil over the years. Bhandari et al. (1992) reported that applying NPK fertilizers alone or in combination with organic sources of N, increased available N and P by 5-22 kg and 0.8 to 3.8 kg ha\(^{-1}\) respectively from their initial values. Jagat and Sharma (1995) conducted an experiment on green gram grown in the plots previously sown to wheat or pigeonpeas and reported that P application to pigeonpea and wheat significantly increased the available P status of soil.

Chetteri et al. (1998) found that Farm Yard Manure (FYM) is an important manure on farm input which does not increase soil fertility but also improves general soil health. FYM in association with inorganic fertilizers increased the availability of major and minor nutrients by improving physical and chemical environment of the soil.

Ravankar et al. (1998) while conducted an experiment sowing soyabean, green gram, groundnut and pigeonpeas in kharif using 0,15,30 or 45 kg ha\(^{-1}\) and wheat in Rabi on the same fertility and observed that soil organic carbon was highest after soyabean and groundnut.

Kumar. (2000) found that organic carbon content helps in maintaining soil fertility and productivity under modern intensive farming, organic carbon is gradually depleting, hence its maintenance is of utmost importance. Continuous cropping without fertilizers caused a fast decrease in organic carbon.
Singh and Swarup. (2000) reported that continuous cropping for 12 years reduced the pH from 9.2 to 8.5. Mohanty and Sharma. (2000) reported that reduction in soil pH is low in case of inorganic treatment alone whereas reduction in pH is significant in NPK plus FYM treatment plots.

Pasoquin and Ragme. (2001) reported that 6th year, there was no difference of organic carbon. However, the total carbon was highest in treatment with FYM and NP + GM. Yaduvanshi. (2001) reported use of inorganic fertilizers with organic and green manures significantly enhanced the organic carbon content of the soil. Sharma and Sharma. (2002) reported that different combinations of NPK had no significant effect of organic carbon content of soil. Whereas, combinations of NPK resulted in higher organic carbon content in soil than N alone. Application of NPK resulted in significant increase in organic carbon content of soil over NPK application.

Kumar et al. (2002) reported that organic carbon percent of soil decreased to 0.23 from its initial value of 0.37 after 16 cycle of rice-wheat sequence. However, the organic carbon increased to 0.461 percent with the application of 100 percent NPK through fertilizers. The combined use of fertilizers and organic N sources (50% NPK + 50% FYM) further increase the level of organic carbon to 0.58.

Patidar and Mali (2002) reported that residual effect of FYM, 75% and 100% recommended level of fertilizer (N and P) significantly influence the available P status in soil. Charjan (2005) reported that NPK concentration in plants and available NPK in soil were highest with FYM at 10 t ha⁻¹ and green manure + Azotobacter species + PSB except for P.
Kumar Yadav. (2003) reported that pH of the soil decreased considerably from their initial value (8.8) in mineral fertilizer treated plot and in combination with organic N source but reduction was higher in FYM with 50-57 percent mineral fertilizer plot.

Ghosh et al. (2004) reported that organic carbon status at 5 locations viz., Ludhiana, Jabalpur, Bangalore, Ranchi and Bhubaneshwar was found maximum in 100 percent NPK + FYM over all other treatments.

Qureshi et al. (2005) reported that combined application of phosphate solubilizers with FYM improved the organic carbon status and proliferation of phosphate solubilizers. Niranjan and bharat (2005) reported that increase fertilizer levels enhanced available N, P and K in soil.

Satish, Chander and Tripathi (2006) highlights the importance of INM, which encompasses all the sources of plant nutrients i.e. organic manures, biofertilizers and chemical fertilizers. They advocated that INM is not only essential for substantial agricultural production but also for improving soil health. They further reported that an application of 8 mt ha$^{-1}$ of FYM to wheat each year along with 100% recommended NPK dose, lead to higher yield, restored the organic carbon status and improved availability of N,P,K and micronutrients.

Paslawar et al. (2007) conducted an experiment on pigeonpea+soyabean intercropping system and found soil heath of organic treatments were improved particularly in organic carbon and available N status, while bulk density of soil was reduced from 1.54 to 1.44 g cc$^{-1}$.

Singh (2007) reported that soil quality in terms of RSQI (residual soil Quality index) was increased by 12-19 units in INM trial as compared
to 7-9 units in farmers practice (FP). He also stated that the soil quality in terms of C.E.C, pH, N.P.K, Organic matter, soil texture etc increased upto 58% under INM trial.

**Gable et al. (2008)** found the significant improvement in physico-chemical properties of soil like pH, electrical conductivity, bulk density, field capacity and permanent wilting point, with the application of 75% RDF+25%N through leucaena+ biofertilizer, during the experiment to study the effect of integrated nutrient management in maize-chickpea cropping system on physico-chemical properties of soil.

**Arun et al. (2009)** conducted an experiment to assess the effect of integrated nutrient management of fertilizers and farm yard manure(FYM) on soil physiochemical properties in rice-niger cropping system, and they found significant increasing value of physicochemical properties like Bulk density, O.C.content, pH of surface & subsurface & highest value of cation exchange capacity with application of 50% of NPK along with 50% of FYM.

**Ramesh et al. (2009)** found the grater uptake of nutrients, soil organic carbon, soil biological parameters (dehydrogenase, phosphatase and microbial biomass carbon), and available soil N, P and K compared to RDF and control, also recorded that Soil bulk density and mean weight diameter were not affected by the treatments, during experiment on effect of organic nutrient management practices in mustard & its residual effect on soil properties.

**Rather and Sharma (2009)** conducted a field experiment at research farm of A.S. (P.G.) College, Lakhaoti, Bulandshahar (Uttar Pradesh, India) to find out the effect of integrated nutrient management applied to wheat (Triticum aestivum) on soil properties and fertility status. The result revealed that a significant improvement in soil properties and
fertility status was found under treatment (T20) comprising of 100% Rec. NPK+Vermicompost+Zinc+PSB. Organic carbon content of soil improved from 3.0 to 4.6 g/kg soil, bulk density reduced from 1.50 to 1.32 tonnes/m3, water holding capacity increased from 20.32 to 23.72%, available N from 197.0 to 219.0 kg ha\(^{-1}\), available P from 13.0 to 19.1 kg/ha\(^{-1}\), available K from 113.0 to 130.4 kg ha\(^{-1}\) and available Zn from 1.50 to 1.87 mg kg\(^{-1}\) soil by the integration of organics with inorganics. However, the pH and electrical conductivity of soil were not reflected to a considerable extent.

Babar & Dongle (2011) conducted an experiment to study the effect on residual fertility by INM in mustard-cowpea-rice cropping sequence and found a significant improvement in soil fertility parameters viz., bulk density, porosity, organic carbon content, microbial count & content of available nutrients (NPK) with the application of organic, inorganic & organic + inorganic sources of nutrients compared to control treatment.

Khambalkar et al. (2012) reviewed during seed inoculants (Azotobactor and PSB), and FYM in combination with chemical fertilizers, positive influx of N, P and K over unfertilized control and other combinations of fertility. The B: C ratio was higher for chemical fertilizer along with Azotobactor and PSB in pearlmillet (4.0) due to lesser cost of cultivation compared to other treatments, where as it was highest (4.0) with 100% NPK+FYM (@10t/ha/year) + Azotobactor + PSB in mustard. Thus, INM with organic manure, inoculants and chemical fertilizers not only provided higher productivity but also sustained the soil fertility.

Malhi (2012) Conducted a field experiment on S-deficient Gray Luvisol (Typic Haplocryalf) soil to determine the relative effectiveness of N alone versus combined annual application of N (120 kg N ha\(^{-1}\)) and S (15
kg S ha\(^{-1}\)) fertilizers to a wheat-canola rotation on storage of total organic C (TOC) and N (TON) and on the light fraction organic C (LFOC) and N (LFON) in soil. Compared to N alone, annual applications of S fertilizer in spring in a combination with N resulted in an increase in soil of TOC (by 2.18 Mg C ha\(^{-1}\)), TON (by 0.138 Mg N ha\(^{-1}\)), LFOC (by 1,018 kg C ha\(^{-1}\)), and LFON (by 42 kg N ha\(^{-1}\)). The relative increases in organic C or N due to S fertilizer application were much higher for the light organic fractions (36.9% for LFOC and 27.5% for LFON) than for the total organic fractions (9.2% for TOC and 7.3% for TON). The findings demonstrate the importance of a balanced/combined application of N and S fertilizers to crops in storing more organic C and N in this S-deficient soil.

**Quddus et al. (2012)** conducted a field experiment on Chickpea-Mungbean-T.Aman cropping pattern at Pulses Research Sub-Station, Madaripur, results revealed that among the treatments the highest seed and stover/straw yields in mungbean (2208 kg/ha and 5121 kg/ha) and T.Aman (5414 kg/ha and 5615 kg/ha) were recorded in treatment T2. After completion of two years’ pattern cycle, the organic matter, total nitrogen, phosphorus, sulphur, zinc, and boron were higher in treatment T2, also found that the soil test based fertilizer dose may be considered as suitable dose for this cropping pattern that ensure higher yield and increase soil fertility.

**Niaz et al. (2013).** Carried a study on associated with wheat-cotton rotation in 80 farm fields, belonging to different soil series, in four districts of cotton belt of Punjab, Pakistan to assess concentrations of extractable B in soils and found the Boron fertilizer demonstration plots laid out at farmers’ fields low in extractable B, in each district not only enhanced grain yields of wheat crop but also contributed a significant increase towards seed cotton yield of succeeding cotton crop through
residual B effect. In conclusion, the findings suggest that many soils in the cotton belt of Punjab may be low in extractable B for wheat and cotton, especially when these crops are grown on low OM soils

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