This dissertation presents results of agronomical studies with (A) root and (B) seed crops of carrot for the purpose of finding more profitable methods of production. The work reported was carried out for four years at Ludhiana (Punjab - India) loamy sand soils using carrot variety Pb. No. 29. Two experiments were conducted on the root and two on seed production. The salient features of the investigations are presented in this Chapter.

A. Root Production Studies

Experiment 1. Effectiveness of NPK fertilizers alone and in combination with micronutrients in relation to production of carrot roots.

Preliminary studies were conducted in the field for two years to compare the effect of soil applications of two fertilizers containing low (N, 56 kg; P, 28 kg; K, 56 kg per hectare) and high (N, 84 kg; P, 42 kg; K, 84 kg per hectare) levels of N, P and K alone and in combination with spray fertilization of micronutrients B, Cu, Fe, Mn and Zn on some growth and quality factors of carrots. There were 13 treatments, having the 5 micronutrients sprayed at the low and high NPK levels designated as \( F_1 \) and \( F_2 \), respectively along with \( F_1 \) and \( F_2 \) alone and an unfertilized check - \( F_0 \). The treatments were replicated four times in a randomized block design. In the light of the results obtained all the six treatments comprising the high fertility series were dropped and the modified experiment with seven treatments was conducted simultaneously in the field and pot cultures next year. A randomized block design with five replications was employed. The
major findings were:

(i) A significant response to both $F_1$ and $F_2$ fertilizer treatments was observed in carrots as measured by top growth, root yield and quality of root.

(ii) The effect of treatment $F_1$ was better than $F_2$ on the yield of roots but $F_2$ was more effective in stimulating top growth. $F_2$ also proved harmful to the market quality of carrots as it caused significantly more forking, splitting as well as bolting of roots as compared to $F_1$.

(iii) Significant increases in the root production owing to fertilizer level $F_1$ were associated with a significant improvement in the nutritional quality of carrots as indicated by carotene and crude protein contents. There was little or no change in the ascorbic acid, sucrose, glucose, dry matter, ash, phosphorus, potassium, calcium, and iron contents of the root.

(iv) Amongst the micronutrients only boron when added in combination with treatment $F_1$ produced significant beneficial effects on root yield with a mean gain of 17.9 per cent over $F_1$ alone. The food value as well as market quality of carrots was not significantly modified due to supply of micronutrients to the plants.

(v) In conclusion, the best results were achieved when carrots raised at the low level of NPK ($F_1$) were also treated with boron.

Experiment 2. Relation of seed size and stage of harvest to seed quality, plant growth, root yield and quality in carrots.

Large and small carrot seeds sorted from the first and second harvests of the promising treatments in experiment 4, and the unsorted seed representing the bulk sample were compared to determine the effect of seed size and stage of harvest on the production of carrot roots. A comparison in seed quality amongst the seeds obtained was also made. These five variables were replicated four times in a randomized block design. The major findings of the 2-year data are summarized
(i) A significant response to seed size was obtained from carrots as measured by top growth, root development and yield. Large seed A obtained from the second harvest caused significant increases in fresh foliage weight, root length and diameter, root yield per plant and per hectare than the small seed B produced in the same harvest.

(ii) The differences due to stage of seed harvest were also significant. Seed B, small seed of the first harvest, was found significantly superior to B2, small seed of second harvest, in root length and diameter, root yield per plant and per hectare.

(iii) Carrots with the unassorted seed U, yielded 14.7 per cent higher than B2 and 9.2 per cent lower than A2 seed; the reduction being significant only for the B2 seed.

(iv) No important or significant difference in the root content of ascorbic acid, crude protein, glucose, sucrose, dry matter, ash, phosphorus or potassium was attributable to seed size or stage of harvest, except for a noteworthy increase of carotene in the roots grown from A2 large seed as compared to those of the small seed B2.

(v) This study also indicated that high quality of seed was consistently associated with large seed A, whereas the B2 small seed was significantly inferior in quality as shown by its lightest seed, lowest field emergence and least susceptibility for storage.

(vi) It was inferred that at least seed from the bulk of the produce of the late harvest should be sown screened by sifting out all seed smaller than 1.35 mm.

B. Seed Production Studies

Experiment 3. Initial and residual value of micronutrients in carrot seed production.

This experiment measured the direct effect and residual value of the
micronutrients under study in the production of carrot seed. In order to measure the residual effect, the stecklings raised with micronutrients at F<sub>1</sub> level of PK including F<sub>1</sub> as control from experiment 1 were transplanted for raising seed. For studying the direct effect the F<sub>1</sub> treatment stecklings of the same experiment were planted and fresh applications of micronutrients were made on the plants. Total treatments numbered 11 and were tried in randomized blocks with four replications. The results concluded that:

(i) The micronutrients B, Cu, Fe, Mn and Zn either applied directly to the plants or indirectly through the stecklings failed to demonstrate any regular or significant influence either on plant growth, seed yield, or quality of carrot seed.

(ii) The results of both years indicated that these nutrient elements are of no benefit in the production of carrot seed under the conditions of this experiment.

Experiment 4. Spacing-cum-fertilizer studies on carrot stecklings in relation to seed production.

A 2-year study was made to determine the optimum spacing and N, P and K requirements for the production of carrot seed. Total treatments numbered 36 and were the combinations of three row spacings (S<sub>1</sub> - 45 cm; S<sub>2</sub> - 60 cm; S<sub>3</sub> - 75 cm), three levels of nitrogen (N<sub>0</sub> - no nitrogen; N<sub>1</sub> - 56 kg N/ha; N<sub>2</sub> - 112 kg N/ha), two levels of phosphate (P<sub>0</sub> - no phosphate; P<sub>1</sub> - 56 kg P<sub>2</sub>O<sub>5</sub>/ha) and two levels of potash (K<sub>2</sub> - no potash; K<sub>1</sub> - 56 kg K<sub>2</sub>O/ha). These were replicated thrice in a single split-plot design with spacing x nitrogen in the main plots and phosphate x potash as sub-plot treatments. The results when summarized were:

(i) Spacing had a significant effect on plant growth, including the branching habit and the intensity of lodging. The number of primary and total branches as well as the amount of lodging were maximised at the S<sub>3</sub> spacing and consistently decreased with decreasing spacing. A significant difference in the mortality of stecklings, leaf number and height of plants was not found in relation
to changes in spacing. Seed yields per plant averaged significantly the greatest under spacing $S_2$. In per hectare total seed yield, however, both the $S_1$ and $S_2$ spacings yielded significantly higher than $S_3$ but $S_2$ spacing was definitely more profitable. The seed quality as indicated by test weight improved significantly with increasing spacing, the percentage of large seed tended to increase and that of small ones to decrease. The extra-small seed and the seed viability were relatively unaffected.

(ii) Of all the factors studied, $N$ had the biggest effect on plant growth, seed yield and quality of seed, and, almost each variable showed better response to $N_2$ than the $N_1$ level. $N$ significantly influenced the primary and total branches and final height of plants. The amount of lodging, however, increased significantly with increasing $N$. The effect of $N_2$ level was significantly better than the $N_1$ effect on the per plant and per hectare seed yields. In the pooled results, the total seed yields per hectare from both the early and late harvests combined under the $N_1$ and $N_2$ doses were 29.0 and 36.8 per cent more than no - $N$ and the net profits were Rs. 607 and 758 in the same order. $N$ had a significant effect on test weight and seed size but had a little effect on seed viability. Both the 500 - seed weight and the amount of large seed increased with increasing $N$ while the small seed suffered a corresponding reduction with little or no change in the extra-small seed.

(iii) P did not significantly affect the vegetative growth in plants except a significant increase in the number of total branches. $P_1$ treatment increased seed yield per plant and per hectare significantly with a mean extra response of 19.1 per cent in total seed yield per hectare and additional profit of Rs. 426 over no - $P$. Among the seed quality characters studied, only the test weight was significantly improved by $P$ fertilization.

(iv) A significant response as measured by plant growth and quality of
carrot seed was not observed in relation to K. The per plant and per hectare seed yields increased both years, the effect being significant in the pooled data of the two years' total per hectare seed yield. Still, a dose of 56 kg K₂O/ha appeared to be necessary and the net returns of Rs. 93 to 101 obtained justified its use at the rate applied.

(v) The most important interaction was between spacing and N rate for per hectare seed yield. The best yield occurred with the S₂ x N₂ combination.

(vi) The response in mean seed yield to doses of N for spacing S₂ was linear. However, for the S₁ spacing the quadratic effect was also significant. The optimum dose of the fertilizer for this spacing worked out to 71.8 kg N/ha. On this basis, it appeared that the optimum N dose for spacing S₂ fell near above the N₂ level.

(vii) Interrelationships among yield components indicated that the per plant as well as the total seed yields were positively correlated with the number of primary and total branches produced by a plant. However, the total seed yield was not significantly correlated either with the mortality of stocklings or the incidence of lodging.

(viii) It was concluded that 112 kg N plus 56 kg each of P₂O₅ and K₂O per hectare is the best fertilizer for producing carrot seed. The results further favoured the planting of stocklings in rows 60 cm apart with a root-to-root spacing of 45 cm.

Practical Considerations:

On the basis of the results obtained during the course of present investigations, the following inferences of practical importance can be drawn for the production of root and seed crops of carrot.

A. Production of Carrot Root

1. From a series of tests to assess the effects of different micronutrients
and levels of NPK, it is established that complete fertilizer mixture providing 56 kg N, 28 kg P₂O₅ and 56 kg K₂O per hectare is sufficient to satisfy the major nutrient requirements of carrot roots in sandy loam soils of Ludhiana. Any level higher than this is not only wasteful but also harmful as it lowers yield and quality both. Besides the response to NPK at this level, the crop also benefits from a spray application of 2.2 kg borax to a hectare.

2. The results of the study on seed size and stage of harvest are conclusive, and strongly indicate the superior value of large seed in sharp contrast to the poor performance of small seed maturing late in the season. It is, therefore, essentially urgent that bulk of the seed of the late harvest should be sown screened to eliminate all seed smaller than 1.66 mm. This also suggests that it would be worthwhile and desirable for a practical seed grower to grade his seed as A₂, A₁ and B₁ and price it suitably so that premium could be put on the quality of seed. This device is characterized by its simplicity, rapidity and provides an objective means for successful carrot culture.

B. Production of Carrot Seed

1. The findings of the spacing-cum-fertilizer studies conclusively suggest that in order to obtain reasonably good yields of better quality seed, the crop should be planted in rows 60 cm wide with a root-to-root spacing of 45 cm and fertilized with 112 kg N and 56 kg each of P₂O₅ and K₂O per hectare.

2. From the experiment on the initial and residual value of micronutrients it appears that none of these nutrients are beneficial to the seed crop.