REVIEW OF LITERATURE
CHAPTER - II

REVIEW OF LITERATURE

Mustard is an important crop of *Rabi* season in India. The review of literature on various aspects of "Integrated nutrient management in relation to soil properties, yield and quality of mustard" have been presented under following heads:

2.1 Integrated Plant Nutrient Management on yield attributes and yield.

2.2 Integrated Plant Nutrient Management on quality of mustard.

2.3 Integrated Plant Nutrient Management on soil properties.

2.4 Integrated Plant Nutrient Management on nutrient uptake by mustard.

2.1 INM on yield attributes and yield of mustard:

Pathak and Tripathi (1979) found that the sulphur significantly increased yield attributing character and growth of main mustard variety Varuna. However, significant positive correlation was found between seed yield in mustard with Zn application.

Singh and Chauhan (1979) reported that the application of sulphur 40 kg, Zn 10 kg and boron 1.0 kg ha\(^{-1}\) significantly increased the plant height, dry matter yield, number of primary and secondary branches and grain yield of mustard variety Varuna. Singh and Singh (1984) notice in factorial combination of 0, 40, 80, or 120 kg S ha\(^{-1}\) as powdered gypsum and soil moisture level of 95, 140 or 160 mm in the top 1 m of profile, increased seed yield by 14.7-38.1 kg ha\(^{-1}\).
Chatterjee et al. (1985) carried out experiment on intensively cultivated sandy loam soil containing 75-100 ppm S, 0.05-0.5 Ca, 5 ppm B, 12-15 ppm Zn, 16 and 96 g available P and K ha\(^{-1}\), respectively, revealed that application of 20 kg S ha\(^{-1}\) through gypsum in conjunction with borax (10 kg ha\(^{-1}\)) increase 42% in seed yield of mustard. Borax, zinc sulphate (equivalent to 20 g S ha\(^{-1}\)) and gypsum when compared alone, production increase 34, 26 and 39% in yield, respectively. The increase in yield was due to an increase in the number of siliqua per plant and 100 seed weight.

Seed yield of *Brassica juncea* were increase by N rates from 0 to 120 kg, S rate from 0 to 30 kg ha\(^{-1}\) and by applying 10 kg Zn and 1.0 kg B ha\(^{-1}\) (Saini et al. 1985) Tiwari (1985) reported that the significant increase in seed yield of mustard (*B. juncea*) was obtained by applying S, Mn or Zn.

Singh et al. (1986) reported that the mustard grown on an alluvial soil given NPK and pyrite at 400 kg ha\(^{-1}\) increased the seed yield from 1.43 to 1.83 q ha\(^{-1}\).

Khan et al. (1986) noticed that the different combination of 0 or 100 kg N and 0, 50, 75 or 100 kg P\(_2\)O\(_5\) ha\(^{-1}\) were applied to mustard crop, the highest seed yield was with 100 kg each N and P\(_2\)O\(_5\) ha\(^{-1}\) (1, 0.8 ha\(^{-1}\) ) when compared with 0.7 t ha\(^{-1}\) without fertilizer. Increasing P and K rates increased plant height, branches per plant, pods per plant, length of main shoot and 100 seed weight, pod number on the main shoot did to increase above 100 kg N + 50 kg P\(_2\)O\(_5\).

Singh et al. (1988) investigated in field experiment during Rabi (winter) season 0, 25, 50, 75 and 100 ppm S (elemental and gypsum) were applied to *B. Juncea* cv. T-59 and found increased seed yield to a maximum of 1.64 t ha\(^{-1}\).
Krishna and Singh (1992) conducted an experiment on Indian mustard *Brassica juncea* cv. Varuna, given 0, 15, 30 or 45 kg ZnSO$_4$ ha$^{-1}$, seed yield increased with up to 30 kg ZnSO$_4$. Similarly on clay loam soil at Sabour (Bihar) 0, 25, 50, 75 or 100 kg N as urea 0, 25, 50, 75 or 100 kg S ha$^{-1}$ applied to *Brassica juncea* cv. Pusa Bold, seed yield increased with up to 75 kg N and 50 kg S. A further increment of 25 kg N and 25 kg S decreased oil yield followed a similar pattern to seed yield (Mohan and Sharma, 1992).

Mandal *et al.* (1992) reported in cv. B-67 was given 30, 60 or 90 kg N, 33.6 or 67.2 kg P and 0 or 10 t FYM ha$^{-1}$, seed yield increased with rate of N, P and FYM application. There was a significant interaction between the effect of N, P and FYM application. Same as application of 25 kg N+ 50 kg P in the inorganic form produce oil yield of 0.50 t ha$^{-1}$ (Tomar *et al.* 1992).

Dubey and Khan (1993) reported at Powerkhed (M.P.) in *B. juncea* cv. Varuna which was given 0-90 kg N ha$^{-1}$ and 0-50 kg S ha$^{-1}$. Dry matter production plant$^{-1}$, seed yield increased up to 30 kg S ha$^{-1}$. Khanpara *et al.* (1993) conducted experiment on clay loam soil at Udaipur (Rajasthan) *B. juncea* cv. Kranti with 0-60 kg N and 50 to 200 kg S ha$^{-1}$ and reported that dry matter production per plant, LAI at 59% flowering, number of primary and secondary branches per plant and seed yield ha$^{-1}$ increased with up to 100 kg S ha$^{-1}$ only.

In a field experiment of Zn deficient (0.56 ppm) sandy loam soil 6 mustard (*Brassica juncea*) cultivars supplied with 0, 5 and 10 kg Zn ha$^{-1}$ as zinc sulphate produced mean seed yield 1-66, 1-76 and 1-92 t ha$^{-1}$. Oil yield was 735, 75 and 847 kg ha$^{-1}$, respectively (Singh *et al.* 1993).

Sardana and Sindhu (1994) in a trial at Ludhiana on the integrated requirement of India rape intercropping system reported that organic manures
(GM/FYM) increased oil yield of component crops significantly over without organic manures and also with successive levels of N and P upto N\textsubscript{75}+75 and P\textsubscript{2}O\textsubscript{5}, respectively. But oil yield was maximum with green manure.

In a experiment on a clay loam (containing 18.7 kg available P and 8.20 ppm S) during the Rabi season at Udaipur, Rajasthan. \textit{B. juncea} cv. T-59 was given 0-60 kg P\textsubscript{2}O\textsubscript{5} and 0-75 kg S ha\textsuperscript{-1}, results dry matter yield were increased with upto 40 kg P\textsubscript{2}O\textsubscript{5} and 50 kg sulphur (Jain \textit{et al.} 1995).

Tomar \textit{et al.} (1995) reported that the 0-90 kg N + 40 kg P\textsubscript{2}O\textsubscript{5} + 20 kg K\textsubscript{2}O + 0-50 kg sulphur ha\textsuperscript{-1} was applied to \textit{B. juncea} cv. Varuna sown in rcw 30 cm apart sown on 11 November and 28 October, respectively. Seed and stover yield were increased withioncrease in N and S rate. However, Trivedi \textit{et al.} (1995) reported in \textit{Brassica juncea} grown on Rabi season received 0, 45 or 90 kg N, 0, 20 or 40 kg P\textsubscript{2}O\textsubscript{5} and 0 or 60 kg sulphur and observed that highest seed yield, stover yield was with the application of 90 kg N+40 kg P\textsubscript{2}O\textsubscript{5} + 60 kg sulphur.

Ali \textit{et al.} (1996) reported that nitrogen up to 120 kg ha\textsuperscript{-1} increased the yield components (plant height, primary branches plant\textsuperscript{-1} and seeds siliqua\textsuperscript{-1}) seed yield, stover yield and harvest index of the Indian mustard. Yield attributes, seed and stover yield, HI progressivelly increased with the level of sulphur.

Singh and Kumar (1996) investigated the effect of four level of nitrogen 0, 30, 60 and 90 kg ha\textsuperscript{-1} and three levels of sulphur 0, 20 and 60 kg ha\textsuperscript{-1} on growth, yield attributes and yield of Indian mustard cv. NDR-8501 under rainfed condition of eastern U.P.. Significant increase in growth, yield attributes and seed and stover yield was recorded with increase in levels of nitrogen up to 60 kg ha\textsuperscript{-1}. Sulphur @ 40 kg ha\textsuperscript{-1}significantly increased the
growth, yield attributes and yield of Indian mustard compared with 0 and 20 kg S ha$^{-1}$.

Subbiah and Mitra (1996) reported that the acid lateritic soil (containing 2 ppm Zn, 0-36 ppm B, 0-91 ppm Mo) at Kharagpur (West Bengal). *B. juncea* cv. Varuna, application of Zn with recommended 80:40:20 kg NPK ha$^{-1}$ increases seed yield by 26% and 18% increase in seed yield was associated with increase in siliqua plant$^{-1}$, seed per siliqua and 1000 seed weight. While Borare (1997) observed that the application of gypsum @ 20 and 90 kg S ha$^{-1}$ significantly increased the seed yield of mustard variety Varuna.

Singh and Singh (1997) at Hisar showed that application of FYM @ 5 and 10 t ha$^{-1}$ significantly increased the growth yield attributes and yield of sunflower over no FYM and Azotobacter incubation. There was 10% and 16% increase with 5 and 10 t FYM, respectively over no FYM. Increasing levels of N and P significantly increased plant height, yield attributes and seed yield up to 80 kg N and 40 kg P$_2$O$_5$ ha$^{-1}$ and leaf area, dry matter and stalk yield up to 120 kg N and 60 kg P$_2$O$_5$ ha$^{-1}$. Increase in seed yield over the control was 36.7% and 58.7% with 40 and 20 kg and 80 and 40 kg N and P$_2$O$_5$ ha$^{-1}$ in combination with 10 t FYM ha$^{-1}$ gave seed yield at par with 80 kg N and 40 kg P$_2$O$_5$.

Tripathi and Sharma (1997) conducted a field trial at Azamgarh (U.P.) in loam soil on *B. juncea* having four levels nitrogen 0, 30, 60 and 90 kg ha$^{-1}$ and three levels of sulphur viz., 0, 20 and 40 kg S ha$^{-1}$. Yield component and yield was increased with increasing level of N and S. Further, Trivedi and Sharma (1997) at Gwalior (M.P.) evaluated that the nitrogen and sulphur fertilization significantly increased the seed yield.
A field experiment conducted by Deekshitulu et al. (1998) at Bapatta (A.P.) on *B. juncea* cv. Seeta was given 0, 50, 100 or 150 kg N ha⁻¹ and 0, 25 or 50 kg S ha⁻¹. Seed and oil yield increased with increasing N and S rate.

Jaggi (1998) studied the individual and interactive effect of different rate of S and P fertilizers on Indian mustard cv. Varuna. Seed yield was increased by S application at 60 at kg ha⁻¹. S application of 30, 60 and 90 kg ha⁻¹ increase seed yield by 121, 157 and 176%, respectively, compared with no sulphur. Similar increases in seed yield with P₂O₅ rates of 30 and 60 kg ha⁻¹ were 36% and 82% respectively. A significant positive interaction between the two nutrients increasing seed and straw yield was observed giving the highest seed (21.50 q ha⁻¹) and straw (69.0 q ha⁻¹) yield with combined application of sulphur and phosphorus at their maximum rates. An improvement in seed straw ratio accompanied by early crop maturity, as evident from the flower count, was affected by both the nutrients at their sole application rates of 30 kg ha⁻¹. Highest seed : straw ratio (0.33) was evident from the treatment combinations of 60 kg S and 60 kg P₂O₅ ha⁻¹.

Khurana et al. (1998) at Fatehpur, Punjab to study the effect of applying 0-40 kg sulphur and 0-11 kg zinc ha⁻¹ on *B. juncea* cv. RL-19, S and Zn application increased *B. juncea* seed yield. The highest seed yield of 1.09 t ha⁻¹ was obtained with 20 kg S +11 kg Zn, which was 45.3% higher than control yield.

Mankotia and Sharma (1998) examined that the intercropping Gobhi and Toria were given 40, 80, 120 or 160 kg N ha⁻¹, 40 or 80 kg P ha⁻¹ and FYM 5 t ha⁻¹, observed that seed yield of Gobhi and Sarson increased with increasing supply of N, P and FYM.
Patel and Sheik (1998) found the yield and yield component values were greater with than without FYM and generally increased with increasing P and S rates. Patel et al. (1998) at Anand (Gujrat) gave 0, 10 or 20 t FYM ha\(^{-1}\) and 25, 50 or 75 kg N ha\(^{-1}\) as urea + DAP or Ammonium sulphate + SSP. Seed and stover yield is significantly higher with FYM applied at 10 or 20 t ha\(^{-1}\). Increasing N rate progressively raised seed and stover yield.

Purkayastha and Nad (1998) conducted an experiment in trypic ustovrept soil on Indian mustard cv. Pusa Bold gave 0-90 kg S and 0-60 kg Mg ha\(^{-1}\). In combination with 1 ppm Mo. The highest yield was by combined application of all nutrients. Singh et al. yield was by combined application of all nutrients. Singh et al. (1998) conducted experiment on mustard cv. Pusa Bold was given various nutrient combination 40 : 20 : 0, 80 : 40 : 5 or 120 : 60 : 10 kg N, P and Zn ha\(^{-1}\) and 0, 30 and 90 kg S, significantly increased the plant height, branches, pods/plant, seed per pod, 1000 seed weight, protein, oil, seed and stover yield was with application of 120 kg N + 60 kg P\(_2\)O\(_5\) + 10 kg S ha\(^{-1}\). Whiole Solanki et al. (1998) reported that the seed yield, number of primary branches plant\(^{-1}\), siliqua plant\(^{-1}\) and test weight of India mustard T-59 increased with increasing level of S up to 60 kg ha\(^{-1}\).

Puri et al. (1999) reported that the highest seed yield (16.8 q ha\(^{-1}\)) was obtained in the treatment 10 : 50 : 20 kg N,P,K ha\(^{-1}\) and also found significantly negative correlation coefficient soil content with yield.

Ram et al. (1999) noticed that the application of 15 kg P\(_2\)O\(_5\) ha\(^{-1}\), significantly increased plant height, dry matter accumulation meter\(^{-1}\) row, number of siliqua plant\(^{-1}\), seed siliqua\(^{-1}\), length of siliqua and test weight over the control (no P) but the number of primary and secondary branches was higher with 30 kg P\(_2\)O\(_5\) ha\(^{-1}\). The seed and straw yield were increased by 30 kg P\(_2\)O\(_5\) ha\(^{-1}\) compared with 15 kg or no P. Application of 60 kg S ha\(^{-1}\)

[11]
increased the number of primary and secondary branches plant\(^{-1}\), dry matter accumulation meter\(^{-1}\) row, yield attributes and seed stover yield compared with no sulphur. Seed inoculation with phosphorus solublizing bacteria (PSB) increased plant height, dry matter accumulation meter\(^{-1}\) row, number of siliqua plant\(^{-1}\), seed and stover yield of mustard compared with no inoculation.

Singh (1999) observed that branches, pod, pod weight, seed weight\(\text{plant}^{-1}\) and 1000 grain weight of mustard cv. Varuna increased significantly with each successive increase in the level of nitrogen from 0-160 kg ha\(^{-1}\) and S from 50 kg + Ca from 0-100 kg ha\(^{-1}\).

Abraham (2000) grown *Brassica juncea* at New Delhi on sandy loam soil having combination of 40 or 60 kg S ha\(^{-1}\) and N 100 or 50 kg ha\(^{-1}\). Chlorophyll and rate of photosynthesis were highest with 60 kg S + 100 kg N ha\(^{-1}\). Kumar *et al.* (2000) noticed an increase in mustard yield by about 165% at the highest rate 60 kg N + 36kg P + 24 kg K ha\(^{-1}\) fertilizer application. But difference between inorganic or combined organic and inorganic fertilizer sources was not significant. However, Nanwal *et al.* (2000) conducted experiment on *B. juncea* cv. RH-30, RH-819 or Laxmi with 0, 20, 40, 60 kg N with and without *Azotobacter*. Growth and seed yield increased with increasing N rate and also with Azotobacter, RH-819 generally gave best yield.

Sakai *et al.* (2000) conducted multi-locational demonstration in farmers field to evaluate the response of mustard to Zn, B and S application in calcareous soils of north Bihar. Available Zn, B and S in the initial soils ranged from 0.35-0.33 and 3.3-8.0 mg/kg, respectively. Application of Zn @ 5 and 10 kg ha\(^{-1}\) in cv. Varuna produced the seed yield response ranging between 300-500, 450-700 kg ha\(^{-1}\), respectively. Addition of B @ 2 kg ha\(^{-1}\)
exhibited the grain yield response ranging between 300 and 500 kg ha$^{-1}$ and seed yield response at 20, 40 kg S ha$^{-1}$ ranged from 200-300 and 400-500 kg ha$^{-1}$ with corresponding percentage yield response varying from 17-23 and 29-38, respectively. The application of micro and secondary nutrients in judicious amount is imperative to enhance the productivity of mustard.

Singh and Nad (2000) grown 6 juncea cv. Pusa Bold treated with NP, NPK, NPKS, FYM, NPKS+FYM or hole N + PKS + FYM. Mustard seed yield was increased by FYM, N and P having best yield with NPKS + FYM.

Kumar et al. (2001) reported that Narendra Rai 1 and Varuna gave higher plant height, branches plant$^{-1}$, Siliqua plant$^{-1}$, seeds siliqua$^{-1}$, 1000 grain yield and HI and resulted significantly higher seed and stover yield than Vardan. The application of 40 and 60 kg S ha$^{-1}$ at par with each other gave significantly higher yield over 20 kg S ha$^{-1}$ as well as no sulphur application. The growth and yield attributing characters also showed similar trend.

Recently Gauri Shankar et al. (2002) carried out field experiment on effect of INM on yield of mustard. The results revealed that highest seed yield was recorded with 100% recommended NPK along with 10 t FYM ha$^{-1}$ and Azotobacter inoculation.

Mandal and Sinha (2002) reported that the plant height branches plant$^{-1}$, siliqua plant$^{-1}$, seeds siliqua$^{-1}$, 1000 seed weight, seed and oil yields of Indian mustard were improved at 100% recommended dose of NPK (80 : 17.2 : 3.3.2) + FYM @ 10 t ha$^{-1}$ when compared with 100% NPK alone. It was par with 100% NPK + borax @ 10 kg ha$^{-1}$, ZnSO$_4$ @ 20 kg ha$^{-1}$ and 50% NPK + 10 t FYM + 10 kg borax + 20 kg ZnSO$_4$ ha$^{-1}$. Seed yield increased by 27, 26 and 25% at 100% NPK + FYM, 100% NPK + borax + ZnSO$_4$ and
50% NPK + FYM + borax + ZnSO₄, respectively over 100% NPK and 134, 132 and 130 in the corresponding treatments over control.

2.2 Integrated plant nutrient management on quality of mustard:

Pathak and Tripathi (1979) found oil percentage increased where as nitrogen decreased significantly. Optimum dose of sulphur and nitrogen were 80 kg and 120 kg ha⁻¹, respectively. Singh and Chauhan (1979) noticed that application of sulphur 40 kg ha⁻¹, Zn 10 kg ha⁻¹ and Boron 1.0 kg ha⁻¹ significantly increased the oil content in mustard seed variety Varuna.

Singh (1984) notice in combination of 0, 40, 80 or 180 kg S ha⁻¹ of gypsum increased oil and allyl isothiocyanate content increased with increasing S rate. Saini et al. (1985) reported that oil content decreased with increasing N rates and increased slightly with S, Zn and B application.

Singh et al. (1986) reported that the mustard grown on an alluvial soil given NPK and pyrite @ 400 kg ha⁻¹ increased the protein and oil contents in seeds.

Singh et al. (1988) investigated in field experiment during Rabi season 0, 25, 75 and 100 ppm S (elemental and gypsum) were applied to Brassica juncea cv. T-59 and found increased oil content in seeds. Gypsum was superior to elemental sulphur.

Krishna and Singh (1992) carried an experiment on India mustard B. juncea cv. Varuna given 0, 15, 30 or 45 kg ZnSO₄ ha⁻¹ reported that oil, protein and glucosinolate content increased with Zn application. Application of no fertilizer, 40 kg N + 20 kg P + 20 kg K ha⁻¹ double or triple of these gave 39.66, 39.29, 38.66, 37.85% oil content in mustard seed (Tomar et al. 1992).
Dubey and Khan (1993) carried an experiment on *Brassica juncea* cv. Varuna given 0-90 kg N ha\(^{-1}\) and 0-50 kg S ha\(^{-1}\) and reported that oil content increased with up to 40 kg S ha\(^{-1}\).

Sardana and Sindhy (1994) in a trial at Ludhiana on the integrated requirement of India rape + swede rape intercropping system reported that organic manures (GM/FYM) increased protein content of component crops up to though significantly up to oil yield of component crops also increased significantly with organic manures and also with successive levels of n and P upto N\(_{100+50}\) and P\(_{30}\), respectively. Increase in protein and oil content was comparatively more with FYM over GM, but oil yield was maximum with GM.

Trivedi *et al.* (1995) suggested in *Brassica juncea* grown on Rabi season received 0, 45 or 90 kg N 0, 20 or 40 kg P\(_2\)O\(_5\) and 0 or 60 kg S ha\(^{-1}\) and observed the highest oil and protein content in seed was with application at 90 kg N, 40 kg P\(_2\)O\(_5\) and 60 kg S and also reported that seed oil content was decreased by increasing N, but was increased by increasing P and S rates.

Ali *et al.* (1996) reported that increasing level of N decreased the oil and increased the protein content in seed but sulphur increased the oil content and decreased the protein content in seeds while Bora (1997) observed that application of gypsum @ 20 and 90 kg S ha\(^{-1}\) significantly increased seed oil content and oil yield of mustard variety Varana.

Trivedi and Sharma (1997) evaluated the nitrogen and sulphur fertilization significantly increased the oil and protein yield and also the protein content in the mustard seeds. Higher dose of N decrease oil content in
seeds, where as sulphur application upto 60 kg ha$^{-1}$ significantly increased mustard oil content.

A field experiment carried out by Deekshitula et al. (1998) on *B. juncea* cv. Seeta was given 0, 50, 100 or 150 kg N ha$^{-1}$ and 0, 25, or 50 kg S ha$^{-1}$ and reported oil content increased with increasing S rate, but peaked with 100 kg N, then decreased.

Khurana et al. (1998) conducted an experiment at Fatehpur, Punjab on *B. juncea* cv. RL-617 applied 0-40 kg S and 0-11 kg Zn ha$^{-1}$ and reported oil content in seed was increased by 20% by the combined application of S and Zn.

Patel and Sheike (1998) found oil and protein contents were greater with than without FYM and generally increased with increasing P and S rates. Abraham (1999) at New Delhi gave 40 or 60 kg S and 100 or 150 kg N ha$^{-1}$ to *B. juncea* cv. Pusa Jaikisan and found total oil content was highest with 60 kg A + 100 kg N. While Dileep and Arvind (1999) grown Indian mustard cv. Kranti at Pant Nagar 0-160 kg N and 0-60 kg S ha$^{-1}$ applied. Seed oil content decreased with increasing N rate and increased with increasing S. Where as protein concentration as increased by both S and N.

Abraham (2000) grown *B. juncea* applied 40 or 60 kg S and 100 or 150 kg N ha$^{-1}$ and reported soluble protein content were highest with 60 kg S + 10 kg N ha$^{-1}$. However, Nanwal et al. (2000) given 0, 20, 40, 60 kg N ha$^{-1}$ with and without *Azotobacter* reported oil and protein, content increased with increasing N rate and also with *Azotobacter*.

Kumar et al. (2001) reported that Narendra Rai 1 and Varuna gave higher oil and protein content that Vardan. The application of 40 and 60 kg S ha$^{-1}$ at par with each other gave significantly higher protein and oil content in
seed over 20 kg ha\(^{-1}\) as well as no sulphur application. Use of farm yard manure (FYM) and sulphur increased the oil and protein content in mustard seeds significantly (Gauri Shankar et al. 2002).

Singh and Nad (2002) investigated different combinations of nutrients on protein, oil yield and oil quality in mustard cv. Pusa Bold. Protein yield was largely governed by N and P. The content and yield of oil were favourably influenced by the secondary nutrients (S, Mg and Ca). Though both protein and oil yield were improved by N and S, addition of excess N rate resulted in lower saponification and higher iodine values. Addition of S and P had the opposite effect.

2.3 Effect of integrated plant nutrient management on soil properties:

Singh (1961) reported that application of BGA in usar soil increased the organic matter, water holding capacity and exchangeable calcium when compared with control. In long term experiment Prasad et al. (1989) found that the application of manurews and fertilizers together increased organic carbon, NH\(_4\)-N, NO\(_3\)-N and P in soil, pH as well as organic carbon decreased with increased time of inoculation. Organic carbon decreased with the increase in combination of inorganic fertilizer with organic manures was better than fertilizer or manure alone.

Kumar and Tripathi (1990) reported that incopraion of FYM wi 100% NPK increased N, P, organic carbon, aggregate stability and water retention in soil as compared to 100% NPK alone. While Chauhan (1992) noticed that the application gypsum or pyrite appreciably decreased pH, EC and ESP of a highly deteriorated sodic soil of Indo Gangetic Plains.

Ram et al. (1992) studied the effect of Azospirillum, 10 t FYM ha\(^{-1}\) and 40 kg N + 30 kg P + 20 kg K ha\(^{-1}\) alone or in combination on organic
carbon content of soil. Highest organic carbon was measured with application of 10 t FYM ha\(^{-1}\). Sharma (1992) applied the recommended N, P, K and 6 t FYM ha\(^{-1}\) and found increased water holding capacity and improved physico-chemical properties of the soil.

Kabeerthumma (1993) conducted and experiment on continuous cropping of cassava applied organic and inorganic fertilizers and reported that application of FYM along with NPK help the soil zinc status.

Katyal (1993) evaluated the application of organic manures and biofertilizers, FYM poultry manure, human excreta, city compost, green manure, wheat straw and Azolla on soil. They reported improved soil organic carbon and phosphorus status, enhanced nutrient availability, improved soil structure and reduced soil erosion. Patel and Suiphu (1993) observed that application of gypsum improved pH, EC, ESP and infiltration rate of saline sodic soils.

Patiram and Singh (1993) reported that after three year of application of organic carbon, available phosphorus, CEC, exchangeable Ca\(^{+2}\), Mg\(^{+2}\) and K\(^{+}\) of the soil and decreased the amount of exchangeable Al\(^{+3}\) exponentially. Sinha and Sakal (1993) reported that conjunctual combined use of pyrite and organic manures appreciable increased the available sulphur status of sulphur deficient calcareous soil. Higher levels of pyrite in combination with organic manures proved very effective even up to the third crop after application with respect to sulphur nutrition of crop in that calcareous soil.

More (1994) reported that application of 25 t ha\(^{-1}\) FYM + 20 t pressmud ha\(^{-1}\) decreased the pH and ESP of the soil, infiltration rate increase due to application of organic wasted and manure. All the treatments increased

[18]
the content of organic carbon, available N, P and K in soil particularly by FYM + Pressmud.

Kumar and Yadav (1995) reported the effect of long term field experiment of different soil properties. N and P content in soil were increased more with the application of FYM along with NPK fertilizers than NPK fertilizer alone.

Bellakki and Badanur (1997) conducted field experiment at Regional research station Bijapur. Application of sunhemp in combination with fertilizer improved the infiltration rate, water soluble aggregates, porosity, field capacity and maximum water holding capacity under dry lands. Continuous application of organic matter increase the CEC and exchangeable calcium while a decrease in Na, bulk density and CaCO3 was observed. Application of 10 t flyash ha⁻¹ in groundnut increased available NPK and exchangeable Ca⁺⁺, Mg⁺⁺ and also micronutrients like Zn⁺⁺, Cu⁺⁺, Fe⁺⁺ and Mn⁺⁺ and proved better in improving soil properties.

Bellakki et al. (1998) obtained that application of various organic materials to meet 50% N along with 50% NPK significantly increased the availability of major and micronutrients in soil. Similary application of organic manure influenced favourably the physico-chemical properties of the soil like bulk density, maximum water holding capacity, organic carbon content, CEC, C : N ratio (Panda et al. 1999).

Santhy et al. (1999) reported that the highest microbial biomass and N content under the integrated use of organic manure (FYM) + inorganic fertilizer (NPK). The continuous application of varying quantities of inorganic fertilizer and combination of NPK + FYM did not alter the soil pH
appreciably where as a slight increase in salt content was observed with 100% NPK + FYM.

Sharma (1999) concluded that the treatment involving FYM and crop residues applied either alone or in combination with reduced levels of fertilizer N and P were most effective in buildup of soil fertility in the long run. Vasanthi and Kumaraswami (1999) reported that, organic carbon content and fertility status reflected by the available status of N, P and K micronutrients and CEC were higher and bulk density lower in the treatments that received vermicompost + N, P and K than in the treatment with N, P and K alone.

Gauri Shankar (2000) conducted an experiment on mustard cv. Varuna various INM modules and reported that highest total NPK content in soil was observed under treatment consisting 100% NPK + FYM followed by treatment having 75% NPK + FYM.

Kumaran and Solaimali (2000) found that application of 34 : 17 : 54 kg NPK ha\(^{-1}\), 12-5 t FYM ha\(^{-1}\) + 17 kg P\(_2\)O\(_5\) (30 DAS) + 400 kg gypsum ha\(^{-1}\) (40 DAS) to irrigated groundnut recorded significantly highest soil available N, P, K after crop harvesting. The organic materials applied alone or in combination with inorganic fertilizer gave greater residual soil fertility in term of increase in organic carbon content from 0.36% to as high as 0.61% and the available N, P and K in the second year cropping cycle.

Very recently Gauri Shankar et al. (2002) carried out on effect of integrated nutrient management on properties of soil revealed that application of farm yard manure along with inorganic fertilizer improved the bulk density, organic carbon content, CEC and available N, P and K content in soil at harvest of crop.
Choudhary et al. (2003) reported that availability of N, P and K and Zn was higher under sulphur application as compare to no sulphur application N, P, K, S and Zn availability in soil after harvest of the crop increased significantly with the addition of sulphur upto 60 kg ha\textsuperscript{-1}.

2.4 Integrated pant nutrient management of nutrient uptake by mustard:

Nad and Goswami (1983) conducted experiment in pot culture and found that by the direct application of sulphur increases S uptake irrespective of the sulphur status of the soil. Singh and Singh (1984) conducted experiment on calcareous clay vertisol. The S content tended to decrease with increasing crop age. Elemental S was more stable and gave 16.9, 15.3, 17.2 and 16-7% more S uptake at 25, 45, 60 and 75 days after sowing, respectively over the control. Soil applied gypsum, elemental S potassium sulphates, ferrous sulphate and sulphuric acid caused 18.3, 17.3, 29.3, 58.7 and 58% more uptake of S, respectively, over the control. Foliar spray of sulphate salts also produced differences in content and uptake of S but of low magnitude. Foliar spray of sulphate of iron, zinc and manganese and sulphuric acid gave 5.9, 5.0, 1.7 and 10.7% more S uptake, respectively, over the control.

Singh et al. (1986) noticed that the mustard grown on an alluvial soil given NPK and application of agricultural grade pyrite at 400 kg ha\textsuperscript{-1} increased N and S uptake. The residual pyrites increased N and S uptake of the subsequent crop. However, Singh et al. (1988) investigated in field experiment during Rabi season 0, 25, 50, 75 and 100 ppm S (elemental of gypsum) were applied to B. juncea cv. T-59 increased N, P, K and S uptake of NPK and S by seeds. Gypsum was superior to elemental S of N and S uptake, application of sulphur as well as P increased the concentration and uptake of NPK and S.
Dravid and Goswami (1988) examined that the application of P alone or in combination with Zn or FYM significantly increased total P uptake and percentage P utilization in mustard. At Allahabad (U.P.) 0, 50, 75 and 100 kg P$_2$O$_5$ and 0, 5 and 10 t poultry manures ha$^{-1}$ applied to *B. juncea*. The highest P, S and Fe uptake were obtained with 100 kg P$_2$O$_5$ and 10 t manures ha$^{-1}$ (Prasad *et al.* 1991).

Jahan *et al.* (1992) conducted field experiment with 14 different treatment combination of N, P, K and S on sandy loam of Sonatala (Bangladesh) in *B. juncea*. Nutrient uptake by the crop reflected a complementary relationship between N and S fertilizer application Krishna and Singh (1992) revealed that Zn application increased uptake and decreased the content and uptake of P and S in seed and stove, Tiwari and Singh (1992) reported that the 30 kg S ha$^{-1}$ increased the content of sulphur in mustard crop significantly by using gypsum.

Dubey and Khan (1993) reported that application of sulphur up to 30 kg ha$^{-1}$ increased the S and N content in plant and seeds significantly. Whereas, Singh *et al.* (1993) reported that the Zn uptake increased in seed and straw with increasing its rates ZnSO$_4$.

Sinha and Saka (1993) applied pyrite @ 0, 2, 4 and 8 q ha$^{-1}$ and organic manures @ 10 t ha$^{-1}$ each of FYM and pressmud separately as well as in combination with pyrite to lentil in sulphur deficient calcareous soil. Application of pyrite, FYM and pressmud appreciably increased concentration and uptake of sulphur by grain. Higher level of pyrite either alone or in combination with organic manure proved very effective with respect to S nutrition of the crop.
A field experiment conducted by Dubey and Khan (1993) revealed that the N @ 90 kg ha\(^{-1}\) and application of sulphur up to 100 kg ha\(^{-1}\) significantly increased the N content in plant and seed of the mustard under irrigated vertisol.

Jain et al. (1995) reported in a clay loam soil containing 18.7 kg ha\(^{-1}\) available P and 8.2 ppm S, the *Brassica juncea* cv. T-59 was provided 60 kg P\(_2\)O\(_5\) and 75 kg S ha\(^{-1}\) increased the uptakes of N, P, K and S in seed and stover.

A field experiment conducted at Central Research Station, Akola in combination of 25 kg N and 50 kg P\(_2\)O\(_5\) + 10 t FYM, found to be best one regarding uptake of N, P and K in the form of both kerr\_al and haulm were recorded in P\(_2\)O\(_5\) + FYM treatment (Deshmukh et al. 1995).

Tomar et al. (1995) suggested that the 0-90 kg N + 40 kg P\(_2\)O\(_5\) + 20 kg K\(_2\)O + 0-40 kg S ha\(^{-1}\) in Varuna increased the N content and N uptake in the plant and seed with increase in N rate and was higher at early growth stages up to 45 DAS.

Patel and Sheike (1998) observed that the quality of the Indian mustard was influenced with FYM application due to more uptake of phosphorus and sulphur as they play an important role in oil synthesis and protein metabolism.

Patel et al. (1998) conducted an experiment at Anand during 1992-94 *B. juncea* was given 0, 10 or 20 t FYM ha\(^{-1}\) and 25, 50 or 75 kg N ha\(^{-1}\) as urea + DAP or Ammonium sulphate + SSP, P content in stover, S content in stover and seed and N uptake during 1st year, P and S uptake in both the year were significantly higher with FYM applied at 10 or 20 t ha\(^{-1}\) increasing N

[23]
rate progressively raised the N and S content in seed and stovers, raised N, P and S uptake.

Purkayastha and Nad (1998) observed that uptake of N, P and K in *Brassica juncea* is higher with the increase in S level. Singh and Singh (1998) observed that increasing levels of N significantly enhanced the nutrient content and uptake in promising Indian mustard varieties.

Molewar *et al.* (1999) conducted experiment in vertisol associated with 25 treatment combinations revealed that uptake of N, P and K by crop were significantly higher under the treatments receiving FYM 10 t ha⁻¹ + full recommended dose of N, P, K (80 : 40 : 40) and flyash (10 t ha⁻¹) alone over other fertilizer treatments.

Mishra *et al.* (1999) studied that the uptake of N, P and K by crops was greater with than without lime and increased with increasing S rate. Puri *et al.* (1999) noted significantly influence of varying degree of soil fertility status on nutrient concentrations of major nutrients (%) were in the following order: N (2.1) > K (0.76) > P (0.62) > Ca (0.566) > Mg (0.225) > S (0.218). The removal of major nutrients was significantly affected by fertilization. The N and P content in seed and total removal of nutrients (NPK) were significantly affected by level of fertilization (NPK).

Raut *et al.* (2000) noticed significantly higher content of sulphur and phosphorus in straw and seed and total uptake of sulphur, nitrogen and phosphorus by mustard crop in treatment receiving 60 kg S ha⁻¹.

Sakal *et al.* (2000) applied Zn, B, S in calcareous soils of Bihar and Noticed, increasing level of Zn, B and S progressively increased the uptake of Zn, B and S by the crop. However, Singh and Nad (2000) studied that the N-S interaction with respect to the direct effect of different combinations of
nutrient uptake in mustard. The total N uptake values in mustard were significantly higher due to the individual application of N or FYM, whereas, the total uptake of S was increased by inclusion of P, N and individual treatments of FYM.

Mandal & Sinha (2002) very recently studies nutrient uptake by Indian mustard as influenced by different INM treatments and notice significant improvement owing to appropriate combination of nitrogen, phosphorus, potassium, FYM, borax and zinc sulphate for uptake of nutrients.

Singh et al. (1991) reported mustard (B. juncea) cv. KOS-1 grown at sopore, Jammu and Kashmir in 1986-87 was given 0, 30, 60 or 90 kg N and 0, 20, 48 or 60 kg P$_2$O$_5$ ha$^{-1}$ moong (Vigna radiata) cv. Pusa Baisakhi grown after mustard in the Kharif season was given 20 kg N and 20 kg K$_2$O ha$^{-1}$. Yield opf moong increased with increasing P rate applied to the preceding crop.

Mandal and Sinha (1997) found that the green gram (Vigna radiata) seed yield was the highest (1.52 t ha$^{-1}$) in plot previously grown mustard B. juncea given 40 kg P$_2$O$_5$ + 10 kg Borax ha$^{-1}$. However, this residuLAI treatment combination was statistically at par with 40 kg P$_2$O$_5$ + 20 kg borax ha$^{-1}$.

Bhunia et al. (1998) conducted a experiment in rabi season on mustard cv. RW 351 given 2 or 4 irrigation and 50% of 100% of recommended fertilizer rates of 80 : 40 : 40 kg ha$^{-1}$ on N : P$_2$O$_5$ : K$_2$O. Moong cv. B-105 was grown in summer to determine the residual effect of mustard treatments and found seed and stover yields of Moong were slightly increased by the residual effects of the higher fertilizer rate.
Khurana et al. (1998) reported that a portion of applied nutrients remained in soil after harvesting of mustard, which significantly increase the grain yield and the uptake of SA and Zn in subsequent maize crop.

Singh et al. (1998) carried out experiment on response of Indian mustard (*B. juncea*) and black gram (*Phaseolus mungo*) rotation to S fertilizer application. The residual effect of 80 kg S ha$^{-1}$ increased black gram grain yield by 200 kg ha$^{-1}$ compared with no sulphur.

Kumar et al. (2000) reported that the organic materials applied alone or in combination with inorganic fertilizer gave greatest residual soil fertility in terms of increase in organic carbon content from 0.36% to as high as 0.61% and the available N, P and K in the 2 year cropping cycle.

Singh and Nad (2000) determine residual effect of nitrogen, phosphorus, potassium, sulphur and Farm Yard Manure on a summer crop of Moong (*Vigna radiata*) cv. PS-16 and reported seed yield of moong was only affected by residual N, with NPK giving the greatest yield. N and S uptake were also highest with NPK.