REVIEW OF LITERATURE

Little research work has been done in India on the agronomic aspects of radish seed crop with the result that only scanty published information is available on this aspect. However, some agronomic aspects of radish seed production have been studied in other countries. Some closely allied Brassica oil seed crops have also been the subject of similar agronomic studies whose results can be usefully employed in radish seed production. Therefore, literature on radish along with that on allied crops of Brassica family is briefly reviewed here.

SEED SIZE:

For about 300 years plant propagators have been separating seeds into size grades (Yokeli, 1903). During the last 50 years, mostly before 1930, some investigators (Schmidt, 1924; Cummings, 1914; Kesselbach, 1924; De Lassus, 1911) reported that the plants produced from heavier seeds showed more vigorous growth, attained greater weight and size, and produced larger yields than the plants grown from lighter seeds.

On the other hand, some workers have shown that seed weight is a significant factor for plant size during the early stages of growth only. If the growing season is long enough,
the superiority of early growth might disappear entirely
(Gelinska, 1929; Kotovski, 1929; Rohmoler, 1939; Vanselov,
1933).

Findlay (1919), while studying various crop seeds
including turnip, viewed the problem from two aspects viz.
(a) different sized seeds in the same sample and (b) different
sized seeds from different samples of the same kind of seed.
They concluded that turnip showed a slight consistent
increase in yield with large sized seeds over small sized seeds
in a given sample, but small sized seeds of some other good
strains proved superior to the large seeds of a poor quality
strain.

Brechlely (1923) and Oxenmann (1942) concluded from
experiments on a variety of crops that with short duration
species there was an advantage in using heavier seeds but the
advantage became less marked, though still in evidence, with
long duration species. Their conclusions are in agreement
with that of Kedovski (1929) who found that size of seed
influenceed the size of plant during the first 60 days, but
the effect disappeared afterwards.

Some Russian workers have also studied this problem in
grain crops (Budkov, 1919; Tikhonov and Nadeov, 1947; and
Verena', 1947) and *Oxusubite* (Lutebin, 1947) and concluded
that larger seeds gave greater yields.

Cummings (1914) reported that radishes, which are one
of the shortest duration crops, showed good gain with large
seeds. Large seeds gave a more uniform crop ready for use about one week in advance of the small seeds. Plants grown from large seeds possessed more leaves of greater surface area and of higher assimilation power. He further stated that sorting the size from the same parent gave as great a contrast as sorting opposite samples.

Legatt and Ingalls (1949) reported that small sized seeds of turnip, when tested for germination rate and capacity, were generally similar to seeds of larger size, but failed to give as good stand as did the latter in the field. Roots produced by the smallest sized seeds tended to be flatter in shape than those produced by larger seeds, but did not differ significantly from the latter in size or uniformity of shape.

Dhesi et al. (1965), who isolated turnip seed in bold, medium and small grades, concluded on the basis of two years' study that large and small seeds were similar in germination capacity on blotter, but in sand the germination capacity and rate of germination of small seeds was significantly lower. Besides, the roots produced from small seed were significantly smaller in size though similar in shape. Almost similar observations were made by Galloway (1894); Hicks and Dabney (1896); and Cummings (1914) on radish and by Zativ (1905), Findlay (1919) and Dhesi et al. (1965) on turnip.

According to Semistatnova (1967), radish and lettuce yields were related to seed size rather than to specific gravity. The highest yields and germination percentage in radish were
obtained with large seed followed by very large, medium, mixed sizes and finally the small seeds. The percentage of very large and large radish seeds produced was higher from the transplanted than from seed-sown plants.

The work of Cummings (1914) with parsley, lettuce, sweet peas and spinach also confirmed the superiority of large seeds over the small ones. According to Rotunno (1924) and Legatt and Ingalls (1949), however, large and small seeds were equally efficient in radish and turnip production.

Hösslin (1954), working on the influence of seed size in black radish and kohlrabi concluded that there was a positive relationship between seed size, on the one hand and earliness and total yield on the other. Likewise, Schwanitz (1950) also held that the size of seed on quick maturing vegetables would influence the yield.

SEED-ROOT SIZE:

Jauhari and Purandare (1959) on the basis of one-year study indicated that 3/4 length of 22 cm long radish gave higher seed yield than the 1/4, 1/2 or whole roots.

According to Chauhan (1965), usually 3/4 of the lower portion of the radish root is cut and 1/4 top portion with crown leaves (about 7-8 cm) is planted for seed crop.

Dhesi and Nandpuri (1964) stated that the upper half of radish root is used for raising seed. However, Hussain (1964) recommended that for radish seed production the seedling
length should be 20-22 cm after rejecting 8-10 cm of root from the bottom. The length of leafy crown should be 7-8 cm.

So far no work seems to have been carried anywhere to find out the optimum girth, length or combination thereof to get the maximum seed yield.

N P K AND SPACING:

Nitrogen:

Most of the Indian soils are lacking in N and the research work conducted so far distinctly brings out its need as an essential fertilizer element. Dass (1949) reported that, on the average, N content of the Indian soils is 0.05 per cent against 0.15 per cent of the European and American soils. Voelker (1893), Vaidyanathan (1933), Parker (1946) Ray Chaudhary (1952) and Pathak (1953) have also pointed out the general deficiency of N in Indian soils.

On the basis of 20 years' experiments conducted by the Punjab Agricultural Department, Johnston (1934) reported that the application of ammonium sulphate generally gave good results and held that N was one of the most important factors in crop production.

Lucas and De Freitas (1960) studied the response of radish to the nutritional deficiencies of major and minor elements, when grown in black pots in sand using Hewitt's nutrition solution and its modifications omitting one of the essential elements at a time. They observed that plant growth
was checked most severely by the lack of N or Ca, substantially by the lack of P, K or Mg and only slightly in the absence of other nutrients. Root development was practically nil without N, K or Ca, poor without P or Mg and almost normal in the absence of any one of the other nutrients.

Parewal (1949) recommended the application of 68 kg N/ha from ammonium sulphate and 22 m tons farmyard manure for radish seed production in Kulu Valley.

The highest radish seed yields were obtained by Lamm and Hintze (1954) with half the dose of nutrients as stable manure and the other half from artificial.

Hussain et al. (1964) conducted manural trials on radish seed crop and concluded that 68 and 100 kg N/ha as ammonium sulphate gave significantly higher yields than the lower doses.

The highest seed yields of winter turnip were obtained with 120-160 kg N/ha when 20 kg N/ha was applied in autumn and the rest in spring (Adamszewski and Musicki, 1967). Nitrogen did not affect the 1000-grain weight, but reduced the fat content of the seed.

In spring overwinter rape, Bunting (1956) obtained good response with 66-78 kg N/ha.

Increasing N dressing from 45-90 kg and 90-135 N/ha in rape increased their seed yields by 530 kg and 310 kg, respectively (Gisiger and Bonjeur, 1967). It was concluded
that the application of P and K might be omitted on soils containing more than 8 mg/100 gm available P and more than 2 mg available K, especially where dung had been ploughed under.

Kürten (1966) applied split application of high dose of N to winter rape (160 kg N/ha in spring and 40 kg N late in the season) and obtained an average yield of 2.18 tons/ha.

Andersson et al. (1956) also applied graded doses of N to winter rape and found that the Svalof varieties of winter rape gave increased seed yield by 19 per cent with 400 kg/ha calcium nitrate (15.5% N).

In manuriial trials on raya (R. juncea) at Ludhiana the application of 34 kg N/ha gave an increased yield of 356 kg/ha (Anon., 1963-64).

Mohammed (1940) concluded that the application of 44 kg N/ha to toria (Brassica campestris var. toria) in the form of ammonium sulphate gave the highest seed yield at Lyallpur, West Pakistan.

Chela (1951) found 28 kg N/ha to be the economic dose for toria grown on loamy soil at Lyallpur. He recommended a dose of 56 kg N/ha for soils of medium fertility on the basis of two years' experiments.

Work on the improvement of some important oilseed crops was in progress at Gurgaon and Faridkot since 1950. Agronomic investigations at the two stations have clearly brought out
the desirability of liberally fertilising *rava* (*B. juncea*), *sarson* and *toria* (*B. campestris*) with nitrogenous fertilizers. Maini *et al.* (1959) concluded that under Gurgaon conditions *sarson* and *rava* showed a strong linear response to nitrogenous fertilizers up to 100 kg N/ha, but the economic dose for the two crops was 56.5 kg and 91 kg N/ha, respectively. At Faridkot, *toria* and *rava* responded up to 28 kg N and 44 kg N, respectively.

In another experiment at Gurgaon with graded doses of N from 22 to 110 kg/ha on *sarson*, the seed yield increased up to 18 per cent and 100 per cent with 22 kg and 44 kg N/ha, respectively. In similar experiments on *rava* var. L. 18, the seed yield increased to 21 per cent and 44 per cent over 'control' with 22 kg and 44 kg N/ha, respectively. The yield decreased with higher doses of nitrogen (Anon., 1963-64).

Similar experiments were conducted at Kapurthala with the same doses of N on *toria* and *rava* as at Gurgaon. The yield of *rava* L. 18 increased with every additional increment of fertilizer dose up to 110 kg N/ha, but at all the doses only 98 kg and 110 kg N/ha gave significant increase over control. The highest dose resulted in a yield increase of 63 per cent over control. In case of *toria*, the highest yield was recorded with 66 kg N/ha, which was 50 per cent more than that of 'control' (Anon., 1963-64).

Trials conducted on the manurial requirements of *sarson* (Anon., 1958-59 to 1960-61) in the districts of Hissar
and Sangrur showed that the application of 44 kg N/ha was optimum.

Under the Project for the Intensification of Regional Research on Oilseeds at Patiala, the results obtained on *toria* and *taramira* (*Eruca sativa*) during 1959-60 indicated a linear response up to 66 kg N/ha (Anon., 1959-60).

Singh and Singh (1959) found 56 kg N/ha to give significant increase in the seed yield of both *rai* (*B. juncea var. rai*) and yellow *sarson*. *Rai* varieties benefited more than *sarson*. According to Singh (1958) the optimum dose of nitrogen for *sarson* in Assam was 44-66 kg N/ha.

Johl (1959) reported a response up to 56 kg on *toria* crop.

Bose (1957) found that nitrogen deficiency in mustard caused the maximum reduction in its yield as compared to P and K deficiencies.

On the basis of several years' fertilizer trials Dalal *et al.* (1962) recommended that drilling of ammonium sulphate at sowing gave the highest yield of *sarson* and *raja* at 66 kg and 44 kg N/ha, respectively.

Bhatty (1964) stated that the application of 44 kg and 88 kg N/ha from ammonium nitrate to two rape varieties, namely Golden and Arlo, on five sandy loam and loamy soils increased seed yield and protein content but decreased oil content.
Phosphorus

Hartwell and Damon (1927) working on rape, and Prokofjeve (1955) and Bose (1957) working on mustard reported beneficial effect of P on the seed yield and oil content of these crops. The Departments of Agriculture, Bihar (Anon., 1940), Madhya Pradesh (Anon., 1949) and Assam (Anon., 1951) reported significant increase in the yield of mustard with phosphate manuring.

In order to elucidate the role of P in the metabolism of mustard, Sen and Sarkar (1958) undertook investigations at the University of Calcutta, and confirmed the findings of the above mentioned workers. They showed that increase in P accelerated the rate of growth and hastened maturity. Further, P increased total dry matter, particularly the proportion of root. Phosphorus also showed beneficial effect on seed and oil yield. The treatments without P did not show characteristic P-deficiency effects. The lack of P seemed to have been compensated to some extent by sulphur.

Heckensmith et al. (1933) obtained samples from 93 fields of known response to superphosphate in some of the irrigated valleys of Colorado. Twenty one of these fields showed a marked response to the application of treble superphosphate, 5 only a slight response, and 67 no response at all. The results of their investigations indicated that even when the laboratory test shows a soil to be deficient in available P, an exploratory field trial should be conducted before a large
quantity of phosphate was purchased. Similar views were held by Gericke (1941) who advocated that the P uptake of crops, as calculated from their P content, cannot be used as a guide to their phosphate fertilization. Practical experiments must be carried out. Likewise, Gericke (1940) experienced a definite response to phosphatic fertilizers with different vegetables, notwithstanding the high phosphoric acid content of the soils and the use of large amounts of stable manures.

Sandhu et al. (1966) while working on turnip seed crop, reported that the application of 36 kg P$_2$O$_5$/ha brought about increase in yield up to 19.2 per cent.

Maini and Negi (1957) in the fertilizer trials on raya crop at Gurgaon found that 28 kg P$_2$O$_5$/ha gave significantly higher yield.

In a manurial trial with superphosphate on raya for several years at Ludhiana the highest yield was obtained under 3½ kg P$_2$O$_5$/ha (Anon., 1963-64).

Parr and Bose (1944) found that P played an important role in increasing crop yields.

Dass (1943) stated that mustard showed 19-27 per cent increased seed yield according to the quality of phosphatic fertilizer used. Superphosphate was the best amongst them.

The results of experiments conducted with P on Brassica oilseed crops in Assam (Anon., 1956-57) with six graded doses
of $P_2O_5$ from 11-66 kg / ha showed that the yield of the treated plots was not significantly more than that of the control.

Experiments conducted on *toria* and *sarson* at Gurgaon during 1955-56 (Anon., 1955-56) registered no beneficial effect with phosphate applied alone or in combination with $N$. However, a similar trial conducted during 1956-57 (Anon., 1956-57 a) showed a positive response to 28 kg $P_2O_5$/ha.

Johnston (1934) reported that $P$ fertilization had practically no effect on summer rapes, while Bose (1957) laid great emphasis on the adequate supply of $P$ to mustard for increasing seed yield and oil content.

**Potassium:**

Vaidyanathan (1933) summarized the results of permanent manuriial trials conducted at Coimbatore and found no increase in the yield of several field crops with the application of potassic fertilizers.

Ray Chaudhari (1952) stated that the status of total and available $K$ in alluvial soils was fairly high and usually significant responses had not been obtained with potassic fertilizers in various manuriial trials conducted during the past. However, he recommended its use for balanced manuring, especially with heavy doses of $N$ and $P$.

Sandhu *et al.* (1966) found that with the application of 56 kg $K_2O$/ha to turnip seed crop a small increase in seed
yield accrued, which was hardly enough to meet the fertilizer cost.

Crowther and Yates (1941) held that the addition of potassic fertilizers to soils deficient in available $K_2O$ definitely increased the yield, but the response to these fertilizers varied markedly with soil, crop, and season. This was confirmed by Stewart (1947) on the basis of huge experimental evidence on manuring in India. He also referred to numerous instances in which the application of potash had not only failed to show a positive response, but had even caused reduction in yield.

However, Pathak et al. (1949) laid great stress on the potassium requirement of Indian soils, besides N and P. According to Beckera (1940) the best time to apply potassic fertilizer is before planting, but a later top-dressing should also be given if deficiency is feared.

Potash is also known to have some influence on the absorption and transpiration of water, and the crops respond best to potassic fertilizers during the dry season. $K$ also promotes flowering, fruit setting and rate of ripening, and increases resistance to all kinds of pests and diseases (Lowton and Cook, 1954; Premi, 1957)

Mandal and Mukherjee (1954), in their experiments on the manurial requirements of different crops in Bihar soils, found that application of $K$ was helpful in increasing the yield.
The results of trial conducted at Patiala during 1959-60 (Anon., 1959-60) on *toria* and *taramira* clearly indicated the ineffectiveness of K application for increasing their yield.

These results were further corroborated by the results of manorial trials on *rava* conducted at Ludhiana (Anon., 1963-64). However, in trials conducted on *sarrow*, potash applied in combination with P and N registered highest yields (Anon., 1958-59 to 1960-61).

**Combinations and interactions of NPK:**

Sometimes the response to the application of a given factor is appreciably modified by the presence or absence of another factor. If these factors are tried at varying levels, the response of an individual factor may vary with changes in the level of the other factor. Such discrepancies in response are known as interaction effects between the factors involved.

Brenzake (1928) stated that the absorption of P was stimulated in the presence of N. Coleman (1944) showed that the soils having low N content did not permit the proper utilization of P. He further concluded that non-legumes would not respond to P if N remained limiting.

Majumdar (1965) studied the uptake of N and P in rape seed (*sarrow*) and their effect on seed size and yield response.
Increasing rates of N and P₂O₅ up to 56 kg/ha each increased the total N and P uptake as well as the seed yield, but decreased the proportion of the absorbed N passing to the seed.

According to Duncan (1965) high radish seed yields in Oregon (U.S.A.) have been reported where a combination of 112 kg N and 224 kg P₂O₅ were applied as side band shortly after emergence. Unfertilized plots yielded less than one-half as much as the fertilized ones. They also observed delay in maturity due to excessive N. Similar results were reported by Schudel (1952).

In Southern Rhodesia, about 500 kg/ha of NPK 8:16:8 fertilizer are broadcast before planting or banded below seed. In Mauritius, nursery beds of radish received 250 kg superphosphate, guano and well-rotted manure at 30 m tons/ha. In Hong Kong the land is dressed at planting with diluted, liquified night-soil (Anon., 1961).

In Denmark, 300 kg superphosphate with 300-400 kg nitrate of potash/ha is usually applied before planting followed by side-dressing of 300-400 kg/ha of saltpeter (Anon. 1961).

Stat. Forsøgsvirksomheden (1960) reported that in 12 experiments conducted in Denmark at four centres from 1956-59 on winter rape (B. napus var. oleifera, sub var. biennis) on clay loam soil plots received 500-1000 kg superphosphate and 300-1140 kg potash fertilizer per ha. The preceding crop
was invariably a cereal crop except in one case. Calcium nitrate was applied in early spring at 0, 1000, 2000, 3000 and 4000 kg/ha in the beginning of growth following sowing the previous August. At harvest in July, seed yield, crude oil and crude protein content increased with the application of Ca(NO$_3$)$_2$, but increase in yield per increment of 1000 kg/ha fell sharply with increasing application. Crude oil content decreased, protein content and 1000-grain weight increased and the harvest date was delayed with increasing application of Ca(NO$_3$)$_2$.

Hall and Smith (1948) found that the effect of nitrogenous fertilizers was greatly increased in conjunction with phosphatic and potassic fertilizers.

The results of trial conducted on a carrot in Punjab (Anon., 1958-59 to 1960-61) also confirmed that the best yields were obtained with NPK combination. In recent experiments conducted at Ludhiana on turnip seed crop, 84 kg N + 56 kg P$_2$O$_5$ + 56 kg K$_2$O / ha gave the highest yield (Sandhu et al., 1966).

Webster (1942) stated that to an overwintered turnip crop in British Columbia 16:20:0 fertilizer may be drilled at 112-224 kg/ha followed by a side-dressing of 5:10:5 at the rate of 224 to 336 kg/ha in spring. A similar dose of 16:20:0 is commonly applied to turnip seed crop as side-dressing in Oregon (Schudel, 1952). Schudel further observed that N applied
168-224 kg per hectare resulted in seed yield as high as 2240 kg/ha. However, lodging became a serious problem when the application of N exceeded 168 kg/ha. The optimum level under Western Oregon conditions was found to be below 132 kg N/ha.

Lucas and De Freitas (1958) used radishes as test crops in fertilizer trials with NPK, Ca and their combinations. They found highly significant response to N, P and NP, but little to K. In the absence of N, the response to Ca was appreciable, otherwise it was positive but not significant.

Pikul (1962) working at Babrowkro on brown earth soils with a clay subsoil and at Kielcein on light pedoul with a sandy loam subsoil, reported that N increased the seed yield of white mustard crop, while P and K did not significantly affect the yield of seed, oil or straw or the number of pods.

In an F.A.O. publication (Anon., 1961), the use of both N and P has been recommended for obtaining increased yield of radish seed. Higher yields were obtained with a combination of 100 kg N + 200 kg P₂O₅/ha applied as side-dressing. On light soils at least 300-400 kg/ha of 2:1:1 fertilizer was necessary. It was also suggested that too much N might delay seed maturity. Drilling the seed with fertilizer was likely to injure young seedlings, and, therefore, not more than 60-70 kg of high analysis NPK fertilizer should be mixed directly.
Barrons and Kremer (1945) recommended the use of 335-450 kg/ha of 2-12-4 fertilizer for radish seed crop on light soils of Michigan. However, for fertile soils on which liberal amount of farmyard manure had been used, the application of superphosphate only was enough.

Groven (1959), on the basis of manurial experiments on radish seed production from 1922-1935, advocated a combined application of N and K for raising high quality seed. For a turnip seed crop, whose fertilizer requirements are similar to those of radish, Singh et al. (1960) recommended the incorporation of 22-30 quintals/ha farmyard manure before sowing and later on application of 7 quintals of farmyard manure along with 224 kg of superphosphate/ha to the autumn transplanting of developed roots. One application of ammonium sulphate at 112 kg/ha was further recommended at the pre-bolting stage followed by a similar dose before flowering in spring.

**Seed Rate and Spacing:**

While sufficient data exist concerning spacing requirement of various field crops, little is known about the optimum spacing of radish seed crop in relation to fertilizer level.

Hawthorn and Pollard (1934) considered optimum a spacing of 90 cm between rows and 15 cm within the row for radish seed-roots for seed production.

Shoemaker (1953) recommended the use of 3.5 kg radish seed per ha in drills 90 cm apart followed by thinning to 9-15
om between plants in the row.

In Mauritius, stocklings of common radish are transplanted on ridges 90 cm apart and 45 cm within the row (Coombes and Julien, 1949). The stocklings of Chinese radish are, however, planted in rows 120 cm apart and spaced 60 cm in the row.

According to an F.A.O. Publication (Anon., 1961), for radish seed production in U.S.A. and Canada, the seed is sown directly in field at 3-4 kg/ha in rows 70-75 cm apart. In Denmark, 5.6 kg of seed per ha is sown in rows 60 cm apart. In Great Britain, a higher seed rate of 10-15 kg/ha is sown in rows 45-60 cm apart.

In South Rhodesia, 8-10 kg of seed per ha is sown in rows 30-45 cm apart. Later on, the seedlings are thinned to 2.5-7.5 cm in the row. In Hong Kong, the seed is first sown in nursery and then the selected stocklings are transplanted. For this purpose 8-9 kg seed is sown/ha in 15 x 15 cm beds and transplanted later in 90 cm rows. In Taiwan, 5-8 kg seed/ha is sown in rows 30 cm apart. Being a poor competitor of weeds, radish is sown in rows and seedlings thinned at 2-4 leaf stage. Roots are spaced 20-30 or 35-45 cm apart depending upon their size. For biennial (European) types, roots are lifted and stored over winter in clumps. In Denmark, roots are usually stored in sand pits alternating with sand layer. The stocklings are replanted the following season in good
fertile soil. Planting of stocklings is done in rows 60-65 cm apart and 20-25 cm in row.

Hussain et al. (1964) carried out spacing trials on Japanese radish for seed production and concluded that 0.16 sq. m spacing/plant was better than wider spacing.

Atanasov (1965) studied the spacing requirements of radish seed crop and recommended an area of 400-800 sq.cm/plant. Further increase in spacing in variety Saxa-2 prolonged the vegetative growth, reduced plant height and increased the number of pods per plant.

FERTILIZER PLACEMENT:

Little work seems to have been done on this aspect of radish seed crop.

Dalal et al. (1962) on the basis of several years data, concluded that for obtaining high yields of sarson and raya the fertilizer should be drilled along with seed.

In manural-cum-irrigational trial on raya at Ludhiana (Anon., 1963-64), the crop responded best to N and P drilled before sowing.

Maini and Negi (1957) also studied the effect of time of application and the method of fertilizer placement on the yield of raya. They obtained the best yields with ammonium sulphate drilled 10-12 cm deep before sowing. The second best treatment was drilling half the fertilizer before sowing and broadcasting the other half with first irrigation. Superphos-
phate, too, significantly increased yield when drilled 10–12 cm deep before sowing.

Iwata and Eguchi (1958) observed that the seed yield of Chinese cabbage supplied with 15 ppm/P from planting to the end of flowering (late September to late April) were similar to plants supplied with P throughout the growth season. Yields were lower when P was supplied only with early flowering or until initial inflorescence extension. Plants supplied with P until flower bud differentiation only, gave only two-fifths of the yield of control. P content of seed was directly related to the time at which P supply was stopped.

Sinha et al. (1962) tried 66 kg N/ha on E. juncea at sowing, the same dose one month later or half at sowing and half one/two months later and found that N uptake increased by N application even at the last application date. The oil content decreased and the alliin-thiosynate and iodine values of oil increased under nitrogen application.

Barrons and Kramer (1945) stated that the fertilizers may be drilled in before planting, placed in band along the row to the side of and below the seed. Many growers make a practice of mixing fertilizers with the seed, but it is risky to apply more than 112 kg or ordinary grades in this manner because of the fertilizer injury to the young plants. If a high analysis fertilizer is used not more than 67–84 kg per ha should be mixed.
MICRONUTRIENTS:

Boron and Zinc:

The importance of micronutrients in crop production is well recognized (Bertrand, 1958; Kanwar and Randhawa, 1967).

Although Jay (1895) had suggested that B might be found in all plants, little attention was given to its importance in plant growth until the research work of Agulherson (1910) and of Branchley (1914) on the relation of the element to crop production. Warrington (1923) was the first to establish the essential nature of B for plant growth.

Scripture and Hargue (1945) studied the role of B supply in relation to carbohydrate metabolism in radish and concluded that B was essential for this function. Roots of radish plants from boron-free solution had a stronger oxidase activity than those from the healthy plants grown with 0.5 ppm boron solution. Boron deficiency in swedes growing in sandy soils was corrected by broadcasting 30 kg borax/ha in spring before sowing or by spraying 10-15 kg borax/ha in mid June (Stat. Forsvärvk, 1958).

Zikhman and Zikhman (1943) reported that the total yield as well as the size of individual seeds of radish, carrot and table beet was significantly increased in pot experiments in which 0.048 gm of boric acid was applied to 5.5 kg of soil + complete fertilizer. Boron prolonged the formation of generative organs and hastened the onset of
flowering.

In Chinese cabbage which had ceased growing because of B deficiency the foliar spray application of B at 0.5 and 1.5 ppm or addition to the nutrient solution at 1.5 and 4.5 ppm resulted in resumption of growth within 2 weeks and considerable increase in the number of leaves formed (Park and Song, 1965).

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Singh (1963) studied the effect of different micronutrients sprays on the growth and yield of *Brassica*. With one or two foliar sprays of 500 ppm B and Zn the number of silique/plant increased significantly due to increased number of siliqueae on the main shoot and primary branches. The yield of seed/plant as well as the yield / ha significantly increased over the control.

Spray of 10-20 mg borax/ha on carrots, celery, cabbage, shallot and leek (Hansen and Hansen, 1962, 1963) resulted in lowering the yields of marketable carrots significantly as compared with the untreated plots of high B content. Shallot showed a significant increase with both Zn and B and the highest yield was obtained with their combined application. With other crops the results were not significant.
Manganese and Iron:

In Cruciferae, *inter alia*, the Mn deficiency disease, is characterised by yellow interveinal mottling in soils with low available Mn (20 ppm) as compared with some non-susceptible soils with 93-915 ppm available Mn (Skene and Keeford, 1955). Deficiency occurs only after liming has raised the soil reaction to about 6.3 pH. Below this reaction as little as 2 ppm of available Mn seems adequate for susceptible vegetables grown in pedocic soils.

Agarwala et al. (1965) studied the effect of graded doses of Fe supply ranging from acute deficiency to excess on growth, tissue concentration of iron chlorophyll content and specific activity of enzymes-catalase, peroxidase, fructose-1, 6-diphosphate aldolase, acid phosphate, etc. in maize and radish grown in sand culture. The optimal yield of maize and radish was obtained with 0.5 and 0.1 mM Fe, respectively. In both plant species characteristic Fe-deficiency effects were produced on lower levels of iron supply.

Datta and Bains (1960) and Ghosh et al. (1964) reported that none of the microminerals had any effect on the yield of rape seed.

Hasler and Maurize (1947) studied the action of boron on seed setting in rape (*B. napus* L. var. biennis). According
to them B-deficiency is associated with a distinct alkaline soil reaction or an excess of calcium nitrate in the soil. With pot experiments, B was found to be essential for seed setting. They also asserted that it was the pollinated plant and not the pollen-bearing plant for which the B was essential.

Joshi and Joshi (1955) held that the use of micronutrients is imperative with high fertilizer doses for obtaining high yield. Raheja et al. (1959) stated that micronutrients should be applied as foliar spray as under most conditions the spray application of micronutrients was likely to manifest its effect more clearly than their soil application.

**Molybdenum and Copper:**

Mulder (1954) carried out a series of pot and field experiments on several crops with Mo. Radish and turnip, *inter alia*, responded clearly to this micronutrient. In some other experiments, cabbage, rape, turnip and radish responded more or less clearly when grown on Mo-deficient soils. The first two species showed mottled leaves for want of Mo. Rape gave higher yield with the application of Mo when grown on a number of soils in glass jars, but did not respond in field experiments. But turnip gave higher yield with Mo in the field experiments. Radish plants deficient in Mo were chlorotic with frequent cupping of leaves and marginal necrosis.
The yield was also considerably reduced.

Hewitt and Belle-Jennes (1952) also studied the influence of Mo on the growth of *Brassica* crops and described the visual symptoms of acute Mo-deficiency. These *Brassica* crops showed some differences in their ability to recover from the initial deficiency of Mo.

Davies (1945) discovered that the disorder long known as 'Whiptail' in cauliflower and broccoli and widely distributed was rectified by the soil application of micronutrient mixtures containing Mo. Malformation or death of growing point in cauliflower, swede and Savoy cabbage recovered with Mo but, not in rape or brussel sprouts.

Plant (1956) conducted field trials on cauliflower and other *Brassicae* on three acid soils treated with limestone, dolomite, gypsum and sodium molybdate. He found that the application of lime and dolomite was effective in correcting both Mo-deficiency and mineral toxicity, but raised the Mo status of leaves and reduced their Mn content. Gypsum reduced the uptake of Mn from two soils derived from old Red Sandstone and tended to alleviate Mo-deficiency, but it had the opposite effect on a soil derived from the Lower Greensand and produced plants containing up to 4000 ppm Mn. Mo-deficiency was characterised by a higher level of nitrate and lower level of ascorbic acid in the leaves of some *Brassicae*. 
In recent investigations carried out by Parkash and Bhardwaj (1965) on cabbage seedlings in plots, the seedlings received two sprays of a 20 mg/l solution of either Mo or Co four and five weeks after transplanting. Mo-sprayed plants matured 10 days before the Co-sprayed and gave appreciable increase in the weight and volume of heads and in the weight and number of outer leaves. Mo inhibited longitudinal root growth, but improved the horizontal spread.

Schrütte (1957) reported that radish plants grown in sand culture without one of the elements B, Cu, Mn or Zn wilted more rapidly under low moisture conditions than those supplied with all the four microminerals. Lack of Co or Zn greatly increased their susceptibility to wilting.

Sobackin (1958) conducted pot experiments with sand and acid soils containing 15 gm Al/100 gm. Application of sodium molybdate improved the growth of cauliflower. The greatest yield increase was obtained with 0.5 mg Mo/kg sand or 5-10 mg Mo/kg soil. The addition of Mo increased also the total and protein N and amide and amino acid contents.

GROWTH REGULATORS:

No work seems to have been reported on the treatment of radish seed-roots with plant regulators and its subsequent effect on plant performance. However, extensive research work has been reported from Michigan on the treatment of
radish besides some other vegetable crops with gibberellin to obtain early emergence of seed-stalk and early flowering (Wittwer and Bakovac, 1957; 1957a; 1957b; 1957c; 1958), but nothing has been reported as to the extent of increase in seed yield. In these trials varying quantities of gibberellin up to 100 ug was applied to the growing tip of the radish plant when the root was nearing the marketable stage. Seed-stalk emergence in the treated plants took place within a few days and flowering occurred within 30 days as compared to control plants which flowered four weeks later.

Radish treated with 1, 10 and 100 ppm of Gibberellin showed increased height and paler-green, less pliable leaves curled-under at the edges (Armstrong, 1958).

In Japan (Chiba and Fujisawa, 1964) induced the acceleration of flowering by treating the radish foliage of vernalised seedlings with 500 ppm of commercial ribonucleic acid, but treating the unvernalised seedling promoted growth only.

Eguchi et al. (1965) exposed radish seedlings of different stages of development to low temperature conditions from 3-30 days and observed that an increase in the period of exposure resulted in earlier and more uniform flowering, fewer abnormal flowers, height, fruit setting percentage, larger fruits, heavier seed and a higher percentage of larger seeds.