

India is a major producer of rapeseed mustard with an area of about 67m hectare. Among the *rabi* oil seed crops cultivation of rapeseed and mustard is a common practice through out West Bengal. But the productivity is very low in *terai* region of West Bengal. Formulating proper nutrient package for improving the yield and quality of the yellow sarson with proper maintenance of the soil fertility status can minimize the problems related to low productivity. In this chapter an attempt has been made to collect the information as to how the integrated nutrient management and seed soaking agro-chemical influence the growth attributes, yield components and yield of rapeseed-mustard and other crops.

2.1 Effect of chemical fertilizers on growth and yield of crops:

About half of the total increase in food grain production in the post-green revolution era has been attributed to the use of fertilizers (Randhawa, 1992). Venkateswarlu *et al.* (1985) estimated that fertilizer N alone contributed 37% towards increasing the productivity of high yielding rice varieties during the seventies. There is a general need for nitrogen in most rice growing areas while phosphorus and potassium needs are less widespread (Ramiah, 1954). But P application is more important than nitrogen and its absence or deficiency hampers the normal growth of the plant (Sircar and Sen, 1941). Reddy and Reddy(1989) found that the number of panicles of rice increased from 25-44% in first year and 30 to 56% in second year as the level of N increased from 40 to 120 kg as compared to control and the number of filled grains panicle⁻¹ increased by N-application in both the years. Singh and Bajpai (1990) reported that the rice yields (grain and straw) were significantly increased with 100 kg N ha⁻¹ compared to control and also observed that increasing N level up to 150 kg N ha⁻¹ not only reduced the yield significantly than the other but also was at par with the control.

The nitrogen use efficiency decreased with increasing levels of nitrogen. Similar results were also found by Pandey *et al.* (2000). Subbaiah and Mitra (1997) observed that significant increase in panicle was noticed with the increase in P-levels upto 60 kg ha⁻¹ with rice cv. IR 36 in a rainy season. Though application of P significantly increased the grain yield of rice over no application only upto 40 kg P₂O₅ ha⁻¹. Masthan *et al.* (1998) conducted a field experiment at Rajendranagar and reported that rice in *kharif* needed 60 kg P₂O₅ ha⁻¹ to produce maximum grain yield in rice-sunflower-green gram crop sequence.

The potassium showed a greater influence on some physiological parameters with rice. The application of K₂O at 60 kg ha⁻¹ advanced the crop maturity by three days, deletion of K (control) caused delay in flowering. Higher K dressing greatly improved the phytomass production at flowering time which could be ascribed to more carbon assimilation and effective translocation of assimilates to reproductive parts as a result rice yield and its attributing characters responded favourably to higher dose 60 kg K₂O ha⁻¹ of K but not at lower dose (40 kg K₂O ha⁻¹) (Raju *et al.*, 1999). Prasad and Chuhan (1999) also observed that greater K in plants improved the carbohydrate metabolism and hence yield and decreased protein content of rice grain. They also reported that the application of K alone increased nitrogen translocation to the grain during grain filling. Prasad and Chauhan (1999) also reported that the application of N : P (100 : 50 and NPK (100 : 50 : 50) significantly increased the shoot hill⁻¹, effective shoot hill⁻¹ and plant height than only K and control.

Panicle length of mother shoot and number of tiller were significantly higher with 125% level than 75% but on par with 100% NPK level. Number of rachilla panicle⁻¹, panicle weight, grain weight panicle⁻¹, number of grains panicle⁻¹ on mother shoot as well as tiller were significantly increased with the application of 125% level as compared with 75% and 100% NPK levels. Also grain and straw yield maintained the same trend in rice cv. Aswani (Singh *et al.*, 1998).

Patel *et al.* (1988) conducted a field experiment during the summer season and showed significant and the highest number of branches plant⁻¹, pods plant⁻¹, 1000-grain weight and grain yield were obtained with 20 kg N ha⁻¹ and 10 kg N ha⁻¹ + *Rhizobium* inoculation in greengram. Pathak *et al.* (2001) also reported that application of N @ 20 kg ha⁻¹ significantly increased the plant height, pods plant⁻¹, length of pods, seeds pod⁻¹, 1000-grain weight, grain and straw yield of greengram than nitrogen @ 10 kg ha⁻¹ and control and it was at par with that of 30 kg N ha⁻¹.

Rao *et al.* (1993) reported that irrespective of different greengram varieties, all the growth parameters, yield components, grain and haulm yields increased significantly with an increase in P level from 0 to 50kg P₂O₅ ha⁻¹. Phosphorus application increased the grain yield by 18 and 51.2% at 25 and 50 kg P₂O₅ ha⁻¹ over no P in sandy loam soil with a uniform dose of 20kg N ha⁻¹ was applied. The dry matter accumulation, number of nodules plant⁻¹ and nodule weight plant⁻¹ increased significantly with the increasing levels of phosphorus up to 40 kg P₂O₅ ha⁻¹ (Shukla and Dixit, 1996). They also reported that number of pods plant⁻¹ and grains pod⁻¹ and grain yield were significantly increased up to 40 kg P₂O₅ ha⁻¹. Soni and Gupta (1999) also reported the same trend of result and reported that the use of 40 kg P₂O₅ ha⁻¹ increased the protein production (kg ha⁻¹), the values of consumptive water use and water use efficiency, which might be due to better root growth resulting in improved moisture utilization.

Masthan *et al.* (1998) conducted a field experiment in rice-rapeseed-greengram cropping system and observed that the number of tillers and panicles m⁻² number of filled grains panicle⁻¹, test weight, grain and straw yield of rice increased significantly upto 60 kg P₂O₅ ha⁻¹. The yield components of rapeseed in the succeeding *rabi* season improved significantly by the cumulative influence of residual phosphorus applied @ 60 kg P₂O₅ ha⁻¹ to other preceding rice crop and direct effect of 60 kg P₂O₅ ha⁻¹ to rapeseed. According to them the cumulative residual phosphorus through 60-60 kg P₂O₅

ha⁻¹ to rice-rapeseed also increased the mean seed yield of greengram in the following summer, which was superior than residual influence of 60 kg P₂O₅ ha⁻¹ only to rice or only to rapeseed.

Hasan (1999) conducted a field experiment for five consecutive years, 1990 to 1995 with rice-rapeseed and reported that maximum rice-yield equivalent was obtained with the highest dose of P₂O₅ (90 kg ha⁻¹). Similarly maximum rice-yield equivalent was recorded with P applied to both *kharif* and *rabi*. In general, *kharif* applied P recorded more value of over all yields as compared to *rabi* applied P. Rai *et al.* (1990) also observed in a field with rice-wheat cropping that optimum NPK rates were 60 kg N + 35 kg P + 50 kg K ha⁻¹ for rice and 100, 35 and 35 kg N, P and K ha⁻¹ respectively for wheat. They also mentioned that the grain yields were highest (4.95 and 2.42 t ha⁻¹ for rice and wheat respectively) where each crop received 100% of the optimum NPK rate but were not significantly reduced when one crop received the 100% NPK rate or both received 50%. Though Hegde (1998) reported that 120% of recommended NPK to individual crops of the rice-wheat cropping system was required to maintain the productivity and any reduction in fertilizer level to either rice or wheat significantly reduced the gain yield.

Singh and Singh (2000) conducted an experiment in rice-wheat cropping sequence and reported that the yield components, grain and straw yield of rice and wheat significantly affected by different dose nitrogen and potassium to both the seasons. The highest grain and straw yield of rice and wheat was obtained with the application of 120 kg N ha⁻¹ and 60kg K₂O ha⁻¹ irrespective of the time of application to both the seasons.

2.1.1 Effect of chemical fertilizers on growth and yield rapeseed -mustard:

Gill and Narang (1993) carried an experiment in well drained sandy loam soil during winter season on mustard and reported that an increase of nitrogen 0 to 150 kg ha⁻¹ significantly increased the growth and yield over control. They also reported that the maximum dry matter

production, leaf area indices, leaf area duration the crop growth rate were observed with 150 kg N ha⁻¹. On the other hand the order of net assimilation rate was N₅₀ > N₁₀₀ > N₁₅₀, this is basically a reflection of rate achieved per unit of leaf area and as the leaf area component increased (in the fertilized plants), the ratio decreased proportionally. The same trend in growth parameters, dry matter production, leaf area and branches plant⁻¹ were observed higher with higher nitrogen application by Saran and Giri(1988), Sharma and Kumar(1988), Malavia *et al.*(1988) and Khanpara *et al.*(1993).

Khafi *et al.* (1997) concluded that application of N at each incremental level caused significant improvement in yield attributes of mustard variety “Kranti”. They observed from the pooled data that application of 80 kg N ha⁻¹ recorded significantly maximum values of plant height, branches plant⁻¹, siliquae plant⁻¹, seeds siliqua⁻¹ and 1000, seed weight. The increase in nitrogen application significantly increased the grain and stick yield. Similar trend of results were recorded by Singh and Dixit (1989), Padmani *et al.*(1992), Chauhan *et al.* (1992) Tomar *et al.*(1997) and Bali *et al.*(2000), but the nitrogen levels significantly affected the oil content and increased the protein content (Chauhan *et al.*, 1992; Dubey *et al.*, 1994 and Kaneria and Patel, 1995).

Malavia *et al.* (1988) observed the beneficial effect of phosphorus on number of primary and secondary branches plant⁻¹, plant height upto 50 kg P₂O₅ha⁻¹. Though Tyagi and Rana (1992) reported the significant increase in growth parameter was observed up to 80 kg P₂O₅. Patel and Shelke (1998) reported that the growth parameters and siliqua plant⁻¹, length of siliqua, seeds siliqua⁻¹, weight of seed plant⁻¹ and 1000-seed weight varied significantly up to 120 kg P₂O₅ ha⁻¹ but 80 and 120 kg P₂O₅ ha⁻¹ were at par with each other. The mean seed yield due to application of 80 kg P₂O₅ha⁻¹ over 40 kg P₂O₅ ha⁻¹ and the control was 10.65 and 27.25% higher. Oil and protein quantity was also increased up to 80 kg P₂O₅ ha⁻¹. They also mentioned that synthesis of fatty acids in plants occur through conversion of

acetyl Co-A to malonyl Co-A in presence of ATP and phosphate. The same trend of yield increase due to increasing P application was observed by Jat *et al.* (2000) and Sharma and Jalali (2001).

In a field experiment Mukherjee (1990) applied 0, 20, 40 and 60 kg K₂O ha⁻¹ in mustard cv. T 59 and rapeseed cv. B 9 and reported that significant increase in LAI, CGR, dry matter, seed yield and oil content was with 40 kg K₂O ha⁻¹. On an average, a response of 3.73 kg mustard seeds per kg of K₂O added was reported irrespective of the status of K in the soils (Ghosh *et al.*, 1993).

Saran and Giri (1990) concluded that plant height, branches plant⁻¹, number of siliquae plant⁻¹, seeds siliqua⁻¹, seed weight plant⁻¹, leaf area, dry weight, biomass production and seed yield of mustard cv. Pusa Barani significantly increased with the application of combined application of 40 kg N and 11 kg P ha⁻¹ over control. Also the result revealed that neither N nor P application influenced the oil content of mustard. Samiullah *et al.* (1990) observed that yield and yield attributing characters of mustard were maximally affected by N₆₀P₂₀. However, N₆₀P₃₀ also proved at par for pods plant⁻¹, seeds pod⁻¹, seed yield, oil content and oil yield.

Fertility management with high dose of nutrients (80 kg N, 40 kg P₂O₅ and 40 kg K₂O ha⁻¹) irrespective of their sources, caused appreciable improvement in growth attributes and finally productivities of rapeseed cv. B-9 (Pradhan *et al.*, 1997).

Kumar and Kumar (2007) observed that nitrogen application had significantly increased number of branches, number of leaves leaf area of Indian mustard. The effect of N rates (25, 37.5, 50.0 and 62.5 kg ha⁻¹) and chlormaquat (0, 100, 200,300ppm) were studied at Nagpur, Maharashtra, India during *rabi* 2005-06 by Kumbhare *et al.* (2007). They studied that

among the N rates 50.0 62.5 kg ha⁻¹ resulted greatest leaf area index, plant height, number of branches, dry matter accumulation, crop growth rate, net assimilation rate and seed yield in Indian mustard cv. CAN-9. Kumar and Yadav (2007) observed a limited increase in length of siliqua with increasing levels of phosphorus (0, 13.1, 26.1, 39.1 kg ha⁻¹).

2.2 Effect of FYM on growth and yield of crops:

The use of FYM (farm yard manure) for raising crop is an age old practice. FYM not only supplies organic matter with major nutrients in small quantities but also enriches the soil with several micronutrients. It also increases ion exchange capacity, water holding capacity, buffers the soil against rapid changes in acidity, alkalinity or salinity, acts as a store house for nutrients and releases oxygen and favours better condition for growing beneficial soil micro-organisms.

Ikarashi *et al.* (1990) reported that FYM @5tha⁻¹ significantly increased the LAI value of rice as compared to the control. Budhar *et al.* (1991) observed that FYM @ 5 t ha⁻¹ significantly influenced the plant height and total number of tillers m⁻² in clay-loam soil of Coimbatore in *kharif* rice. The same observation was observed by Das *et al.* (2002).

Mondal *et al.* (1990) reported that the yield components of rice like panicles m⁻², spikelets panicle⁻¹, percent filled grain and test weight of grains improved significantly with the application of FYM (10 t ha⁻¹) over control. Singh *et al.* (1998) further reported that panicle length, number of rachilla panicle⁻¹, grain weight panicle⁻¹, weight panicle⁻¹ and number of filled grains panicle⁻¹ were significantly higher in rice plant with the application of 5.0 tonnes of FYM ha⁻¹ than control, and these results were on par with 7.5 tonnes FYM ha⁻¹. These findings are in agreement with those of Das *et al.* (2002).

Ohyama (1989) reported that yields were higher in most cases with the use of FYM. Average yields over a period of 20 years increased from 5.2 t with no FYM to 6.0 t with 20t FYM ha⁻¹ and 5.89t ha⁻¹ with 30t ha⁻¹ and the highest yield in rice of 6.6t ha⁻¹ was obtained with 40t ha⁻¹ of FYM. Ikarashi *et al.* (1990) observed that application of FYM significantly increased the yields of rice and increased panicle: straw ratio. Application of FYM @ 5 t ha⁻¹ in clay-loam soil having pH 8.1 significantly increased the grain and straw yields over control (Budhar *et al.*, 1991). Application of FYM caused a positive influence on yield of rice (Panda, 1995) and increased the protein content of the grain (Parida *et al.*, 1995).

Reddy *et al.* (1992) conducted an experiment on green gram with different fertility condition in summer season at Tirupati on sandy-loam soil of alkaline reaction having low organic carbon. They reported that application of FYM @ 5 t ha⁻¹ significantly increased leaf dry matter and total dry matter accumulation at different growth stages. The chlorophyll content was 5.86 mg g⁻¹ at 40 days after sowing which was significantly higher than control (4.32 mg g⁻¹) and the seed and grain yields followed the same increment result.

In another experiment Sharma *et al.* (2000) reported that urd bean significantly increased the yield attributing characters and grain yield with the application of FYM @ 5t ha⁻¹ than without manured. The effects of N fertilizer (32, 40, 80 or 120 kg ha⁻¹) with or without farmyard manure (FYM) as mulch (10 t ha⁻¹) on the yield of wheat cv. HS-295 were studied by Chaudhary *et al.* (2001). Data revealed that the highest grain yields were obtained with N at 80 (3877 kg ha⁻¹) and 120 kg ha⁻¹ (3871 kg ha⁻¹) + FYM. N at 80 kg ha⁻¹ + FYM resulted in the highest net return (15275 rupees ha⁻¹), although N at 40 kg ha⁻¹ with no FYM mulch gave the highest cost benefit ratio (1:9).

2.2.1 Effect of FYM on growth and yield of rapeseed-mustard:

Rapeseed mustard is grown on rainfed or in irrigated condition with nominal use or no use of manures and fertilizers. But the nutritional investigation and general experience show that the use of manures and fertilizers has given substantial increase in yield. Lal and Dravid (1993) reported that FYM increased the dry matter production of mustard. Application of FYM @ 10 t ha⁻¹ to Indian mustard crop gave significantly higher plant height and primary branches plant⁻¹ over where FYM was not used (Sadhu *et al.*, 1997). In an experiment results Patel and Shelke (1998) reported that application of FYM @ 5 t ha⁻¹ significantly increased the plant height and leaf area in mustard cv. Pusa Bold in clayey soil of Parbhani in Maharashtra. The manuring with FYM @ 10 t ha⁻¹ significantly increased the siliquae plant⁻¹, seeds siliqua⁻¹, seed weight plant⁻¹ and 1000-seed weight (Sadhu *et al.*, 1997). Patel and Shelke (1998) also observed the same trend of increase in yield component due to application of FYM @ 5 t ha⁻¹ in Indian mustard cv. Pusa Bold.

Jarecki (1991) reported that FYM gave higher yields following inputs of 20-30 t ha⁻¹ four years, but it had no noticeable influence on fat content of rapeseed. Similar increase in mustard or toria yield due to FYM application was also reported by Sardana and Sidhu (1994), Sadhu *et al.* (1997). Significant increase in seed and straw yield of toria cv. DK 1 was recorded due to application of FYM @ 20 t ha⁻¹ and it was 34.4 per cent and 25.4 per cent increase in seed and straw yield respectively over the control (Dixit, 1997). The magnitude of mean increase in seed yield of toria with the application of FYM @ 10 and 20t ha⁻¹ was 11.6 per cent and 8.5 per cent respectively over no application (Patel *et al.*, 1998).

2.3 Effect of vermicompost on growth and yield of crops.

The compost prepared from organic matter through earthworms is known as vermicompost. Earthworms long regarded as the friends of farmers are now recognized in the efficient bio-converters of all types of organic residues. Earthworms have important functions by virtue of their feeding and general behaviours like burrowing, digesting, excreting along with decomposing micro-organisms and supporting further decomposition of biodegradable matters.

Vermicompost improves soil physical, chemical and biological properties on soil turnover (Atlavinyte, 1975), soil aeration (Noble *et al.*, 1997), acceleration of humification, reduces soil erosion (Bhandari *et al.*, 1967), bulk density (Bhole, 1992), increase water retention (Lee, 1985), soil fertility etc.

Application of vermicompost @ 5 t ha⁻¹ to rice cv. Lalat on a sandy loam soil showed higher plant height, number of effective tillers hill⁻¹, length of panicle, number of filled grains panicle⁻¹ than control and FYM @ 5 t ha⁻¹. Also it showed higher grain yield (40.43 q ha⁻¹) than control (12.43q ha⁻¹) and FYM @ 5 t ha⁻¹ (40.00 q ha⁻¹) and straw yield followed the same trend (Das *et al.*, 2002).

Govindan *et al.* (1995) observed that vermicompost @ 12 t ha⁻¹ significantly enhanced the number of leaves, height of plant, number of branches, number of fruits plant⁻¹, length of fruit, fresh weight of fruit and maximum yield of bhindi on a gravelly laterite soil in Kerala than control and FYM @ 12 t ha⁻¹. Each increase in vermicompost dose significantly increased the sorghum yields except green fodder yield in second year, where green fodder yields recorded at 5.0 and 7.5 t ha⁻¹ of vermicompost were at par. The

maximum green fodder dry matter and crude protein yields were recorded at 7.5 t ha⁻¹ of vermicompost (Sharma *et al.*, 2000). Hooda *et al.* (2000) reported that significantly higher grain and biological yields were recorded under the application of vermicompost and it was superior over the FYM in wheat on a sandy loam, alkaline soil. The maximum fresh weight and dry weight of the whole plant and the maximum shoot length, root length and root nodules were observed in the vermicompost mixture in different growth stages. The yield performance of cowpea cv. C₁ was also the best with vermicompost (Karmegam and Thilagavathy, 2000).

Kachapur *et al.* (2001) observed significant increased yield due to vermicompost and fertilizer application over absolute control. Results indicated favourable effect of vermicompost and fertilizers on the production of kharif sorghum. The crop had to be supplied with vermicompost at 0.5 t ha⁻¹ and three-fourth to full dose recommended dose for higher and sustainable yields. In a field experiment Das *et al.* (2002) observed yield components were increased more by integrated application of vermicompost and chemical fertilizers compared to the other treatments in *kharif* rice. The best result in terms of straw and crop yields were obtained with 50% vermicompost + 50% chemical fertilizers.

2.3.1 Effect of vermicompost on growth and yield of rapeseed-mustard:

Bury (1996) reported that application of vermicompost @ 3 t or 9 t ha⁻¹ significantly increased the yield of winter rape cv. Leo than FYM and control. He also observed in that field trials that earlier application of vermicompost was more effective than 5 to 6 leaf stage application in combination of chemical fertilizer. Overall 54-59% yield increase has been observed by him over no application of organic fertilizers in winter rape cv. Leo.

Yield attributes, and oil and protein content of mustard seed (var. Pusa Bold) were compared by Abraham *et al.*(2002) in a field experiment after application of different fertilizers in a cropping system of soybean (*kharif*)-mustard (*rabi*)-fodder cowpea (*zaid*) on a sandy loam alluvium at the Allahabad Agriculture Institute, India. Treatments were 33% recommended dose of NPK, 100% recommended dose of NPK, and combinations of 33% NPK with farm compost + Vermicompost, farm compost + poultry manure, phosphate solubilizing bacteria (PSB) + *Rhizobium* or *Azospirillum* and PSB + foliar application of 33% cows urine. At the end of the experiment, seed yield and biological yield were greatest in the 100% NPK treatment (3486.0 and 13270.0 kg ha⁻¹ respectively). Seed oil and protein content reached the highest levels after 33% NPK + PSB + cows urine (33.06 %) and 33% NPK + PSB + *Rhizobium* or *Azospirillum* (5.147 %) respectively. Soil organic carbon was highest in the 33% NPK + farm compost + Vermicompost treatment (0.714 %) compared to 0.565 % in the unfertilized soil.

2.4 Effect of bio-fertilizers on growth and yield of crops :

Bhati (2005) Showed increased yield of moth bean var.RMO-40 and RMO-257 with inoculation of seeds with *Rhizobium* over the traditional farming. Chatterjee *et al.* (2005) found in an experiment with sprouting broccoli (*Brassica oleracea* L. var. *italica* Plenck) that among different organic the mustard oil cake + bio-fertilizer showed beneficial in terms of Cost-benefit ratio (1:4.46) and highest yield (103.70 q ha⁻¹) also obtained with the treatment.

2.4.1 Effect of bio-fertilizers on growth and yield of rapeseed and mustard:

Vivek Kumar (1994) found in an experiment that inoculation of Indian mustard with *Azotobacter Chroococcum*, Strain M-27 on 3 soil types (sandy loam, loam and clay loam) increased seed yield by 20-30% and

increased oil content on all soil types. In a field experiment Vora *et al.* (1998) observed seed inoculation of mustard seed (*Brassica Juncea*) with *T. globosa* in a vermiculite-based carrier increased seed yield by 36.4-88.5%. In a field experiment Ghosh *et al.* (2001) while studying the response of 3 levels each of K (0, 12.5, 25 Kg ha⁻¹) and N (0, 40 and 80 kg ha⁻¹) and bio-fertilizers (*Azotobacter*, *Azospirillum*) of rapeseed under irrigated condition. The crop responded significantly to K and N application. Seed inoculation with either of the bacteria significantly improves the yield attributes and yield of seeds and oil, though the magnitude of increase was more with *Azotobacter*. Interaction between K and bio-fertilizer and between bio-fertilizer and N were found significant in increasing the yield of rapeseed. Mir (2003) while studying the effect of bio-fertilizers on the performance of Indian mustard cv. T-9 reported *Azotobacter*, applied alone, resulted in the highest value for the parameter measured although all the gave better result compared to the uninoculated control. Seed inoculation with both bacterial culture *Azotobacter Chroococcum* and *Azospirillum* significantly increased growth and yield attributes, viz., number of primary and secondary branches, 1000-seed weight, seed yield, straw yield, oil content and oil yield of *Brassica juncea* cv. RH-30. Both of the bacterial strains remain at par each other.

Chand and Ram (2007) observed that co-inoculation with *Azotobacter* and PSM significantly increased the PSM and *Azotobacter* population in rhizosphere soil of mustard. The study showed significant effect of interaction of fertilizer x bio-fertilizer, FYM x bio-fertilizers, fertilizer x FYM and fertilizers x FYM x bio-fertilizers on PSM and *Azotobacter*. They also observed that the significant and positive correlation of coefficient between *Azotobacter* and N uptake and PSM population and P uptake which ultimately provides circumstantial evidence to the role of these micro-organisms in improving crop productivity in mustard.

2.5 Effect of sulphur on growth and yield of rapeseed-mustard:

Sulphur is an integral part of the sulphur containing acid (cysteine, eystine and methionin) and as such required for the synthesis of oil proteins and oil. The sulphur need of rapeseed in particular is important since sulphur is needed not only for protein, synthesis, but also for glucosinolate (Sharma and Jalal, 2001). Aulakh *et al.* (1985) and Pasricha *et al.* (1990) revealed that *Brassica* sp. respond well to S-fertilization. Oil seed *Brassica* removes 26-45 kg S ha⁻¹ depending on seed yield and other biomass produced. Field experiment result showed an increase in seed yield of mustard due to S-fertilizer of the order of 16-24% under rain-fed condition and 12-13% under irrigated condition. Gupta *et al.* (1996) found application of sulphur increased yield plant⁻¹ for different varieties of rapeseed mustard like , TM-17, NDR-8602, RK- 9082, RK- 9046, Sita and NC-1 at all the doses (10 and 15 kg S ha⁻¹) as compared to control. Mahapatra *et al.* (1999) corroborates with this findings. Sarkar *et al.*(2005) also found that RK-9046, NDR-8602, RK-9046, TM- 17, PBM 16 of Indian mustard (*Brassica juncea* L.) responded well to sulphur and significantly influenced yield and its components.

2.6 Effect of integrated nutrient management on growth and yield of crops:

The basic concept underlying the principles of integrated nutrient management system is the maintenance and possibly improvement of soil fertility for sustaining crop productivity on long term basis which may be achieved through combined use of all possible sources of nutrients and their scientific management for optimum growth, yield and quality of different crops and cropping systems in specific agro-ecological situations (Hegde and Dwivedi, 1993).

Mathew *et al.* (1994) reported that reducing the N dose to 25 per cent but supplemented by FYM did not decrease the rice yield in comparison to the treatment receiving 100% of the N dose. They also stated that integrated nutrient application resulted in favoured vegetative growth as evidenced from the data on plant height and tiller density and finally concluded that the manurial schedules involving 50% N supply as chemical fertilizer and the remaining need of the crop met from the organic manures sources. Jayakrishnakumar *et al.* (1994) also opined the same trend that 50% N was substituted through FYM recorded the highest grain yield of rice. The maximum rice grain yield was observed with 150% of $N_{120}P_{20}K_{42}$ kg ha⁻¹ but it was statistically at par with 100% NPK plus 10 t FYM ha⁻¹ but the soil organic carbon, available Zn, and Mn in inorganic fertilizer treatments were significantly lower compared to the treatments involving fertilizer treatments with organic source (Swarup and Yaduvanshi, 2000). A field experiment was conducted during *kharif*, 1995 with rice cv. ASD18 by Kenchaih and Balusubramanian (1996) to study the organics integrated with inorganic fertilizers on growth, yield and yield components. The study indicated that combined application of FYM + neem cake recorded significantly higher grain yield.

Kale and Bano (1986) reported that requirement of chemical fertilizers to paddy crop was reduced when vermicompost was used. A significant increase in number of effective panicles at (55 DAT), plant height and grain yield was observed with integrated treatment combination of $\frac{2}{3}$ N through inorganic fertilizer and $\frac{1}{3}$ N through vermicompost over the full dose of fertilizer alone (Rani and Srivastava, 1997). Again Vasanthi and Kumaraswami (1999) showed that significantly higher grain yields were recorded in the treatments that received vermicompost prepared from any of the organic materials plus N, P and K than in the treatment that received N, P and K alone.

In a field experiment during *kharif* season with rice cv. Lalat. Das *et al.* (2002) concluded that higher yield of rice grain and straw was recorded in the treatment receiving 50% of chemical fertilizer integrated with 50% vermicompost dose (2.5 t ha^{-1}) which was at par with the yield due to recommended dose ($60\text{-}30\text{-}30 \text{ kg N, P}_2\text{O}_5 \text{ and K}_2\text{O ha}^{-1}$) of chemical fertilizer.

An integrated nutrient supply and management system aims at sustainable productivity (Abrol and Katyal, 1990) with minimum deleterious effect of chemical fertilizers on the health of soil and environment. Sanyal (1991) studied the efficiency and recovery fraction of fertilizer use under different fertilizer and organic manure practices in rice-potato-groundnut cropping sequence and observed that where inorganic fertilizers were added in conjunction with organic manures, the nutrient absorption increased and this resulted to increase in agronomic efficiency values.

Puste *et al.* (1999) reported that the application of 75% of the recommended dose of fertilizer ($\text{N} : \text{P} : \text{K} :: 60 : 30 : 30 \text{ kg ha}^{-1}$) along with 10 t ha^{-1} FYM or crop residues produced the highest rice grain yield during *kharif* and subsequently seed yield of linseed, safflower and niger during winter over the treatments where the crop received the recommended doses of fertilizer only in rice-oilseed cropping sequence.

In a legume based cropping system Abraham *et al.* (2002) observed increased in dry matter production in fodder cow pea with bio-fertilizer with organic spray over no bio-fertilizer application under different fertility levels.

A treatment combination of *Azospirillum* and 60 kg N ha^{-1} rewarded the highest weight per plant, head weight per ha and yield per ha with a benefit : cost ratio of 2.9 of cabbage (Sharma 2002).

Devi *et al.* (2008) found that the inorganic fertilizer and organic manure along with bio-fertilizer inoculation of seedlings significantly increased the yield over inorganic fertilizer along with organic manure and also over the control in cabbage.

2.6.1 Effect of integrated nutrient management on growth and yield of rapeseed-mustard:

The main reason for low productivity is inadequate use of inorganic fertilizers and imbalance in soil fertility arising from it. This needs immediate restoration and sustenance of soil fertility through an integration of different available nutrient sources that will increase yield per unit area to meet the shortage of oilseeds.

Sarkar *et al.* (1997) reported that application of high dose of nutrients (80 kg N, 40 kg P₂O₅ and 40 kg K₂O ha⁻¹) half through organic and remaining half through inorganic fertilizers caused 12.17% and 99.5% increase in grain yield respectively as compared to the high dose of nutrients through inorganic fertilizer and crop receiving no fertilizer.

The application of 100% recommended fertility level and 75% of the recommended fertility levels with FYM @ 10 t ha⁻¹ were statistically at par in all yield attributes, *i.e.*, number of branches plant⁻¹, number of siliqua plant⁻¹, number of seeds siliqua⁻¹, test weight and seed yield (Jain and Sharma, 2000).

In a field experiment Ghosh *et al.* (2001) while studying the response of 3 levels each of K (0, 12.5, 25 Kg ha⁻¹) and N (0, 40 and 80 kg ha⁻¹) and bio-fertilizers (*Azotobacter*, *Azospirillum*) of rapeseed under irrigated condition. The crop responded significantly to K and N application. Seed inoculation with either of the bacteria significantly improves the yield attributes and yield of seeds and oil, though the magnitude of increase was

more with *Azotobacter*. Interaction between K and bio-fertilizer and between bio-fertilizer and N were found significant in increasing the yield of rapeseed.

In another field experiment Mandal and Sinha (2002) studied the growth, yield, seed oil content and nutrient uptake by Indian mustard (*B. juncea*) as influenced by different integrated nutrient management treatments (50 and 100% recommended rate of fertilizers (80.0:17.2:33.2 kg N:P:K ha⁻¹), 10 t farmyard manure (FYM)ha⁻¹, 10 kg borax ha⁻¹ and/or 20 kg ZnSO₄ ha⁻¹). The plant height, branches plant⁻¹, siliqua plant⁻¹, seeds per siliqua, 1000-seed weight, seed and oil yields of Indian mustard were improved at 100% recommended rate of NPK + 10 t FYM ha⁻¹ compared with 100% NPK alone. It was at par with 100% NPK + borax + ZnSO₄ and 50% NPK + FYM + borax + ZnSO₄. Treatment with 100% NPK + FYM, 100% NPK + borax + ZnSO₄ and 50% NPK + FYM + borax + ZnSO₄ recorded 27, 26 and 25% seed yield increase, respectively, over 100% NPK; and by 134, 132 and 130% over the control. Significant improvement owing to the appropriate combination of NPK, FYM, borax and ZnSO₄ was observed for nutrient uptake.

Singh and Singh (2006) reported the response of Indian mustard cv. Rh-30 to FYM (2.5 and 5 t ha⁻¹) and inorganic N (0, 40, 80 kg ha⁻¹) applied alone or in combination with bio-fertilizers (*Azotobacter chroococcum*, *Azospirillum*). Seed oil content and oil yield increased significantly with the application of FYM 5 t ha⁻¹ along with *Azotobacter chroococcum* and *Azospirillum*.

Chand and Ram (2007) observed that the highest seed yield, stover yield under the treatment 10 t ha⁻¹ FYM + 75% of recommended NPK treatment + inoculation with *B. megaterium* var. phosphaticum + *Azotobacter chroococcum*. NPK at 75% recommended dose + *Azotobacter chroococcum* increased mustard seed yield by 23% over the control during a field study in Rajasthan, India.

2.7 Effect of integrated nutrient management on economics of crop production:

Under conditions of fertilizer scarcity and higher cost, economical use of fertilizers and their efficient management is of greater significance. Sharma and Dixit (1988) reported that the additional profit was increased and net profit per rupee investment were decreased with the increase in the application of nitrogen from 60 kg N ha⁻¹ to 120 kg N ha⁻¹ in rice. They again stated that with the increase of NPK dose the yield of crop was increased but the net profit per rupee investment on fertilizer reduced significantly and the highest value (2.80) was obtained with 60-30-30 kg N, P₂O₅ and K₂O ha⁻¹.

Singh *et al.* (1998) conducted a field experiment during *kharif* season and reported that gross returns and variable expenses were significantly higher with increasing rates of FYM application however, the net returns was significantly maximized with addition of FYM @ 5 t ha⁻¹. Further addition of FYM was found to be non economical. Application of 5 tonnes FYM ha⁻¹ increased the net profit by ₹ 611 ha⁻¹ over control. Similarly, gross returns and variable expenses were also found significantly increased up to 125% NPK applied fertilizers, whereas the maximum net returns (₹ 9296 ha⁻¹) was recorded with application of 100% NPK which gave an additional net returns of ₹266 ha⁻¹ over 75% recommended dose of NPK.

Ghosh *et al.* (1995) reported that crop receiving 60 kg N ha⁻¹ paid maximum net return (₹565 ha⁻¹) and highest return rupee⁻¹ invested (2.98) and this was significantly superior to all other nitrogen levels. The optimum economic doses of nutrients obtained from the quadratic equations were 54.4 kg N, 31.4 kg P₂O₅ and 32.3 kg K₂O ha⁻¹ and at this level, the crop recorded net returns of ₹5221.00, ₹5201.00 and ₹5211.00 ha⁻¹ with monetary return rupee⁻¹ invested of 2.9, 2.8 and 2.8 respectively in lateritic belt of West Bengal during *rabi* seasons of 1990-91 and 1991-92 with rapeseed cv. B 9.

Application of FYM to rapeseed produced more net return (11.68%) than control (Patel and Shelke, 1998).

Rathore (1996) reported that the highest net income was obtained from rice-wheat cropping sequence with the application of FYM @ 5 t ha^{-1} + 80 kg N, 50 kg P_2O_5 and 30 kg $\text{K}_2\text{O ha}^{-1}$ in rice and no fertilizer was applied in wheat. Hasan (1999) conducted a field experiment in silty clay loam soil with six cropping systems and raised with the recommended dose of fertilizer to each crop and reported that the maximum relative yield equivalent was recorded with rice-wheat followed by the rice-rapeseed but the rice-wheat was most cost accounted and rice-rapeseed was minimum cost incurred due to lesser investment were required with rapeseed cultivation.

Maibangsa *et al.* (2000) conducted an experiment with twelve different cropping sequences to evaluate and identify the most suitable and remunerative cropping sequence and reported that the net return per day was the highest ($\text{₹}33.67 \text{ ha}^{-1}$) in rice (*kharij*)-rapeseed (*rabi*)-green gram (summer) than other sequences.

Satyajeet *et al.* (2007) obtained the highest mean value of net return with the treatment 100% RDF + vermicompost + bio-fertilizer in pearl millet while studying the integrated nutrient management on pearl millet and their residual effect on mustard cv.RH30.

2.8 Effect of integrated nutrient management on uptake of nutrients:

Sharma and Mitra (1990) opined that application of varying levels of FYM showed no definite change in the content of N, P and K in grain and straw of rice at harvest. However, the total N, P and K uptake was significantly higher than control due to more dry matter production.

Patel *et al.* (1998) proposed that the N content of seed and stover of mustard was not improved significantly due to FYM application in both the years however, pooled data showed the significant improvement in a N content of stover, where in FYM @ 10 t ha⁻¹ registered the maximum N content and as a result the significant increase in N uptake at 10 t ha⁻¹ FYM over no application was noticed. According to their result the application of FYM @ 20 t ha⁻¹ significantly increased the P content of seed over no application but it was at par with FYM @ 10 t ha⁻¹ and it was further stated that the P uptake by the plant was increased significantly with each successive increase in FYM and the highest P uptake was noted with 20 t ha⁻¹ which increased the P uptake to the tune of 18.4 % over no FYM.

A significant increase in N uptake was found with vermicomposted treatments due to higher N percentage in rice straw and grain (Rani and Srivastava, 1997). Nitrogen uptake by the ridge gourd increased significantly with increased levels of vermicompost at all growth stages, while with increasing inorganic fertilizers levels nitrogen content increased significantly at 30 DAS only and among the interaction at 30 DAS nitrogen content was least with F₀V₀ and the highest with recommended (100-50-50 kg N, P₂O₅ and K₂O ha⁻¹) dose plus vermicompost 15 t ha⁻¹ (Sreenivas *et al.*, 2000). According to them 50% recommended dose of fertilizer plus vermicompost @ 10 t ha⁻¹ showed the highest nitrogen uptake at 60 and 90 DAS due to higher dry matter production.

Sharma and Mitra (1990) observed that nutrient uptake was higher with N fertilizer which increased further with the application of P and PK along with N, but the effect of P and K applied singly was not significant. According to them the recovery of applied N was 16% at N₆₀ and increased upto 26 and 31% under NP and NPK respectively. The recovery of phosphorus ranged from 4-22% and was increased considerably by applying P and NPK and the recovery of K was only 15% when K was applied alone but it

increased conspicuously up to 58% when N and P were also applied along with K. Mishra and Sharma (1997) also mentioned that 100% recommended NPK to rice-wheat, and rice-winter maize significantly increased the N, P and K uptake over 50% NPK and control. Rathore and Manohar (1990) from the studies reported that the uptake of nitrogen increased significantly with the application of 120 kg N ha⁻¹ over the control and mentioned that the increased uptake of nitrogen appeared to be due to the cumulative effect of increased grain and stover yields of mustard as well as increased content of nitrogen in both stover and grain of mustard. The same trend resulted with mustard, that 120 kg N ha⁻¹ was statistically superior in respect of uptake of nutrients over the control (Shukla and Kumar, 1994; Thakur and Chand, 1998; Kaneria and Patel, 1995) reported that increase in N level from 60 to 90 kg ha⁻¹ increased the N uptake by Indian mustard, var. varuna. Higher N uptake attributed to favourable effect of N fertilization to crop, higher biomass production consequently removed more N from the soil. They showed the increased of P uptake was 17 and 33% with 75 and 90 kg N ha⁻¹ respectively compared with 60 kg N and the increase in K uptake with 75 and 90 kg N ha⁻¹ was 9 and 16% respectively compared with 60 kg N ha⁻¹. Jaggi and Sharma (1997) reported that the P uptake by seed and total P uptake was significantly increased with the increase of the phosphorus application.

Rao *et al.* (1993) conducted an experiment in sandy loam soil and reported that the uptake of phosphorus increased with the application of phosphorus and the highest and significant P uptake was recorded in green gram seed (4.13 kg ha⁻¹) and haulm (9.11 kg ha⁻¹) with 50 kg P₂O₅ ha⁻¹. The similar trend was noticed by Meena *et al.* (1993) and Shukla and Dixit (1996).

Pramanik and Das (1997) suggested from an experiment on sandy-loam soil with three rice based cropping sequences (rice-wheat, rice-Indian mustard and rice-groundnut) and three doses of fertilizer (75%, 100% and 125% of recommended dose of fertilizer) and reported that at 100% recommended dose of fertilizer higher uptake of N was recorded in rice-

groundnut cropping sequence followed by rice-Indian mustard and rice-wheat sequence and similar observations were recorded for both phosphorus and potassium uptake. Bagavathiammal and Muthiah (1995) reported that the N and K uptake were the highest with 100 K + composted coirpith, while P uptake was the highest with 100 kg K + FYM with rice in ADT 36. Application of 100% recommended dose + FYM @ 5 t ha⁻¹ showed statistically superiority in N, P, K, Ca and S uptake then 100% recommended dose + green manuring by *Sesbania canabina* and only recommended dose (N₈₀P_{17.4}K₃₃ kg ha⁻¹). Application of 100% recommended dose along with FYM @ 5 t ha⁻¹ significantly increased the N uptake in rice grain (68.12 kg ha⁻¹) and straw (43.42), P uptake in grain (12.65 kg ha⁻¹) and straw (2.64 kg ha⁻¹) and K uptake in grain (61.64 kg ha⁻¹) and straw (39.20 kg ha⁻¹) over 100% recommended fertilizer dose (Dhurandher *et al.*, 1999). They also noticed that the N uptake by seed showed the highest value, which was statistically at par with residual effect of 150% NPK and differed from 100% NPK. Though the highest seed and stover P and K value was obtained with the residual effect of 150% NPK but it was statistically at par with the residual effect of integrated use of 100% NPK along with FYM @ 5 t ha⁻¹.

Satyajeet *et al.* (2007) conducted a field experiment to study the effect of integrated nutrient management on available NPK and organic carbon in pearl millet- mustard cropping system and observed the treatments where inorganic fertilizers were applied in conjunction with vermicompost and bio-fertilizer recorded significantly higher available nitrogen and phosphorus and organic carbon in soil. Significant improvement owing to the appropriate combination of NPK, FYM, borax and ZnSO₄ was observed for nutrient uptake also reported by Mandal and Sinha (2002).

Abrol *et al.* (2007) reported the fertilizers applied to maize showed significant effect on nutrient uptake of mustard crop. Mustard crop showed maximum N and P uptake (31.6 and 7.3 kg ha⁻¹ respectively) with the 50% recommend NPK through fertilizer and 50% through FYM. Maximum K

uptake 26.4 kg ha^{-1} obtained application of FYM. Organic carbon and available N-content shows significant increase 3 g kg^{-1} and 31 kg ha^{-1} respectively in 10 t ha^{-1} treated plot during a study was conducted to evaluate the direct and residual effect of organic and inorganic sources of nutrients alone or in combination on yield of *Zea mays* and *Brassica napus*.

Chand and Ram (2007) observed that increasing fertilizer level from 0-100%, FYM at 10 t ha^{-1} and co-inoculation with *Azotobacter* and PSM significantly increased the PSM and *Azotobacter* population in rhizosphere soil. They also observed the significant and positive correlation of coefficient between *Azotobacter* and N uptake and PSM population and P uptake.

2.9 Soil nutrient status as affected by nutrient management:

2.9.1 FYM:

Ganai and Singh (1988) reported that the application of FYM to rice reduced the bulk density significantly, increased the cumulative infiltration of water and also showed a significant reduction in soil penetrometer resistance in rice-wheat cropping sequence. Panda (1995) supported this finding and stated that the physical properties like bulk density and maximum water holding capacity of soil were influenced favourably by the application of FYM.

Application of FYM to rice showed an improvement in pH due to the buffering capacity of FYM, when added in soil having in acidic range (Ganai and Singh, 1988). FYM marked by improved the soil reaction (Jarecki, 1991). In higher soil pH, the application of FYM effectively reduced the flood water pH in puddled rice field (Purakayastha *et al.*, 1997).

Addition of FYM significantly increased the soil organic carbon and total nitrogen in a rice-wheat cropping system (Mahapatra *et al.*, 1991). They also noticed that the increase was more pronounced after rice but decreased after wheat, however, it was more than the initial levels at the end of third year.

Budhar *et al.* (1991) stated that application of FYM increased the post harvest status with 37.7 and 12.5 % higher N and K respectively over the control. Agarwala *et al.* (1993) reported from a long term fertilizers with rice-wheat-cowpea rotation that increased in soil CEC as a result of FYM addition, increased the proportion of soil K present as exchangeable K.

Application of FYM @ 10 t ha⁻¹ to mustard gave significantly higher organic carbon, available P₂O₅ as well as K₂O (Patel *et al.*, 2000).

2.9.2 Vermicompost:

The earthworm cast, which acts as a super manure could be used to improve the soil condition, causes significant reduction in the bulk density and increased the cation exchange capacity (Vasanthi and Kumaraswamy, 1999) and simultaneously it can increase water holding capacity of soil and uptake of soil nutrients (Lee, 1985, Rani and Srivastava, 1997 and Hooda *et al.*, 2000).

The pH of the worm cast itself is closer neutrality (Edwards and Lofty, 1977) which on addition to soil increased the pH of acid soil towards neutrality. Nethra *et al.* (1999) also reported the similar trend. According to them with the increase of vermicompost significantly increased the pH from 5.96 in control to the highest value 6.33 obtained from the application of vermicompost @ 15 t ha⁻¹, which was statistically superior to vermicompost @ 5 and 10 t ha⁻¹ or control.

Vasanthi and Kumaraswamy (1999) reported that organic carbon content increased by 32% due to application of vermicompost @ 5 t ha⁻¹ over the content in N, P and K alone treatment after the *kharif* rice.

Nethra *et al.* (1999) reported that the pooled of three experiments showed the available nitrogen status in the soil was significantly higher in the treatments that received vermicompost besides NPK. Soil available N content increased significantly with increasing levels of vermicompost (V₀ to V₁₅) at all growth stages of ridge gourd (Sreenivas *et al.*, 2000).

Significantly higher labile phosphorus status was observed in the treatment in *kharif* rice that received one of the vermicompost than in the treatment that received N, P and K alone, also available potassium status in the soil was significantly higher in the treatments receiving vermicompost from any one of the dose of vermicompost (Vasanthi and Kumaraswamy, 1999).

Abraham *et al.*(2002) observed in a field experiment , while studying the performance of mustard cv. pusa bold , soil organic carbon was highest in the Vermicompost treatment along with farm compost and one-third of recommended NPK dose (0.714 %) compared to 0.565 % in the unfertilized soil.

2.9.3 Chemical fertilizers:

Application of mineral NPK to aerable crops (winter rape, winter wheat) increased hydrolytic acidity and reduced base supply (Jarecki, 1991). Similar observation in pH after *kharif* rice was observed by (Swarup and Yaduvansi, 2000). Patel *et al.* (1993) conducted an experiment in rice-wheat-green gram sequence and reported that nitrogen fertilizer increased the bulk

density from 1.41 to 1.44 g cm⁻³ and minimum porosity from 46 to 45% were observed after the harvest of rice and also reported that addition of P and K in conjunction with N counteracted the adverse effects of N on bulk density and porosity. Fertilized plots had substantial buildup in available P at different places, where a marginal decline in available K status from its initial level in rice-wheat crop sequence (Hegde, 1998). The similar trend in K-decline in rice-wheat from 1977 to 1982 was reported by Soni *et al.* (1988). In general P applied to *kharif* recorded more overall yield as compared to *rabi* applied P and higher P rates along with its repeated applications to both at rice and rapeseed in rice-rapeseed sequence resulted in higher P build up in the soil (Hasan, 1999).

2.9.4 Bio-fertilizers:

While studying the productivity and quality of Indian mustard cv. RH-30 as influenced by integrated nutrient management treatments, where the treatments were control; 75 and 100% of the recommended NPK, alone or combined with vermicompost; 5 t ha⁻¹ vermicompost and 75 and 100% RDF + vermicompost + bio-fertilizers, Satyajeet and Nawal (2007) found that integrated use of organic, inorganic and bio-fertilizer resulted increased seed yield, protein and oil yield on the residual fertility in pearl millet-mustard cropping sequence.

2.9.5 Integrated nutrient management:

Integrated use of organic manures and chemical fertilizers helped in maintaining stability crop production by improving chemical and physical properties of the soil (Sharma, 1995). Continuous rice-rice cropping increased organic carbon status with the integrated supply of nutrient at different places but had no effect on available P and K status (Hegde, 1996). Tiwari *et al.* (1997) concluded from a long term experiment with rice-wheat-cowpea

and reported that even after 17 years of continuous cropping, the C : N ratio was almost maintained by integrated use of 100% NPK + FYM, as the ratio of this treatment (9:7) was comparable to that fallow (10:6). A combination of organic + inorganic fertilizer increased soil pH of 6.6 to 6.8 in a rice - lentil cropping sequence (Sarkar and Singh, 1997). They also reported that organic manures alone or in combination with inorganic fertilizers increased the level of organic carbon in the soil as well as the total N, P and K content in soil. Continuous rice-wheat cropping depleted available P and K content in control and N alone treatments in comparison to its initial level (Swarup and Yaduvanshi, 2000) and it was also noticed that there was a significant increase in the available P and K status of the soil in plots receiving fertilizer P and K and those getting FYM over the control.

Rani and Srivastava (1997) reported that integrated use of vermicompost and inorganic fertilizer produced higher NH_4^+ N under waterlogged conditions over the control and the application of inorganic fertilizer. Significantly higher available nitrogen, labile phosphorus and available potassium status in the soil was observed after the *kharif* rice with the application of any one of the vermicompost with recommended NPK (Vasanthi and Kumaraswamy, 1999).

2.10 Effect of pre-sowing seed treatment on stand establishment and seedling vigour of crops:

A good stand establishment is essential for successful crop production. Early seedling vigour is necessary to avoid adverse environmental condition (Rao *et al.* 1971). Singh and Tomar (1972) studied on the effect of soaking rice seeds in various chemicals on germination and seedling vigour. They found that soaking in 1% sodium hypochloride solution enhanced germination percentage and rate of elongation of plumule and radicle. Simak (1976) described the advantages of soaking tree seeds in polyethelene glycol (PEG) to improve the speed and percentage of germination. Dayananda *et al.*

(1972) found that seed soaking in water could hasten the germination of wheat seeds by 2 to 2.5 days. Khan and Chatterjee (1981) reported that number of wheat plants emerged from soaked seeds were significantly more than that obtained from unsoaked seeds. Bhattacharya *et al.* (1988) found that in grasspea (*Lathyrus sativus*) seed soaking treatment with ethylene glycol + Na₂HPO₄, significantly increase more number of plants than untreated control. Paul *et al.* (1993) reported that KCl, KH₂PO₄ and K₂SO₄ had no significant difference on germination specially in paper and sand. But under the field conditions, the germination was significantly higher in KH₂PO₄ treatment. They observed that, KH₂PO₄ always had higher values in respect of shoot length, root length (sand), vigour index and dry matter of seedlings. Potassium sulphate had a tendency of depressing the shoot and root length, vigour index and dry matter of wheat seedling.

Narayanaswamy and Chandarayappa (1997) found that germination and field emergence of groundnut seeds were highest in seeds treated with 0.5% CaCl₂, with 0.5% KCl the next most effective treatment. Paul and Choudhary (1993) reported that under field conditions, seed germination and seedling vigour of wheat were higher with KH₂PO₄ than KCl or K₂SO₄ seed soaking. Seed germination, shoot and root lengths and seedling vigour were higher at salt concentrations of 0.5 and 1% than at 2%. Seedling vigour was generally higher from soaking for 18 hrs. than from other duration. Narayanaswamy and Shambulingappa (1998) found that field emergence was highest after seed soaking in 0.5% CaCl₂ compared to 0.5% KCl, KH₂PO₄ and MnSO₄. Kamboh *et al.* (2000) reported that under saline condition pre-sowing seed treatment with calcium or potassium did not lead to significantly higher rate for final germination than the distilled water treatment. But calcium salt treatment significantly improved shoot growth during the early seedling establishment stage of wheat.

2.10.1 Effect of pre-sowing seed treatment on stand establishment and seedling vigour of rapeseed-mustard:

Bose *et al.* (1997) reported that after 12-24 hrs. of soaking, germination percentage of mustard was highest with 7.5 mm $MgSO_4$. But after 42 hrs. there were no significant differences in germination between the treatments $MgSO_4$ and $Mg(NO_3)_2$ solution. Paul *et al.* (1995) observed that the seed germination of toria was significantly higher in KCl, KH_2PO_4 and Na_2HPO_4 treated seed. They also observed that seed germination and seedling vigour decreased with increasing salt concentration, and were significantly higher with water soaked seeds than dry seeds. Soaking of seeds for 10 hrs gave significantly higher seed germination than 6 hrs soaking. In mustard and cauliflower maximum percentage of seed germination was observed when seed treated with Bavistin (Ghosh and Das, 1999). By treating the seed with Dithane M-45 or 0.25% Na_2HPO_4 before sowing encouraging result on germination, vigor and drought tolerance were obtained in Indian mustard (Paul *et al.*, 1999). Mondal *et al.*, (2004) also observed pre-sowing seed treatment with Dithane M-45 or 0.25% Na_2HPO_4 improved emergence in Indian mustard.

2.11 Effect of pre-sowing seed soaking with water on the growth and yield of crops:

Many work found the beneficial effect of pre-sowing seed treatment with water. Ariyanaygam (1953) While studying the growth and developmental change in rice seed reported that pre-sowing treatment with water germination and flowering by a few days as compared with control, also increased tillering and hence the of grains per or the 1000 grain weight. Dayananda *et al.* (1972) reported that soaking of seeds in water pushed up the grain yield of wheat by 1.60 and 2.07 quintal ha^{-1} over crops raised from untreated seeds. Under late sown condition Khan and Chatterjee (1981) pointed that wheat seeds soaked in water for 8-10 hrs and sown in

field produced significantly more grain yield than crop raised from unsoaked seeds. Similar results have also been reported earlier by Heydecker and Coolbear (1977). Sengupta *et al.* (1984) while working on Black gram observed that soaking of seeds in water increased the grain yield by 1.08 and 1.91 quintal ha⁻¹ over untreated control in two successive years.

Paul *et al.* (1993) found that yield of wheat increased significantly when treated with distilled water (1.76 and 1.11 t ha⁻¹) than no soaking control. Harris *et al.* (2001) reported that seed treatment with water have direct effect on crop uniform stands, less need to re-sow, more vigorous, better drought tolerance, earlier flowering, earlier harvest and higher grain yield.

2.11.1 Effect of pre-sowing seed soaking with water on the growth and yield of rapeseed-mustard:

Ghosh *et al.* (1986) reported 24% increase in mustard yield over control due to pre-sowing seed soaking in water. Soaking seeds of Indian mustard in distilled water before sowing produced seed yield of 2.18 t ha⁻¹, which is higher than no soaking (Dobariya and Mehta, 1995).

2.12 Effect of pre-sowing seed soaking with different agro-chemicals on growth and yield of crops:

Pre-sowing seed treatment with different Chemicals also improves the crop performance under adverse condition. Narayanan and Gopalakrishnan (1949) obtained 40% increased in yields by soaking rice seeds in a 20% solution of K₃PO₄. Abichandani and Ramiah (1951) observed highest grain yield of rice by treatment with KH₂PO₄.

At Central Rice Research Institute (CRRRI) Cuttak, Iswaran *et al.* (1962) reported an increase of 10 to 15% in yield due to Soaking of paddy seeds for 24 hrs in KH_2PO_4 , K_3PO_4 , Na_2HPO_4 , $(\text{NH}_4)_2\text{SO}_4$ and NH_4NO_3 with different concentrations.

An appreciable increase in grain and straw yields of rice by pre-sowing seed treatments in nutrient solution has been recorded by Narayanan *et al.* (1958). Mehhotra *et al.* (1967) found that soaking of rice seeds in 15 and 20 % solution of KH_2PO_4 for 18 hrs. before sowing produced increased grain yield over non-soaked seeds. Sinha (1969) observed that crop raised from rice seeds soaked in KH_2PO_4 reduced spikelet sterility greater than those seeds were soaked in distilled water. The best effect has been obtained by Singh and Chatterjee (1980) with soaking of rice seeds with Na_2HPO_4 solution and followed by water soaking and soaking in $\text{Al}(\text{NO}_3)_3$ solution. They observed that crop raised from Na_2HPO_4 soaked seeds gave better yield due to high tiller number per unit area and high shoot and root lengths in the seedling stages. Bhattacharya *et al.* (1984) obtained similar results with blackgram pre-sowing seed treatment with Na_2HPO_4 , caused 13.74% increase in grain yield over control. This pre-sowing seed soaking gave better results than crop raised from water-soaked seeds. The crops raised from treated seeds gave higher yield than those raised from untreated control. The crop raised from pre-sowing treated seeds had higher shoot and root lengths and lower water saturation deficit in leaves than those raised from untreated seeds.

Chatterjee *et al.* (1985a) reported that yield of groundnut pods (average of two seasons) can be appreciable increased (30-50%) through pre-sowing seed treatment with water or with Na_2HPO_4 solution (5×10^{-4} M). the yield increase were mainly due to increase in number of pods per plant and the test weight of karnels. They suggested that due to seed treatments growth of nodules was improved which might have helped in increasing productivity. Chatterjee *et al.* (1985b) also found 37% increase in sesame yield over control due to pre-sowing seed treatment with Na_2HPO_4 . Arjunan

and Srinivasan (1989) studied on pre-sowing seed hardening with inorganic salt and growth regulators for drought tolerance in groundnut. Seed hardening with 1% calcium chloride or 2% KH_2PO_4 was most effective for improving germination, dry matter accumulation and pod yield. Paul *et al.* (1993) recorded significantly higher yield of wheat (1.96 and 1.33 t ha^{-1}) when seed treated with KH_2PO_4 solution. Das and choudhury (1996) recorded increased grain yield of wheat during first year of experiment but not in second year when seed treated with 1% KH_2PO_4 . Ghosh *et al.* (1997) studied the growth and yield of wheat as influenced by seed soaking agro-chemicals and observed that soaking of seeds in 100ppm Na_2HPO_4 of di-kegulac sodium increased the number of tillers per square meter, leaf area index, crop growth rate, number of spikes per square meter, number of grain per spikes, 1000 grain weight and grain yield compared with other treatments.

Under rain-fed upland condition pre-sowing seed treatment with Na_2HPO_4 or KH_2PO_4 on finger millet (*Eleusine coracana*) significantly increased number of ears per square meter, number of fingers per ear, length of fingers, grain per ear, 1000 grain weight, grain yield and straw yield compared with the control and water soaked treatment (Maitra *et al.*, 1997).

Highest pod and seed yield of groundnut obtained by Siddaramappa *et al.* (1993) due to seed soaking with potassium sulphate solution. Under lateritic belt of West Bengal Maitra *et al.* (1999) obtained higher grain yield of finger millet (47, 33 and 21%) when seed treated with 100ppm Na_2HPO_4 , 0.25% CaCl_2 and water respectively. Raju *et al.* (1999) studied on the effect of potassium hydrogen phosphate and *Rhizobium* culture with reduce dose of nitrogen on yield of cowpea. Seed yield was highest from seed-soaking in 100ppm KH_2PO_4 and inoculation with *Rhizobium*. Sabir Ahmed (1999) reported that seeds treated with Na_2HPO_4 at 50 ppm and succinic acid at 20 ppm increased subsequent seed yield of green gram by 17 and 12.87% respectively over untreated control. Pathak *et al.* (1999) reported that direct seeded upland rice in many rice growing areas is

characterized by moisture deficit for much of the crop growth period. Seed hardening with potassium salt together with higher K fertilizer application and use of anti-transpirant can improve water economy, water use efficiency and yield.

Ugale *et al.* (2001) reported that the seed treatment of ragi cultivars viz., CO-13, PR 202 and Indaf 9 with combination of 1 per cent KCl and CaCl₂ had registered maximum yield of 19.6, 17.5 and 13.9 per cent respectively over control. Similarly pre-sowing seed hardening of wheat with CaCl₂ (2.5%) produced significantly higher grain yield (4014 kg ha⁻¹) over control. The higher fodder productivity was observed in seed hardening with KH₂PO₄ (2%) followed by KCl (2%) and KH₂PO₄ (2%) in forage grasses (Swaminathan *et al.*, 2001).

Ramesh (2004) studied that seed hardening with CaCl₂ (2%) increased number of pods per plant, pod yield per plant, seed yield per plant 100 seed weight and HI in chickpea. Foliar application ZnSO₄ (0.5%) increased seed yield and its attributes significantly over the other treatments in pigeonpea (Varma *et al.*, 2004).

2.12.1 Effect of pre-sowing seed soaking with different agro-chemicals on growth and yield of rapeseed-mustard:

Raghavan and Hariharan (1991) reported that the significant increase in pod setting percentage, pod length, number of seeds, seeds setting percentage and dry weight of 1000-seeds due to pre-sowing seed treatment with 2,4-D(1-3ppm) of *Brassica juncea* (L.). Under rain-fed condition, seeds of toria (*Brassica Campestris* var. toria) cv. M-27 and Indian Mustard cv. TM-2 were soaked in water 1% KCl, 1% KH₂PO₄, 0.25% Na₂HPO₄, 5 x10⁻⁴ m Na₂HPO₄ or a slurry of Dithane M- 45 (2g 250 ml water⁻¹) for 10 hrs followed by drying to original weight. Seed yield was greater with all seed treatments that in the Control. Seed treatment with Dithane M-45 gave the

best result, followed by 0.25% KH_2PO_4 and 1% Na_2HPO_4 (Paul *et al.*,1999). Mondal *et al.* (2004) observed pre-sowing seed treatment with Dithane M-45 or 0.25% Na_2HPO_4 improves dry matter accumulation as well as oil yield in Indian mustard. Soaking seeds of Indian mustard in 25 ppm ascorbic acid before sowing produced higher seed yield of 2.32 t ha^{-1} compared to 2.18 t ha^{-1} with water soaking (Dobariya and Mehta, 1995).

2.13 Effect of pre-sowing seed treatment on the quality of produce:

Pre-soaking of seeds with water or other Chemicals also influence the quality of produce like oil content, protein content etc. Siddaranappa *et al.*(1993) found that oil percentage of ground nut was unaffected by molybdenum seed treatment. Under lateritic belt of West Bengal Maitra *et al.*(1999) studied on the effect of pre-sowing seed treatment on yield and quality of fingemillet. Pre-sowing seed treatment with 100 ppm Na_2HPO_4 , 0.25% CaCl_2 and water significantly improve the grain protein content.

2.13.1 Effect of pre-sowing seed soaking on the quality of produce in rapeseed-mustard:

Ghosh *et al.* (1986) found that pre-sowing seed treatment with Na_2HPO_4 or Dithane M-45 increased oil content of mustard by increasing seed size. Mondal *et al.* (2004) observed pre-sowing seed treatment with Dithane M-45 or 0.25% Na_2HPO_4 improved oil yield in Indian mustard.

2.14 Effect of pre-sowing seed soaking on Nutrient uptake:

Nutrient uptake of plant also improves by pre-sowing seed soaking treatment. Maitra *et al.* (1997) found that pre-sowing seed treatment with Na_2HPO_4 significantly increased nutrient uptake of fingermillet compared with the Control and water soaking treatment.

2.15 Physiological basis of yield variation due to pre-sowing seed treatments:

It is well established by many workers that hardening of seeds through pre-sowing seed treatments have beneficial effect on crops. (Adamsvic,1964; Henckel,1964 ; Heydecker and Coolbear, 1977). Joshi *et al.* (1976) recorded the influence of pre-sowing seed hardening on early growth of soybean. Sen and Osborne (1974) working with rye embryos found that hydration pretreatments initially enhanced the ability of the embryo to synthesized protein and RNA compared to Untreated control.

2.16 Effect of interaction between integrated nutrient management and pre-sowing seed soaking on crops:

Venkatakrishnan (1998) observed on the effect of dry land technologies on seed yield of sesame under rain-fed condition. The combination of different dry land technologies such as seed treatment with 2% KH_2PO_4 and *Azospirillum*, cultivation of broad beds (120-130 cm), application of composted coir pith, application of enriched FYM with 75% of the recommended rate of NPK fertilizers and pre-sowing incorporation of fluchloralin at 1 kg ha^{-1} + one hand weeding increased the plant height, root length, number of branches per plant, number of capsule per plant and the seed yield of sesame compared with farmers practices and the dry land technologies used individually.

Raju *et al.* (1998) studied on the effect of potassium hydrogen phosphate and *Rhizobium* culture with reduced dose of nitrogen on yield of cowpea. Seed yield was highest from seed soaking in 100 ppm KH_2PO_4 and inoculation with *Rhizobium*.

Summary:

The above literature shows that fertility level (N, P and K), seed or soil inoculation of bio-fertilizers, pre-sowing seed soaking, application of vermicompost, FYM and Sulfur play a significant role in increasing growth and yield of rapeseed-mustard and other crops. Now a days the integrated approach of the application of organic, inorganic and bio-fertilizers is being considered for producing high yield without harming the soil health and air environment. The literature also shows that works in this particular stream are very meager in the *terai* region of West Bengal, particularly pre-sowing seed soaking along with use of bio-fertilizers after a portion curtailment of the recommended inorganic fertilizer dose. So to get an insight in to the problems, integrated use of inorganic fertilizers, organic manures, bio-fertilizers, application of sulfur along with pre-sowing seed soaking in rapeseed-mustard, main growing oilseed of this region, for maximizing and stabilizing its productivity without harming the soil health and environment, an investigation has been undertaken in *terai* region of West Bengal.