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2.1 RAPESEED AND MUSTARD

2.1.1 Introduction

In trade, the term rapeseed is used to cover sarson, toria and taramira, whereas the term mustard refers only to 'rai'. In the following paragraphs, their nomenclature, botanical description, classification, distribution, climate and soil requirement, cultivation, harvesting, threshing and uses are discussed.

2.1.2 Nomenclature

There exists great confusion about the proper nomenclature of Indian oleiferous Brassicae. In order to avoid the confusion, these are divided into four groups:

1. Brown mustard, commonly called rai (raya or laha) - Brassica juncea (L.) Czern. & Coss.
2. Sarson (i) Yellow sarson - Brassica campestris L. var. Sarson Prain.
   (ii) Brown sarson - Brassica campestris L. var. dichotoma Watt.
3. Toria (lahi or maghi lahi) Brassica campestris L. var. toria Duth.
4. Taramira or tara (Eruca sativa Mill.)
In addition, there are two other species, namely *Brassica nigra* Koch. (Banarasi rai) and *Brassica juncea* var. *rugosa* (Pahadi rai) which do not fall under any of the four groups, and are grown to a limited extent.

2.1.3 **Botanical description**

Rape and mustard include annual herbs. Roots, in general, are long and tapering. Toria is more or less a surface feeder but brown sarson has long roots, with a limited lateral spread, enabling its successful cultivation under drier conditions. Yellow sarson has both extensive and lateral spread. The height of the stem varies from 0.45 m (in some varieties of toria) to 1.90 m (in yellow sarson). In toria and brown sarson, the branches arise at an angle of 30° to 40°. In yellow sarson, the branches arise laterally at an angle of about 10° to 20° and give the plant a narrow and pyramidal shape. The inflorescence is a corymbose raceme. In the case of yellow sarson, the four petals are spread apart, whereas in brown sarson and toria, the petals overlap or may be placed apart, depending upon the variety. The flowers bear a hypogynous syncarpous ovary. In brown sarson and toria, the ovary is bicarpellary, whereas in the case of yellow sarson, it may also be tri- or tetra-carpellary.
The fruit is a siliqua. The pods are two-valved, three-valved or four-valved, depending upon the number of carpels in the ovary. The flowers begin to open from 8 a.m. and continue up to 12 noon.

2.1.4. Classification

Adopting the system of classification of Bentham and Hooker (1862-1883), all aforesaid oil producing species could be classified as follows:

- **Kingdom**: Plant kingdom
- **Division**: Phanerogamia
- **Sub-Division**: Angiospermae
- **Class**: Dicotyledons
- **Sub class**: Polypetalae
- **Series**: Thalamiflorae
- **Order**: Parietales
- **Family**: Cruciferae

2.1.5 Distribution

The crop is grown both in subtropical and tropical countries. In Asia, it is chiefly grown in China, India and Pakistan. It is also grown in Europe, Canada and Russia and other former U.S.S.R. states. But the forms of the rapeseed and mustard grown there are different from those grown in
India. In India, the chief producer states are Assam, Bihar, Haryana, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal (Anonymous, 1987).

2.1.6 Climate and soil

Members of the group require relatively cool temperature for satisfactory growth. They grow well in areas having 25 to 40 cm of rainfall. Sarson and taramira are preferred in low rainfall areas, whereas raya and toria are grown in medium and high rainfall areas respectively. Rapeseed and mustard thrive best in light to heavy loams (Anonymous, 1987).

2.1.7 Cultivation

Rape and mustard are grown in India during "rabi" (winter) season. The actual time of sowing depends upon the place the crop occupies in rotation. The first half of September is best for sowing toria. If wheat is to follow, toria should be sown by the end of August. Sarson can be sown from 25 September to 15 October and raya, from 30 September to 15 October. However, taramira can be sown throughout October (Anonymous, 1987).

A fine seed-bed is required to ensure good germination. 5 kg seeds per ha are required for all rapeseeds and mustard. Whenever, moisture in the field is
inadequate, the seeds are mixed with moist soil and kept overnight. For distributing evenly, seeds are usually mixed with sand before sowing. Seeds are sown at a depth of 4 to 5 cm in lines, 30 cm apart with a drill or behind the plough. Thinning is done three weeks after sowing to maintain a plant to plant distance of 10 to 15 cm.

The entire quantity of applied fertiliser, particularly nitrogen, is drilled before sowing. Under irrigated conditions, doses of 40, 60 and 80 kg N/ha are considered optimum for raya, sarson and toria respectively. However, under rainfed conditions, 40 kg N/ha is optimum for all rapeseed and mustard varieties. For taramira, which is not irrigated, 20 kg N/ha is sufficient. Two irrigations, one at flowering and other at pod formation, result in maximum yield in raya, sarson and toria (Anonymous, 1987).

2.1.8 Harvesting

Harvesting is done as soon as the crop begins to turn yellow. Toria takes 75-90 days to mature. The other rapeseed and mustard varieties take from 110 to 160 days for maturity.

2.1.9 Threshing

Threshing is done by beating with a wooden stick the seed-bearing part of the plants taken in convenient bundles
or by trampling them under the feet of bullocks. Winnowing is done with the help of natural air current by slowly dropping the threshed produce from a basket held shoulder high. The seed after being dried in the sun is stored in gunny bags or bins.

2.1.10 Uses

The leaves of young plants are used as green vegetable. The plants are also fed to cattle as green fodder. The seeds are used as a condiment and for flavouring curries and vegetable dishes. The seeds contain 30 to 48 per cent oil (Anonymous, 1987). The oil is mainly used either as such or after refinement or after hydrogenation for cooking purposes. It is also used as a preservative for pickles. Hydrogenated refined rape oil is used for the preparation of butter substitutes. The oil is also used for massage in muscular pain, stiff neck, dengue fever and bronchitis. The low grade oil containing high content of erucic acid (as in some varieties of rape and tara) is used for lighting purpose or as a fuel for diesel engines or in industries, like grease, soap, tannery, lubricant, synthetic wax etc.

In the oil extraction process, oil cake is obtained as a by-product. The cake, containing about 25 to 35 per cent protein (Attschul, 1958; Bowland et al., 1965;
Appelqvist and Ohlson, 1972), is mostly used as a cattle and poultry feed. However, presence of glucosinolate compound in inferior cakes makes the meal impalatable and toxic to livestock. Such cake which is not fed to cattle, is used as a manure.

2.2 **INORGANIC PLANT NUTRITION**

2.2.1 **Introduction**

Mineral nutrition is an important sub-science of plant physiology. The term mineral nutrient is generally used to refer to an inorganic ion obtained from the soil and required for plant growth. In general sense, mineral nutrition is concerned with the complex of biosynthetic events, like absorption, translocation and conversion of inorganic nutrients to organic forms.

In the following pages, its history, physiological roles of heavily demanded macronutrients (NPK and S) and their sources, method of nutrient application and their effect on the performance of rapeseed-mustard are visualised.

2.2.2 **Historical**

The practice of application of materials such as wood ashes, plant tissue debris, farm yard manure, ground
bones and compost to soils to increase their productivity is probably as old as agriculture itself (Reed, 1942; Russell, 1950; Bould, 1963).

As early as in 1656, Glauber obtained saltpetre from cattle manure and found that it had great stimulating effect on plant growth. He concluded that fertility of the soil and the value of manures were entirely due to saltpetre (Bould 1963).

In 1699, John Woodward conducted a very interesting experiment. He grew twigs of Mentha in (a) rain water, (b) water from the Thames, (c) effluent from Hyde Park conduits and (d) effluent plus garden mould. After weighing the plants at 77 days, he concluded that the growth of plants was more or less proportional to the quantity of terrestrial matter present in the water (Bould, 1963).

The true role of mineral matter in plant growth was established by de Saussure (1804). Others, who contributed extensively to this important discipline in the nineteenth century included Lawes and Gilbert, Bousingault, Liebig, Sachs and Knop. Their efforts helped not only in the development of reliable field and laboratory techniques that led to outstanding discoveries in the present century but also in the adoption by farmers of sound agricultural
practices, including the application of inorganic fertilisers, for improved yields (Reed, 1942; Russell, 1950).

By using water culture techniques, Sachs (1860) and Knop (1861) were able to demonstrate the importance of ten elements, namely carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S), magnesium (Mg) and iron (Fe). These elements (except iron) are required in rather large quantities (0.1 per cent of dry matter or more) and they have been named macroelements. However, Sachs and Knop failed to note the crucial role played by some other nutrients required in extremely small amounts. Later, plant scientists were able to establish the essentiality of elements, like boron (B), chlorine (Cl), copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn). Since these are required in minute amounts (0.01 per cent of dry matter or less), they have been named as microelements (Bould, 1963) or trace elements (Stiles, 1961).

2.2.3 **Physiological roles of N, P, K and S**

Among macronutrients, much emphasis has been given to nitrogen, phosphorus and potassium, because they are removed by plants in large quantities. In addition to these
three elements, brassicaceous plants remove large amounts of sulphur and are considered to be sulphur carriers. As in the case of other nutrients, N,P,K,S play roles of paramount importance in the life of plants. These roles are summarised below:

2.2.3.1 Nitrogen

Its content in plants approximates 1-3 per cent of dry weight (Salisbury and Ross, 1986). In addition to its absorption in the form of $\text{NO}_3^-$, it is also taken up as $\text{NH}_4^+$ ion. After absorption in the plant, nitrogen is reduced and incorporated into diverse organic compounds (Bandurski, 1965; Beevers and Hageman, 1969). It is one of the more important plant nutrients as it is an integral part of aminoacids, proteins, coenzymes, porphyrins, purines, pyrimidines, chlorophyll, some vitamins and growth hormones (Devlin and Witham, 1986). Deficiency symptoms of nitrogen in young plants include stunted growth and yellowish green leaves. Older leaves are light green, followed by yellowing and drying or shedding, often with abundant anthocyanin in veins. Shoots are short, thin and spindly, with reduced flowering (Noggle and Fritz, 1986).

Application of nitrogen to the soil increases the cation exchange capacity of plant roots and thus makes them more efficient in absorbing other nutrient ions (Tamhane
et al., 1970). Excessive application of nitrogen results in feebly developed root system and low shoot/root ratio, increases leaf production, reduces flowering and seed formation in several crops and delays maturity (Curtis and Clark, 1950; Black, 1973; Devlin and Witham, 1986).

2.2.3.2 Phosphorus

Its approximate content in plants on dry weight basis is 0.2 per cent (Salisbury and Ross, 1986). Phosphorus is absorbed by plants both as monovalent (\(H_2PO_4^-\)) and divalent (\(HPO_4^{2-}\)) anion from soil. The quantity of either ion present in the soil is dependent upon the pH of the soil solution, lower pH favouring \(H_2PO_4^-\) ion and higher pH, \(HPO_4^{2-}\) (Devlin and Witham, 1986).

Phosphorus is a basic constituent of metabolically active compounds, like nucleic acids, phospholipids, phytin, adenosine and other triphosphates, pyridoxal phosphate and thiamine pyrophosphate, phosphorylated sugars and their intermediary metabolic products found in the glycolytic and alternative oxidative pathways, nucleoproteins, nucleic acids, purine and primidine nucleotides and flavin nucleotides (Nason and McElroy, 1963). Phosphate participates directly in the photochemical events of photosynthesis through orthophosphate and nicotinamide adenine dinucleotide
phosphate, required for the production of assimilatory power (Devlin and Witham, 1986).

Phosphorus promotes the formation of lateral and fibrous roots and phosphorus-starved plants have a stunted and poorly developed root system. Application of phosphorus hastens the ripening of the plants. Phosphorus also increases disease resistance in plants (Tamhane et al., 1970). Like nitrogen, phosphorus deficiency results in stunted growth. However, leaves are dark blue-green and often purplish due to anthocyanin accumulation (Noggle and Fritz, 1986).

2.2.3.3 Potassium

Most of the higher plants require potassium in large quantity (1 per cent on dry weight basis) for proper growth and development (Salisbury and Ross, 1986). In contrast to nitrogen and phosphorus, potassium does not form a stable structural part of any molecule inside the plant cells. Potassium activates the enzymes that synthesize certain peptide bonds (Webster, 1953) and enhances the incorporation of amino acids into protein (Webster, 1956). Other enzymes that require potassium (K+) as an activator include fructokinase, pyruvic acid kinase and transacetylase (Nason and McElory, 1963). Potassium is essential for most metabolic processes, including glycolysis, oxidative
phosphorylation and adenine synthesis (Evans and Sorger, 1966). It is involved in the translocation of solutes moving actively across the sieve plate by electro-osmosis (Salisbury and Ross, 1986). It plays a role in tissue hydration and thus helps in opening and closing of stomata (Fischer and Hsiao, 1968; Humble and Hsiao, 1969; Webb and Mansfield, 1992).

Potassium deficiency results in chlorosis of older leaves first. Its deficiency causes scorching of margin and tip, necrosis, rosette or bushy habit of growth and weakening of stems. It also causes reduction in protein synthesis (Hewitt, 1963).

2.2.3.4 Sulphur

Sulphur is absorbed as sulphate ion ($\text{SO}_4^{2-}$). It may also enter through the leaves as sulphur dioxide present in the atmosphere (Thomas et al., 1944). Gilbert (1951) pointed out that the amount of the element varies considerably in different genera and families of plants, usually ranging between 0.1 and 1.0 per cent on a dry weight basis.

Sulphur is a constituent of proteins, in the form of the sulphur-bearing aminoacids cystine, cysteine and methionine, and of many metabolically active compounds, such as thiamine, pyrophosphate, biotin, coenzyme A, lipoic acid,
adenosine 5-phosphate, 3-phosphoadenosine 5-phosphosulphate and sulphydryl groups (Salisbury and Ross, 1986). It has also been reported that sulphur is directly involved in electron transport chain through characterisation of glutathione reductase (Conn and Vennesland, 1951; Mapson and Goddard, 1951). It occurs in certain plants in volatile forms such as sinigrin and sinalbin known as glucosinolate compounds (Trease and Evans, 1972), allyl and vinyl sulphides and mercaptans. It also forms disulphide (cystine) that is involved in forming and stabilising the tertiary structure of enzymes and proteins (Bidwell, 1981). Like nitrogen, sulphur deficiency causes chlorosis, followed by anthocyanin pigmentation. Amino acids and other nitrogen containing compounds accumulate in the tissues and proteolytic activity also increases. Plants look stunted and flowering is delayed (Malik and Srivastava, 1982; Devlin and Witham, 1986).

2.2.4 N,P,K and S containing fertilisers

Continuous cultivation, leaching, immobilisation, denitrification, fixation and volatilisation result in soil nutrient losses. To overcome the affected nutrient supplying power of the soils and to get high yields, plant nutrients must be added. The important sources of N,P,K and S are given below:

Anhydrous ammonia, ammonium sulphate, nitrates and
urea are the more common forms of nitrogen fertilisers. Single superphosphate, triple superphosphate, nitric phosphate and ammonium polyphosphate are the major phosphorus fertilisers. Muriate of potash, (potassium chloride) and potassium sulphate are the principal potassium fertilisers. Soluble sources of sulphur comprise superphosphate, ammonium sulphate, potassium sulphate, magnesia, kaolinite and gypsum (Thompson, 1952; Donahue et al., 1990).

2.2.5 Fertiliser feeding

Nutrient feeding of crop plants takes place generally through their roots under natural conditions. However, under some conditions, e.g. (1) when the nutrients are needed immediately and (2) when nutrients must be added to crops growing in sandy soils, nutrients may be applied through foliage. The feeding through roots may be called root feeding and that through foliage, foliar feeding.

2.2.5.1 Root feeding

There may be several ways of fertiliser application. The important ones are summarised below (Donahue et al., 1990):

(a) Gaseous fertiliser application in soil

Anhydrous ammonia is released as a gas, usually at
10 to 15 cm depth (or even deeper in sandy soils) which is adsorbed on the surface of clay and humus particles.

(b) **In irrigation water**

Applying fertilisers in irrigation water is an old practice. Anhydrous ammonia or other (solid) fertilisers could be metered into the water. The sprinkler irrigation system may encourage more use of fertilisation in the water.

(c) **Banding**

For row crops, fertiliser is usually applied slightly below and to one side of the seed.

(d) **Broadcasting**

The fertiliser is applied in such a way that it covers the total area.

(e) **Strip placement**

The fertiliser is placed in strips so that there is a broad concentrated strip along the crop row. This application is more concentrated than broadcasting but not as dense and localised as banding. The wide strip application encourages more extensive root development than does banding and loses less fertiliser by fixation than does broadcasting.
(f) **Top dressing**

Top dressing is applying a portion of the fertiliser in a second application on the surface.

(g) **Side dressing**

It is either a surface placement or a type of shallow banding put on as a second application as the plant grows.

2.2.5.2 **Foliar feeding**

In this technique, dilute sprays of nutrients are applied to plant foliage. Nutrients from these foliar sprays move into the plant both through the leaf stomata and through parts of the epidermis.

2.2.6 **Soil application of N,P,K and S**

Much of the work on the nutrient requirements of crop plants has been done on scientific lines for more than a century on nitrogen, phosphorus and potassium as these elements are removed in huge quantity for their optimum performance. In oil crops, in addition to nitrogen, phosphorus and potassium, sulphur is required in rather large quantity and, has recently drawn the attention of a few scientists. In the following pages, an attempt has, therefore, been made to review the available Indian
literature on the response of the recently released varieties of the mustard group to these nutrients. For the sake of convenience in comparison, values for $P_2O_5$ and $K_2O$ have been converted into $P$ and $K$ respectively where required.

Sharma (1968) conducted field trials at Meerut (U.P.) on Laha-101 (Brassica juncea) for three successive years. He studied the effect of nitrogen, phosphorus and potassium individually on seed yield. Nitrogen was applied at 0, 22.5 and 45 kg N/ha and phosphorus and potassium each at 0, 4.8, 9.6 and 0, 9.3, 18.6 kg P and K/ha respectively. He noted that application of additional nitrogen exhibited significant rise in the seed yield. However, as compared with nitrogen, phosphorus gave lesser increase in yield. Increase due to potassium applications were lowest and 9.3 and 18.6 kg K/ha did not show worthwhile difference in seed yields.

Arora and Bhatia (1970) reported from Hisar (Haryana) the results of trials conducted for two years on RL-18 and RS-3 varieties of Brassica juncea. They applied three levels of nitrogen (0, 15 and 30 kg N/ha). They reported that nitrogen application increased seed yield, protein content and allyl-isothiocyanate value, but decreased oil content and its iodine value. There were large variations in yield between varieties.
Wankhede et al. (1970), at Sirsa (Haryana), conducted a field experiment on the 'Abohar' variety of Indian rape (Brassica campestris var. toria) in which fertilisers were applied at the rate of 40 kg N + 8.7 kg P and 80 kg N + 17.4 kg P/ha. Half of the nitrogen was applied at sowing and half at thinning, whereas the total amount of phosphorus was applied at sowing. They reported that application of 40 kg N + 8.7 kg P/ha increased the number of branches per plant, capsules per plant and seed yield per ha significantly compared with the unfertilised control. However, at the higher fertiliser level (80 kg N + 17.4 kg P/ha) the increase was less pronounced.

Singh et al. (1971), working at Hisar (Haryana), applied 0 kg N + 0 kg P/ha, 50 kg N + 10.9 kg P and 100 kg N + 10.9 kg P/ha to brown sarson (Brassica campestris var. dichotoma). They reported that 50 kg N + 10.9 kg P/ha gave maximum yield and the highest dose 100 kg N + 10.9 kg P/ha proved ineffective. However, oil content was decreased by the application of the fertilisers.

Singh and Tomar (1971) conducted a field study at Kota (Rajasthan) on mustard (var. not mentioned) for three years. They applied three levels of nitrogen, viz. 0, 70 and 140 kg N/ha with and without three combinations of phosphorus and potassium (0:0, 0:41.5 and 21.8:41.5 kg P:K/ha. Nitrogenous fertilisers were applied in two doses,
half at sowing and the rest at 40 days of crop growth. They noted on pooled basis that increasing doses of nitrogen enhanced seed yield. No response was observed due to application of phosphorus and potassium alone. However, they stressed that for balanced nutrition, a dose of 21.8 kg P and 41.5 kg K should be applied.

Gupta et al. (1972) conducted a field trial with *Brassica campestris* var. Toria T-9 at Kanpur (U.P.). They applied nine treatments consisting of different combinations of nitrogen (0, 40 and 80 kg N/ha) and phosphorus (0, 13.0 and 26.1 kg P/ha). A tenth treatment comprising 80 kg N, 26.1 P and 33.2 kg K/ha was also applied to test if inclusion of potassium would be beneficial. They noted that the combination 80 kg N + 26.1 kg P proved best. They added that phosphorus alone at both the levels showed slight increase in oil content, whereas 80 kg N/ha with or without phosphorus decreased it. The dose 80 kg N + 26.1 kg P showed an increase in oil yield and protein content. Inclusion of potassium did not seem advantageous. However, it increased oil percentage over all combinations of nitrogen and phosphorus.

Kinra et al. (1972), conducting a field experiment at Kanpur (U.P.), applied four levels of nitrogen (0, 50, 100 and 150 kg N/ha) to Indian mustard (*Brassica juncea* var. Appressed Mutant). Half of the dose was applied at sowing
time and the remaining half, 40 days after sowing. They observed application of 100 kg N/ha to be optimum for seed yield.

Mehrutra et al. (1972) working with Indian mustard (Brassica juncea var. RT-11) at Kanpur (U.P.), found that best seed yield and oil and protein contents were achieved by the use of combined nitrogenous and phosphatic fertilisers applied at the rate of 66 kg N + 9.6 kg P/ha. An inverse relationship between oil and protein content of rai seeds was observed by them.

Shekhawat et al. (1972) studied the effect of 3 doses each of nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.0 and 26.1 kg P/ha) and potassium (0, 24.9 and 49.8 kg K/ha), supplied in all possible combinations, on yield of mustard (Brassica campestris var. Sarson Prain) at Jodhpur (Rajasthan). Half nitrogen and full phosphorus and potassium were applied as basal dressing and the remaining nitrogen was top-dressed at flowering. They noted that application of nitrogen at both the levels significantly increased seed yield over control. However, no significant difference was noted between 30 kg and 60 kg N/ha. Neither dose of phosphorus and potassium had any significant effect on seed yield.

Singh et al. (1972), conducting field trials at Gurgaon (Haryana) for two successive years, studied the
effect of three levels of nitrogen (0, 74 and 101 kg N/ha) on four varieties of Indian mustard (Brassica juncea), namely RG-1, RG-3, RL-9 and RL-18. There was significant increase in seed yield with increasing level of nitrogen. Nitrogen application at 101 kg N/ha gave 51.6 and 10.5 per cent more yield over 0 and 74 kg N/ha respectively. In the first year, varieties did not differ from each other in their response. However, in the second year, var. RG-3 gave 11.2, 9.2 and 8.8 per cent more seed yield over RG-1, RL-9, and RL-18 respectively. The averages for the two seasons did not reveal significant varietal differences.

Singh and Yadava (1972), working on Indian rape (Brassica campestris L. var. toria) at Hisar (Haryana) for three successive years, applied different fertiliser nitrogen + phosphorus levels (0 kg N + 0 kg P/ha, 40 kg N + 8.7 kg P and 80 kg N + 8.7 kg P/ha). The data showed that increased fertility levels enhanced primary branches, pods per main shoot, pod length and seeds per pod but decreased 1,000 seed weight. Seed yield was increased significantly with increasing fertility levels in the first year but in the other two years, the effect of 80 kg N + 8.7 kg P/ha was not significant. The oil percentage increased up to 40 kg N + 8.7 kg P in the first year, whereas increasing fertility levels had depressing effect on this parameter during the
other two years. However, oil yield followed the trend of seed yield during all the three years.

Dasgupta and Das (1973) conducted a field experiment at Varanasi (U.P.) on *Brassica campestris* var. Yellow Sarson T-42 for two years. The treatments included 3 levels of nitrogen (0, 50 and 100 kg N/ha); 3 levels of phosphorus (0, 16.3 and 32.7 kg P/ha) and three levels of potassium (0, 31.1 and 62.2 kg K/ha) separately and in all possible combinations. The data on average of two years revealed a gradual increase in number of pods, length of pods, test weight of seeds and seed yield with increasing levels of nitrogen. Application of phosphorus did not exhibit such increase. Potassium application exhibited the same trend as noted for phosphorus application. Oil content of seeds was found to decrease with increasing levels of nitrogen and it increased slightly on application of maximum dose of potassium; but there was no effect of phosphorus application on oil content.

Pasricha and Randhawa (1973) conducted a pot experiment on mustard at Ludhiana (Punjab). They applied 5 levels of sulphur viz. 0, 12.5, 25.0, 37.5 and 50 ppm to mustard (*Brassica juncea* var. RL-18). They reported that, compared to the control, sulphur application increased dry matter yield and oil content of mustard.
Dayanand and Mahapatra (1974), in a field experiment at New Delhi on raya (*Brassica juncea* var. Appressed Mutant), applied three levels of nitrogen, viz. 30, 60 and 90 kg N/ha. They reported that seed yield increased up to 60 kg N/ha; but did not vary significantly among the various levels of nitrogen.

Singh et al. (1974) conducted an experiment on mustard (var. not mentioned) at Kota (Rajasthan) for three years. They applied nine combinations of nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.0 and 26.1 kg P/ha) and potassium (0, 24.9 and 49.8 kg K/ha). Phosphorus and potassium were applied as full dose at the time of sowing, whereas nitrogen was split in two, viz. half at sowing and the rest at first irrigation. A combined dose of 60 kg N + 26.1 kg P + 49.8 kg K/ha proved optimum for yield.

Bhan et al. (1975), studied the effect of three combinations of nitrogen, phosphorus and potassium (0 kg N + 0 kg P + 0 kg K/ha, 60 kg N + 13.0 kg P + 24.9 kg K/ha and 120 kg N + 26.1 kg P + 49.8 kg K/ha) on seed yield and attributes of three varieties of mustard (*Brassica juncea*), namely Appressed Mutant, APP-3 and T-16 at Kanpur (U.P.). They found that application of the highest fertility level resulted in maximum yield of mustard. Among varieties, T-16, proved better than Appressed Mutant and APP-3.
Chundawat et al. (1975) studied at Jaipur (Rajasthan) the effect of 3 levels each of nitrogen (0, 30 and 60 kg N/ha), phosphorus (0, 13.0 and 26.1 kg P/ha) and potassium (0, 24.9 and 49.8 kg K/ha) on yield of mustard (*Brassica juncea* var. RL-18). Half of nitrogen and full amount of phosphorus and potassium were drilled at sowing. The remaining half of nitrogen was top-dressed at first irrigation. They found that application of 60 kg of N and 26.1 kg P/ha was economical. However, the increase in yield with increasing dose of potassium was not significant and response to potassium was restricted to 24.9 kg K/ha).

Sahu and Behura (1975) performed field experiments at Bhubaneswar (Orissa) for two consecutive years on *Brassica juncea* var. Appressed Mutant. They applied nitrogen at 0, 50 and 75 kg N/ha, phosphorus at 0, 10.9 and 21.8 kg P/ha and potassium at 0, 20.7 and 41.5 kg K/ha). Nitrogen was applied in two equal splits, i.e. half at sowing and half before flowering. The maximum, as well as economical, seed yield was given by a combined dose of 50 kg N + 10.9 kg P + 20.7 kg K/ha. Maximum oil content was, however, obtained with 21.8 kg P/ha alone.

Bhan and Singh (1976 a) studied the effect of three levels of nitrogen (0, 40 and 80 kg N/ha), three levels of phosphorus (0, 13.0 and 26.1 kg P/ha) and two levels of
potassium (0 and 33.2 kg K/ha) alone and in combination on yield and yield attributes of brown sarson (*Brassica campestris* var. not mentioned) at Kanpur (U.P.). They reported that fertiliser application markedly improved pods per plant, seeds per pod, seed yield and oil content in seeds. The increase due to nitrogen application was significantly high at 40 kg N/ha. Nitrogen at 80 kg N/ha further improved the yield, but it slightly reduced the oil content in seed. Phosphorus also improved yield and other characters but when combined with nitrogen it did not result in any additional yield over that of nitrogen alone. Potassium, given with 80 kg N + 26.1 kg P/ha, failed to give any effect. They concluded that brown sarson may profitably be grown with a dose of 40 kg N/ha under dryland farming in Uttar Pradesh.

Bhan and Singh (1976b) conducted another field experiment on mustard (*Brassica juncea* var. T-16) at the same place. They applied five levels of nitrogen (0, 40, 80, 120 and 160 kg N/ha), three levels of phosphorus (0, 10.9 and 21.8 kg P/ha) and two levels of potassium (0 and 20.7 kg K/ha), separately and in all possible combinations. A gradual increase in yield was noted by the application of nitrogen up to 80 kg N/ha. Application of 160 kg N/ha caused a depression in yield. The effect of phosphorus was found beneficial, with 10.9 kg P/ha proving optimum. Application
of 20.7 kg K/ha gave significantly higher yield over the control. They concluded that for optimum yields and profits the mustard crop may be supplied with a dose of 80 kg N + 21.8 kg P + 20.7 kg K/ha in the central region of Uttar Pradesh.

Agrawal and Gupta (1977), working at Haridwar (U.P.), studied the effect of four graded doses of nitrogen, viz. 0, 25, 50 and 75 kg N/ha on two varieties of toria (Brassica campestris var. toria), namely Toria T-9 and Lahia T-36. Phosphorus and potassium were applied uniformly at the rate of 8.7 and 16.6 kg P and K/ha. Half the dose of nitrogen and full dose of phosphorus and potassium were applied at sowing and the remaining half dose of nitrogen was applied as top dressing after first irrigation. There was increase in yield and yield attributing characters with increasing doses of nitrogen, with 50 kg N/ha proving optimum as well as economical. For varietal response, Toria T-9 proved better than Lahia T-36.

Aulakh and Pasricha (1977) conducted a pot experiment at Ludhiana (Punjab) with rapeseed (Brassica napus var. ITSA). They applied sulphur, magnesium and potassium each at 0, 25 and 50 ppm alone and in combination. A uniform level of nitrogen, phosphorus, zinc and calcium was maintained. They noted that sulphur fertilisation,
individually and in combination with potassium, increased seed yield. Applied magnesium depressed the yield of seeds. Application of 25 ppm of potassium increased rapeseed production. The interaction effect of S x K was consistently favourable for seed yield.

Dasgupta and Ghosh (1977), applied four doses of nitrogen, viz. 0, 40, 80 and 120 kg N/ha, to two Indian mustard (*Brassica juncea*) varieties, namely Appressed Mutant and T-59 at Varanasi (U.P.). According to them, the oil content was not affected but protein percentage increased with higher doses of nitrogen.

Singh and Singh (1977a) conducted a pot experiment at Hisar (Haryana) with raya (*Brassica juncea* var. RL-18). They applied sulphur at 0, 30, and 60 ppm with four doses (0, 2.5, 5 and 10 ppm) of selenium. Data revealed that sulphur-containing amino acids, oil percentage and allyl-isothiocyanate value increased with the sulphur application, whereas it decreased with selenium application. It was noted that the negative effect of selenium was counteracted by sulphur application.

Singh and Singh (1977b), performing another pot experiment at the same place, applied sulphur at the rate of 0, 15, 30, 60, 90 and 120 ppm to raya (*Brassica juncea* var. RL-18). Application of sulphur at 60 ppm proved optimum for
plant growth, 1,000 seed weight and seed yield. The effect of 60 ppm was similar to that of 90 ppm but 120 ppm proved maximum for yield.

Patil and De (1978), working at I.A.R.I., (New Delhi), studied the effect of three levels of nitrogen (0, 30 and 60 kg N/ha) on rapeseed (*Brassica campestris*). They noted that nitrogen fertiliser enhanced seed yield. However, it decreased oil content. The reduction in oil percentage was, however, too small to affect the oil yield per hectare. On calculating, it was found that application of nitrogen at 53 kg N/ha was profitable for the rapeseed.

Singh et al. (1978a), working at Jodhpur (Rajasthan), applied nitrogen at 0, 30, 60 and 90 kg N/ha to two varieties of mustard (*Brassica juncea*), namely T-59 and KYSR, under limited moisture supply. On the basis of the results, they suggested that for high yield of mustard with limited moisture supply, application of 30 kg N/ha seemed necessary. For varietal response, they noted that the oil percentage and oil yield were more in KYSR than in T-59 at all nitrogen levels.

Singh et al. (1978b) conducted a field experiment at Ludhiana (Punjab) for two years. They applied four levels of nitrogen (0, 50, 75 and 100 kg N/ha) to four varieties of
raya (*Brassica juncea*), namely RL-18, Prakash, T-59 and RLM-198. The data revealed that the increase in yield was significant only at 50 kg N/ha on the basis of pooled analysis. Regarding varieties, RLM-198 proved better than the other varieties. The varieties RL-18 and Prakash outyielded RLM-198 at the zero level of nitrogen, whereas RLM-198 gave higher yield than Prakash and RL-18 at all other levels of nitrogen. RLM-198 did not differ significantly in yield from T-59 at any of the nitrogen levels in any year.

Singh and Singh (1978) performed a pot experiment on raya (*Brassica juncea*) at Hisar (Haryana). They applied sulphur at the rate of 0, 15, 30, 60, 90 and 120 ppm with 60 ppm nitrogen, 30 ppm phosphorus and 5 ppm of zinc + iron + manganese. They found that seed yield per pot and oil content increased with the application of sulphur up to 90 ppm, while at 120 ppm both declined.

Bishnoi and Singh (1979a) conducted a field experiment at Hisar (Haryana) for two years on three varieties of raya (*Brassica juncea*), viz. RH-29 (Prakash), RH-30 and RL-18. Nitrogen was given at the rate of 0, 30, 60, and 90 kg N/ha. Half of nitrogen was applied at sowing and half at first irrigation. A gradual increase in seed yield, dry weight per plant and 1,000 seed weight was obtained with increasing level of nitrogen. Variety RH-30 showed significantly more test weight than RH-29 and RL-18 during
both the years. The varieties did not show any significant
difference with regard to seed yield.

Bishnoi and Singh (1979b) further reported the
effect of nitrogen application on oil quality of the three
mustard varieties. Nitrogen application decreased oil
content but increased oil yield significantly. Iodine value,
allyl-isothiocyanate and free fatty acids were also found to
be increased by nitrogen application. As far as varieties
were concerned, it was noted that oil content in RH-30 was
highest, followed by RL-18 and RH-29. However, varieties did
not show any significant difference with regard to other
quality characteristics, except iodine value which was
highest in RL-18.

Jain and Jain (1979) studied the effect of five
fertility levels on Brassica juncea var. T-59 at Udaipur
(Rajasthan). The various fertiliser doses were: control (no
fertiliser), 30 kg N/ha, 30 kg N + 10 kg P + 20 kg K/ha,
60 kg N/ha and 60 kg N + 10 kg P + 20 kg K/ha. They noted
that there was a significant increase in yield with
application of 30 and 60 kg N/ha. The average increase in
yield over the control was 240 kg/ha with 30 kg N/ha. A
further increase of 180 kg/ha was obtained with 60 kg N/ha.
The addition of phosphorus and potassium in both the
nitrogen treatments, though giving higher yields, did not
prove economical.
Mudholkar and Ahlawat (1979) conducted an experiment at Sirsa (Haryana) on three varieties of yellow sarson (YSS-8, 4 Valved Mutant and YS-24). Nitrogen was applied at 0, 40 and 80 kg/ha. A basal dose of 17.4 kg P and 33.2 kg K/ha along with nitrogen as per treatment was applied at the time of sowing. They noted that application of nitrogen increased pods per plant and 1,000 seed weight. The higher dose (80 kg/ha), however, had no additional advantage over 40 kg N/ha in respect of all plant characters and seed yield. Varieties tested did not behave differently with regard to all parameters, including pod number, 1,000 seed weight and seed yield.

Pandey et al. (1979), working at I.A.R.I., (New Delhi), studied the effect of graded levels of nitrogen (0, 20, 40 and 60 kg N/ha) and phosphorus (0, 8.7 and 17.4 kg P/ha) along with a constant dose of 33.2 kg K/ha on mustard (Brassica juncea var. BSH-1). They observed that increasing levels of nitrogen increased seed yield. However, phosphorus application did not show significant difference in seed yield.

Aulakh et al. (1980) conducted trials at Ludhiana (Punjab) for three consecutive years with yellow mustard (Brassica campestris) and mustard (Brassica juncea) to test the effect of nitrogen and sulphur application. Three levels of sulphur (0, 30 and 60 kg S/ha) in combination with four
levels of nitrogen (0, 25, 50 and 75 kg N/ha for yellow
mustard and 0, 60, 120 and 180 kg N/ha for mustard) were
applied. During the third year (1977-78), the levels of
nitrogen were changed to 0, 30, 60 and 90 kg N/ha for yellow
mustard and 0, 50, 100 and 150 kg N/ha for mustard. A
uniform dose of 8.7 kg P/ha was drilled with sulphur. Yellow
mustard var. BSH-1 was sown in each year, while mustard var.
RLM-198 was sown in the first two year and RL-514, in the
final year. The data revealed that in all the three years,
seed and oil yields of both mustard cultivars were
significantly enhanced with increasing nitrogen rates.
However, maximum seed and oil yields were obtained only when
high rates of nitrogen and sulphur were applied together.
The adequate N:S ratio appeared to be 7.5:1 or less for good
performance of these varieties. Sulphur (but not nitrogen)
application improved oil content in seeds. Protein content
of seeds increased with applied nitrogen and sulphur.
Regarding varieties, mustard performed better than yellow
mustard.

Patel et al. (1980) conducted a field experiment at
Junagarh (Gujarat) on mustard (Brassica juncea var. Varuna).
They applied various combination of nitrogen (0, 25, 50 and
75 kg N/ha) and phosphorus (0, 10.9, 21.8 and 32.7 kg P/ha).
All the phosphorus and half the dose of nitrogen were
applied before sowing and the remaining nitrogen was top-
dressed one month after sowing. They reported that the application of 50 kg N/ha and 21.8 kg P/ha significantly surpassed the rest of the nitrogen and phosphorus combinations for yield attributing characters.

Vir and Verma (1981) applied four levels of nitrogen (0, 30, 60 and 90 kg N/ha) and three levels of phosphorus (0, 13.0 and 26.1 kg P/ha) to mustard *Brassica juncea* var. T-59 at Agra (U.P.). They found that, among nitrogen levels, 60 kg N/ha and, of the phosphorus doses, 13.0 kg P/ha proved better for pod number and seed yield. Oil content in seeds remained unaffected by nitrogen and phosphorus fertilisation.

Parvaiz et al. (1982b) conducted a field trial at Aligarh (U.P.) on two varieties of mustard, namely *Brassica campestris* L. var. Peeli Sarson and *Brassica juncea* L. Czern. & Coss. var. Laha-101, to study the effect of five selected combinations of nitrogen and phosphorus, i.e. N₀P₀, N₄₀P₈.₇', N₄₀P₁₇.₄', N₆₀P₈.₇ and N₆₀P₁₇.₄. Potassium was applied uniformly at the rate of 33.2 kg K/ha. They noted that the treatment N₄₀P₁₇.₄ gave values for seed yield, oil yield, oil percentage and hecto-litre weight. However, pods per plant and seeds per pod were maximum in the treatment N₆₀P₁₇.₄ and N₆₀P₈.₇ respectively. For most of the yield characters, of the varieties, Laha-101 out-
yielded Peeli Sarson. The interaction $N_{60}P_{17.4} \times \text{Laha-101}$ registered highest values for seed and oil yield.

Singh and Dhankhar (1982) conducted a field experiment at Bawal (Haryana) on mustard (Brassica juncea L. Czern & Coss var. Prakash) to study the effect of four levels of nitrogen (0, 20, 40 and 60 kg N/ha) and three levels of phosphorus (0, 20, and 40 kg P/ha) applied at the time of sowing. They noted that application of nitrogen and phosphorus increased seed yield, with 60 kg N and 20 kg P/ha giving the maximum value.

Afridi et al. (1983), working with Brassica juncea L. Czern & Coss var. Laha-101 at Aligarh noted, in the presence of a uniform dose of 33.2 kg K/ha, the superiority of basal 60 kg N + 8.7 kg P/ha over 30 kg N + 4.4 kg P/ha with regard to some yield characters as well as final yield. For example, they found that the higher dose increased pods per plant by 67.0 per cent, seeds per pod by 8.3 per cent and seed yield by 43.8 per cent over the lower dose. They also pointed out that although oil content was reduced by 8.5 per cent total oil yield was increased by 35.6 per cent mainly due to the spectacular increase in seed yield noted above.

Parvaiz et al. (1983) conducted a field trial at Aligarh (U.P.) with two varieties of mustard (Brassica
They observed the effect of application of two levels of phosphorus (4.4 and 8.7 kg P/ha) in the presence of 60 kg N and 33.2 kg K/ha applied uniformly. They noted that the higher dose of phosphorus 8.7 kg P/ha proved superior to the other dose for all the characters studied, including shoot length per plant fresh weight per plant, dry weight per plant, pod number per plant, seed number per pod, hecto-litre weight, oil percentage, oil yield and seed yield. Regarding varietal difference, Laha-101 performed better than Peeli Sarson.

Samiullah et al. (1984) conducted a field trial on mustard (Brassica juncea) var. Varuna at Aligarh (U.P.) to study the effect of different combinations of phosphorus (17.4, 26.1 and 34.8 kg P/ha) and potassium (33.2, 49.8 and 66.4 kg K/ha) on pods per plant, seeds per pod, hecto-litre weight, oil content, seed yield and oil yield. A uniform dose of urea nitrogen at the rate of 90 kg N/ha was also applied at the time of sowing. The effect of phosphorus alone, as well as in combination with potassium, was found significant for all parameters studied. The combination 26.1 kg P + 33.2 kg K/ha proved optimum, producing about 12 and 23 per cent more seed and oil yield respectively than the control.
Mohammad et al. (1985) conducted a field experiment at Aligarh (U.P.) to study the effect of four levels of nitrogen, viz. 30, 60, 90 and 120 kg N/ha, on yield and quality characteristics of mustard (Brassica juncea) var. Varuna. A uniform dose of 17.5 kg P, as monocalcium superphosphate, and 33.2 kg K/ha, as muriate of potash, was also given before sowing. Of the four doses of applied nitrogen, 90 kg N/ha proved optimum for most of the parameters, including pod number per plant, seed number per pod and seed and oil yield/ha. Seed yield was 58.8 per cent and oil yield, 50.2 per cent higher in 90 kg N/ha than in 30 kg N/ha. However, iodine value and saponification value showed a decreasing trend with increasing dose of nitrogen but acid value increased with increasing level of nitrogen.

Samiullah et al. (1985) and Mohammad et al. (1986a), working with Brassica juncea L. Czern & Coss var. Varuna at Aligarh, U.P., noted that in the presence of a uniform dose of 33.2 kg K/ha, 60 kg N + 17.4 kg P/ha proved better for pods per plant, seeds per pod, seed yield, oil percentage and oil yield than 40 kg N + 8.7 kg P/ha. The treatment $N_{60}P_{17.4}K_{33.2}$ increased pods per plant by 11.0 per cent, seed number per pod by 6.0 per cent, seed yield by 41.0 per cent and oil yield by 45.0 per cent over $N_{40}P_{8.7}$. 
Antil et al. (1986) conducted a field experiment at Hisar (Haryana) on three varieties of raya, namely Prakash, RH-30, and RH-7513, to study the effect of five levels of nitrogen, i.e. 0, 30, 60, 90 and 120 kg N/ha on dry matter and seed yield and uptake of nitrogen. A basal dose of 13.0 kg P/ha was applied along with half of nitrogen by drilling at sowing and the remaining half of nitrogen was applied at 45 days with first irrigation. They noted that, among nitrogen levels, 90 kg N/ha proved better for dry matter and seed yield. However, dry matter yield of Prakash at 45 days was less than that of RH-30 and RH-7513 and at 90 days, there was no significant difference; but at 135 days, Prakash gave higher dry matter yield than the other two varieties. The agronomic efficiency of Prakash, RH-30 and RH-7513 was 7.6, 8.5 and 8.9 kg seed per kg of applied nitrogen, respectively. Increasing nitrogen levels increased its concentration and uptake. Of the total nitrogen absorbed, 22.9, 25.4 and 21.8 per cent and 91.6, 87.8 and 71.9 per cent at 120 kg N/ha was absorbed at 45 and 90 days by Prakash, RH-30 and RH-7513 respectively.

Samui et al. (1986) conducted a field experiment at Kalyani (West Bengal) on Indian mustard (Brassica juncea Czern & Coss var. Varuna), to evaluate the effect of seven combinations of nitrogen and iron sulphate (no nitrogen and iron sulphate, 50, 100 and 150 kg N/ha with and without
20 kg iron sulphate/ha). Phosphorus and potassium were applied uniformly at sowing as single superphosphate and muriate of potash, respectively at 26.1 kg P and 33.2 kg K/ha. They noted that, application of nitrogen increased dry matter accumulation and yield attributing characters of mustard over control. Nitrogen, both alone and in combination with iron sulphate, significantly increased seed yield over the control. There was, however, no significant difference in yield between 100 and 150 kg N/ha or between 100 kg N/ha plus 20 kg iron sulphate/ha and 150 kg N/ha plus 20 kg iron sulphate/ha. Oil content was not affected by nitrogen or iron sulphate.

Malavia et al. (1988) conducted field trials at Junagarh (Gujarat) on mustard (Brassica juncea L. var. Varuna) for three successive years. They applied four levels each of nitrogen (0, 25, 50 and 75 kg N/ha) and phosphorus (0, 10.9, 21.8 and 32.7 kg P/ha). It was noted that the growth and yield attributes, except 1,000 seed weight, were significantly influenced by application of nitrogen and phosphorus. Number of primary and secondary branches per plant, plant height and seed weight per plant responded to nitrogen upto 50 kg/ha and to phosphorus upto 21.8 kg P/ha. However, seed yield responded to nitrogen upto 50 kg N/ha and to phosphorus upto 10.9 kg P/ha only.
Prasad and Eshanullah (1988) conducted field trials at Pusa (Bihar) on mustard (Brassica juncea L.) var. Varuna for two years, in which they studied the effect of three levels of nitrogen (40, 60 and 80 kg N/ha) on yield and yield attributes of mustard. The length of silique increased with increasing level of nitrogen but number of seeds per pod and 1,000 seed weight were enhanced with nitrogen application up to 80 kg/ha. However, yield response to nitrogen was recorded up to 60 kg N/ha. Oil content was not affected by nitrogen levels.

Khan et al. (1990) conducted a field experiment at Aligarh (U.P.) to study of four combinations of nitrogen and phosphorus, i.e. N60P20, N60P30, N90P20 and N90P30 (with a uniform dose of 30 kg K/ha) on yield attributes (pods per plant, seeds per pod, Hecto-Litre weight, oil content, seed yield and oil yield) and on quality (acid, iodine and saponification values) of KRV-47, Pusa Bold, PR-18, RK-1467, RK-8201 and Varuna varieties of mustard (Brassica juncea L. Czern & Coss). It was noted that yield and its attributing characters were increased maximally by N60P20. For oil quality, minimum iodine value and maximum saponification value was noted with N60P30 and N60P20 respectively. Regarding varieties, Varuna proved better than the others for all parameter studied. For nutrient and variety interaction, N60P30 x Varuna resulted in maximum seed and oil yield.
Katole and Sharma (1991) performed a field experiment on mustard (*Brassica juncea* L. Czern & Coss) var. Varuna at Kota (Rajasthan) for two years. They studied the effect of three basal nitrogen levels (30, 60 and 90 kg N/ha) on seed yield and other yield attributes of mustard. Application of 90 kg N/ha resulted in maximum branches per plant and seed yield. However, 60 kg N/ha resulted in maximum pods per plant. Nitrogen fertilisation also increased consumptive water use and water use efficiency.

Rana et al. (1991) conducted a field trial on (*Brassica juncea* L. Czern & Coss) var. Pusa Bold at Baraut (U.P.) for two years. In their study, the effect of four levels of basal nitrogen (0, 50, 100 and 150 kg N/ha) on oil content, oil yield, nitrogen content and nitrogen uptake of mustard was studied. A negative effect of nitrogen application on oil content was observed, but the total oil yield was increased by the application of nitrogen. The content and uptake of nitrogen was observed to be increased upto 150 kg N/ha.

Singh et al. (1991) carried out a field experiment on *Brassica juncea* L. Czern & Coss var. Varuna, at Varanasi (U.P.) to study the effect of four levels of nitrogen (0, 25, 50 and 75 kg N/ha) and three levels of phosphorus (0, 8.7 and 17.4 kg P/ha) on growth and yield attributes of mustard under rainfed conditions. They noted that the growth and
yield attributes were increased significantly by the increasing levels of nitrogen and phosphorus. The maximum seed yield was recorded with 75 kg N/ha, which was higher by 7.13 q/ha over control. However, increasing doses of nitrogen decreased oil content. The maximum seed and oil yield were noted with the highest dose of phosphorus. There was no effect of phosphorus on oil content.

Chaudhary et al. (1992) conducted a field trial on mustard (Brassica juncea L. Czern & Coss) var. Varuna at Pusa (Bihar). They studied the effect of four levels of basal nitrogen (20, 40, 60 and 80 kg N/ha) and three levels of sulphur (0, 25 and 50 kg S/ha) on yield and yield attributing characters of mustard. A basal dose of 21.8 kg P/ha and 16.6 kg K/ha was applied in all plots. It was noted that pods per plant and seed yield were increased upto the highest levels of nitrogen and sulphur. Oil content was not affected by nitrogen application. Application of sulphur increased the oil content. However, the effect of 0 and 25 kg S/ha on the oil content was at par.

Tomer et al. (1992a) experimented on mustard (Brassica juncea L. Czern & Coss) var. Varuna for two years at Gurkul-Norson, Hardwar (U.P.). They studied the effect of four levels of fertilisers (no fertiliser, 40 kg N + 8.7 kg P + 16.6 kg K/ha, 80 kg N + 17.4 kg P + 33.2 kg K/ha and 120
kg N + 26.1 kg P + 49.8 kg K/ha) on growth, yield and quality characteristics of mustard. It was noted that pods per plant and seed yield were increased up to 120 kg N + 26.1 kg P + 49.8 kg K/ha. On the other hand, oil yield was maximum with 80 kg N + 17.4 kg P + 33.2 kg K/ha. The maximum oil content was noted with no fertiliser. Tomer et al. (1992b) further reported on the basis of the same experiment that increasing levels of fertility increased nitrogen and phosphorus uptake both in seed and stover of mustard.

2.2.7 Foliar application of N, P, K and S

The absorption of nutrients through aerial parts and their subsequent metabolism is known as foliar nutrition and the technique involved is known as foliar application. The process of foliar absorption takes place in three stages. In the first stage, substances supplied to the surface of leaves penetrate the cuticle through sub-microscopic canulae and cellulose wall via free diffusion. In the second stage, these substances are adsorbed to the surface of plasma membrane by some form of binding. In the third stage, the adsorbed substances are taken up into the cytoplasm by active processes requiring metabolically derived energy (Franke, 1967).
Foliar application has been found to have some advantages over soil application. These are summarised below:

1. Rapid fixation, volatilisation, microbial degradation and leaching of nutrients in the soil makes them unavailable to the crop. For example, about 70 per cent applied phosphorus (Russell, 1950) and about 50 per cent applied nitrogen (Anonymous, 1971) are rendered unavailable to crop plants due to these factors. The best remedy for such hidden hunger of plants is the application of appropriate nutrients to the leaves in the form of dilute sprays applied to standing crop.

2. There is a quick response of plants of foliar application of nutrients as compared to soil application. For example, the soil application of lime and magnesium salts requires about three years for commercial control of magnesium deficiency in apple trees, whereas foliar application of epsomsalt temporarily controls the deficiency during this period. Thus, foliar application may be adopted as an emergency treatment to check deficiencies of nutrients (Bould and Tolhurst, 1948).

3. Some crops such as sugarcane remove large quantities of nutrients during early vegetative growth and
require foliar nutrients as supplement at later stage when soil application is not feasible (Ali, 1981).

4. The elements, which become immobile when applied to the soil, are readily available to the plants through foliar application. Elements like boron, copper, iron, manganese and zinc have been used successfully for the treatment of deficiencies of these elements (Boynton, 1954; Bould, 1963).

5. Where fertiliser cost or unavailability is a major constraint at the time of sowing, supplemental foliar feeding has proved to be economical and more effective compared to the technique of soil application of fertiliser, such as top dressing (De, 1971; Afridi and Wasiuddin, 1979; Mohammad et al., 1987).

6. Foliar application may be beneficial over soil application under hilly or dryland conditions or where soils are porous and sandy, highly alkaline, acidic or water logged (Bould 1963; Afridi and Samiullah, 1973; Mohammad, 1992).

This technique has been known since 1803 when Forsyth used it for the first time (Bould, 1963). Among the other early workers of the last century, the work of Gris in 1844, Mayer in 1874 and Bohm in 1877, has been cited by
Wittwer and Teubner (1959). Later, Ballard and Volck (1914), Johnson (1924), Felix (1927), Chandler et al. (1932), Lewis (1936), Wallace and Jones (1942), Bould and Tolhurst (1948), Wittwer and Lundahl (1951), Cook and Boynton (1952), Thorne and Watson (1952, 1953), Tolhurst and Bould (1952), Hinsvark et al. (1953), Yatazawa and Higasino (1953), Yatazawa and Tai (1953), Thorne (1954, 1955), among others, made notable contributions in the field. The work done on foliar application has been reviewed from time to time (Boynton, 1954; Wittwer and Teubner, 1959; Wittwer and Bukovac, 1969; Mehrotra and Lal, 1970; Anonymous 1971; De, 1971; Afridi and Wasiuddin, 1979; Kannan, 1986).

In India, the first report on foliar application using urea seems to be that of Sadaphal and Das (1956). This was followed by the work of others on various crops, including Anonymous (1958), Barat and Das (1962), Kannan and Ranganathan (1963), Ranganathan and Govindan (1964), De and Seth (1965), Sadaphal and Das (1966), De et al. (1968), Afridi and Samiullah (1973), Samiullah and Afridi, (1975), Afridi et al. (1977; 1978a,b,c); Akhtar et al. (1984), Samiullah et al., (1986); Khan et al., 1987, 1992, 1993).

The available recent literature on foliar application of nutrients to mustard crop in India is reviewed below:

De (1971) discussed the work of Lahiri and De (1971) on foliar fertilisation of mustard in a review covering
several crops. In the field trial conducted at I.A.R.I. (New Delhi), four doses of nitrogen, viz. 40, 60, 80 and 120 kg N/ha were given as soil application. The experiment included the treatments where nitrogen was supplied partly through the roots (at the time of sowing) and partly through the foliage. The split doses of nitrogen comprised 40 + 20, 40 + 40, 60 + 20 or 60 + 40 (basal + foliar). Mustard yield was noted to increase with increasing rates of nitrogen supply. However, the increase was much higher in comparison with full soil application when part of nitrogen was supplied through foliage, irrespective of the rate of nitrogen. It was found that the supply rate of 80 kg N/ha either by 40 + 40 or 60 + 20 (basal + foliar) gave higher yield than when the same quantity of nitrogen was applied through the soil only. This efficiency of foliar application was also reflected in the economics of crop production. At 80 kg N/ha, the soil + foliar method recorded an extra income of Rs 300 to 400/ha over the soil application.

Naqvi et al. (1977) conducted a field trial at Aligarh (U.P.) on mustard (Brassica juncea L. Czern & Coss) var. Laha-101. They applied three basal levels of phosphorus, i.e. 0, 8.7 and 17.4 kg P/ha along with 60 kg N and 33.2 kg K/ha. Plants were sprayed with phosphorus (0.87 kg P/ha) and sulphur (1 kg S/ha) alone or in combination. They concluded that Laha-101 could be grown profitably with
8.7 kg P/ha supplemented by two sprays of 0.87 kg P/ha each at flowering and fruiting stages.

Afridi et al. (1978a) studied the effect of foliar application of phosphorus on mustard var. Laha-101, grown at Aligarh (U.P.). In a field with high available phosphorus and potassium, only nitrogen was applied at the rate of 60 kg N/ha. Plants were sprayed once with 0, 0.6, 1.2 or 2.4 kg P/ha at 70 days of growth, except the lowest dose of phosphorus (0.6 kg P/ha), which was repeated at 90 days. They concluded that two sprays of the lowest dose of phosphorus gave the best results. The seed yield was 63 per cent higher than in the control sprayed with water. The oil content of the seed was also enhanced by 15 per cent.

Vir and Verma (1979), working with mustard (Brassica juncea var. T-59 at Agra (U.P.), applied all combinations of two levels of urea nitrogen (30 and 60 kg N/ha) and three methods of nitrogen application (full dose of nitrogen as basal, 3/4 basal + 1/4 foliar and 1/2 basal + ½ foliar) with two additional treatments one for absolute control and another for water spray. A uniform dose of 13.0 kg P/ha as single superphosphate was also added. They reported that application of 3/4 as basal + 1/4 through foliage was the best method of nitrogen fertilisation. Of the doses tried, 60 kg N/ha (applied as above) proved to be the most economic dose, giving a net profit of Rs. 4,547/ha.
Parvaiz et al. (1982a), working with Laha-101 at Aligarh (U.P.), studied the effect of foliar application of nitrogen, phosphorus and sulphur, sprayed in various combinations, viz. $N_0P_0S_0$, NP, NS, PS and NPS, at different stages of growth, i.e. 50 and 70 (vegetative and flowering), 50 and 90 (vegetative and fruiting) or 70 and 90 days after sowing (flowering and fruiting). The N, P and S were sprayed at 20 kg N, 0.87 kg P and 2 kg S/ha respectively. A uniform basal dressing of 60 kg N, 8.7 kg P and 33.2 kg K/ha was also done. The data revealed that the maximum values for oil percentage, hecto-litre weight and oil yield were obtained in treatment PS. However, the values for pods per plant, seeds per pod and seed yield were maximum in the treatment NPS. Considering the stages, spray at 50 and 70 days (vegetative and flowering) proved best for pods per plant and seeds per pod. However, spray at 70 and 90 days (flowering and fruiting) was found best for seed yield, oil percentage and oil yield. Regarding the interaction effect, the data revealed that, for maximum values for oil percentage and oil yield, PS x (70 and 90 days) was superior but for pods per plant, seeds per pod and seed yield, NPS x (50 and 70 days) was best.

Afridi et al. (1983), conducting a field experiment on mustard (Brassica juncea) var. Laha-101 at Aligarh (U.P.), studied the effect of various combinations of leaf-
applied nitrogen, phosphorus and sulphur (N, P, S, NP, NS, PS and NPS) at two regimes of basal nitrogen and phosphorus. Nitrogen was sprayed at the rate of 20 kg N/ha, phosphorus, at 0.87 kg P and sulphur, at 2 kg S/ha in two equal splits at 70 days (flowering stage) and 90 days (fruiting stage) after sowing. The basal doses of nitrogen and phosphorus were (i) 30 kg N + 4.4 kg P/ha and (ii) 60 kg N + 8.7 kg P. In addition, a uniform dose of 33.2 kg K/ha was added at the time of sowing. It was noted that the spray of NS gave maximum value for pods per plant. However, the values for oil percentage and hecto-litre weight were highest in the treatment PS. The combined spray of nitrogen, phosphorus and sulphur (NPS) proved to be best for seed and oil yield. They inferred that, for optimum yield of Laha-101, the combined spray of 20 kg N and 0.87 kg P and 2 kg S/ha should be done along with a basal dose of 60 kg N, 8.7 kg P and 33.2 kg K/ha.

Samiullah et al. (1983a) conducted a field experiment at Aligarh (U.P.) to study the comparative effect of two levels of basal nitrogen and phosphorus 40 kg N + 8.7 kg P and 60 kg N + 17.4 kg P/ha supplemented with foliar spray on yield and quality of six mustard varieties (Appressed Mutant, R. 75-2, RL-18, T-11, T-16 and Varuna). The spray dose, consisting of 20 kg N + 3.5 kg P + 2 kg S/ha, was given in two equal splits at 70 and 90 days after
sowing. A uniform dose of 33.2 kg K/ha was also given at the time of sowing. The spray treatment at the higher basal dose \( \text{N}_60 \text{P}_{17.4} \) produced more pods per plant and seeds per pod, resulting in higher seed and oil yield inspite of lower oil percentage. This treatment also proved best for iodine value but not for saponification value of oil, whereas hecto-litre weight and acid value were at par at both the basal levels. Among varieties, R. 75-2 and Varuna gave over-all better performance. The varieties R. 75-2 and RL-18 performed better at the higher fertiliser regime, whereas T-11 and T-16 responded better at the lower fertiliser regime. However, a unique feature of Varuna was its commendable performance at both the regimes.

Samiullah et al. (1983b) conducted a field experiment on mustard \((Brassica juncea \text{ L. Czern & Coss})\) var. Varuna at Aligarh (U.P.) to study the effect of four doses of nitrogen (5, 10, 15 and 20 kg N/ha) with or without phosphorus (0.87 kg P/ha) and sulphur (2 kg S/ha), together with a water-sprayed control, (applied in two equal splits, half at 70 days and remaining half at 90 days after sowing) on the maturity of mustard. A uniform dose of 60 kg N, 17.4 kg P and 33.2 kg K/ha was applied uniformly at the time of sowing. They noted that increasing doses of nitrogen spray enhanced seed yield and maturity linearly. The inclusion of
phosphorus and sulphur in the nitrogen spray not only ensured better yield but also further cut down the maturity period.

Parvaiz and Afridi (1985), in a field experiment conducted at Aligarh (U.P.) on four varieties of mustard (Brassica juncea), namely BR-40, Laha-101, T-11 and Varuna, applied five combinations of nitrogen, phosphorus and sulphur, viz. water-sprayed control (N₀P₀S₀), 20 kg N + 0.87 kg P/ha (NP), 20 kg N + 2 kg S/ha (NS), 0.87 kg P + 2 kg S/ha (PS) and 20 kg N + 0.87 kg P + 2 kg S/ha (NPS), applied in two operations at 70 and 90 days after sowing. A basal dose of 40 kg N + 8.7 kg P and 33.2 kg K/ha was applied at the time of sowing. Highest values for seed and oil yield were recorded with the spray treatment NS. However, PS gave the maximum hecto-litre weight and oil percentage, whereas pods per plant were maximum with NP. Variety Varuna gave maximum values for all the characters. For hecto-litre weight and oil percentage, the treatment PS X Varuna was found best, whereas the interaction NS X Varuna gave highest values for pods per plant, seed yield and oil yield.

Samiullah et al. (1985) conducted a field experiment at Aligarh (U.P.) on mustard (Brassica juncea L. Czern & Coss var. Varuna) to study the effect of four doses of nitrogen (5, 10, 15 and 20 kg N/ha) with or without
phosphorus (0.87 kg P/ha) and sulphur (2 kg S/ha), together with a water-sprayed control (given in two equal splits, at 70 and 90 days after sowing) at two basal regimes of nitrogen and phosphorus (N_{40}P_{8.7} and N_{60}P_{17.4}). A uniform dose of 33.2 kg K/ha was applied at the time of sowing. Among spray treatments, N_{20}P_{0.87}S_{2} out-yielded all others, particularly with the higher basal dose.

Mohammad et al. (1986a) conducted a field experiment at Aligarh (U.P.) on mustard (Brassica juncea L. Czern & Coss) var. Varuna to study the effect of phosphorus (0.87, 1.7, 2.6 and 3.5 kg P/ha) and sulphur (2, 4, 6 and 8 kg S/ha), in all possible combinations (applied in two equal splits, half at 70 days and the remaining half at 90 days after sowing) at two basal levels of nitrogen and phosphorus (N_{40}P_{8.7} and N_{60}P_{17.4}). A uniform dose of 33.2 kg K/ha was also added at the time of sowing. Of the spray treatments, P_{3.5}S_{2} gave the highest values, particularly at the higher basal dose (N_{60}P_{17.4}), for pod number per plant, seed number per pod, seed yield and oil yield.

Mohammad et al. (1986b) conducted a field experiment at Aligarh (U.P.), to study the combined effect of soil-applied (60 kg N + 17.4 kg P + 33.2 kg K/ha) and leaf applied (20 kg N + 3.5 kg P + 2 kg S/ha) nutrients on ten varieties of mustard (Brassica juncea L. Czern & Coss). The
varieties included Appressed Mutant, Pusa Kisan, Pusa Kranti, R. 75-2, RIK-3, RL-18, RS-3, T-11, T-16 and Varuna. The nutrient solution was sprayed in two equal splits, i.e. half at 70 days and the remaining half at 90 days. Data revealed that R.75-2, RL-18, RS-3 and Varuna responded well to the combined application of basal and foliar nutrients. All the four varieties proved at par in giving maximum oil yield. R.75-2 (equalled by Varuna) and RS-3 gave maximum yield and oil content of seed respectively.

Mohammad et al. (1987) conducted a field experiment on mustard (Brassica juncea) var. Varuna at Aligarh (U.P.) to study the effect of various doses of nitrogen and that of the method of nitrogen, phosphorus and sulphur application on pods per plant, seeds per pod, hecto-litre weight, seed yield, oil percentage and oil yield of mustard. Basal application of 60 kg N (or even 40 kg N/ha), supplemented with foliar application of 20 kg N + 3.5 kg P + 2 kg S/ha (in two equal splits at flowering and fruiting) ensured better harvest than even 60 kg basal N/ha + 30 kg top N/ha, although the latter proved superior to 90 kg basal N/ha alone. Application of more than 90 kg N/ha either as basal + top dressing or basal + foliar spray proved deleterious while 45 kg basal N/ha proved insufficient, inspite of supplemental nitrogen application as top dressing or foliar spray.
Mohammad (1992) conducted a field experiment at Aligarh (U.P.) to study the combined effect of soil-applied (40 kg N + 10 kg P, 30 kg N + 7.5 kg P and 20 kg N + 5 kg P/ha) and leaf-applied (water, 10 kg N + 2.5 kg P and 20 kg N + 5 kg P/ha) nutrients in the presence of a uniform dose of 15 kg K/ha on two rainfed varieties (RK-9 and RK-1418) of mustard (Brassica juncea L. Czern & Coss) under rainfed conditions. The nutrient solution was sprayed in two equal splits, i.e. half at 70 days and remaining half at 90 days. At harvest, the yield and quality parameters were studied. Treatment $B_{N30}P_{7.5}^+FN_{10}P_{2.5}$ and var. RK-1418 alone as well as in combination proved best, with $B_{N30}P_{7.5}^+FN_{10}P_{2.5} \times RK-1418$ registering 40.0 per cent more seed yield and 37.9 per cent more oil yield than $B_{N40}P_{10}^+FW \times RK-9$ that gave the lower values.

2.3 CONCLUDING REMARKS

It is evident from the foregoing review of literature that nitrogen, phosphorus, potassium and sulphur play an important role in the performance of rape seed-mustard. Further, agroclimatic conditions, quantity and time of application and method of application of the nutrients affect the growth, yield, quality and nutrient status of the crop. It may also be noted that varieties of the same
species differ in their response under common set of condition.

It is, therefore, necessary that thorough and systematic fertiliser trials be carried out under different agroclimatic conditions as and when a new variety is released, which may help in solving the problem of shortage of oilseeds in our country to some extent.