SUMMARY

The present thesis compares six chapters. The importance of the problem undertaken and the justification for the four field experiments conducted have been briefly explained in Chapter 1.

Early history of mineral nutrition of plants, importance of NPK in plant metabolism, leaf NPK content and the effect of basal application of NPK fertilisers as well as that of sowing date and seeding rate on growth, yield and quality of triticale and other cereals, including wheat and rye, have been reviewed in Chapter 2.

Details of materials and methods employed for the four field experiments together with authentic meteorological and edaphic data, have been included in Chapter 3.

Experimental results, based on statistically analysed data, have been presented in Chapter 4 and, subsequently, discussed in Chapter 5. Summary of the results regarding the four field experiments conducted is given below.

Eight varieties of triticale (Bronco 90, Badger PM 118, TL 419, Tigre "S", Juppa "S", Muskox "S", Mula "S" and Delfin) along with one check each of wheat (HD 1982) and rye (Russian Rye) were screened and four of them (TL 419, Tigre "S", Muskox "S" and Delfin) were selected in Experiment 1 on the
basis of population count (number of plants/sq m), growth and characteristics, leaf NPK content/ yield and quality characteristics. Population count was carried out after one month of sowing. Growth characteristics (shoot length, tiller number, leaf number, fresh weight and dry weight) and leaf NPK content were studied at tillering, heading and milky grain stage of growth. Yield attributes, namely ear number, ear weight, ear length, spikelet number, grain number, 1,000 grain weight, grain yield, straw yield and harvest index as well as quality characteristics, viz. grain protein and carbohydrate content and grain protein and carbohydrate yield/ha, were determined at harvest. The remaining three experiments were aimed at establishing the appropriate sowing date, seeding rate and nitrogen and phosphorus requirement of the selected triticales, keeping the same cultivars of wheat and rye as checks. The criteria selected for assessing the performance of the crop were the same as in Experiments 1-4. However, in Experiment 4, NRA in leaf was also included. A brief account of the experiments conducted is given below.

**Experiment 1 (1982-83)**

This was a simple randomised field trial on eight triticales and two checks each of wheat and rye, as mentioned above, to select the better performing varieties. A basal fertiliser dose of N\(_{150}\)P\(_{30}\)K\(_{30}\) was applied uniformly. Crop was sown on 10 November with 50 kg seed/ha.
Rye, followed by wheat, surpassed all the cultivars tested in population density. However among triticales, Delfin gave highest number of plants/sq m, while Bronco 90 showed poorest performance in this regard.

Delfin proved best among all the cultivars tested at each stage for all the growth parameters, except shoot length which was maximum in rye. Whereas, lowest performance regarding shoot length, tiller number and leaf number was observed in wheat, Bronco 90 and Mula "S" respectively, fresh weight and dry weight were minimum in Juppa "S" at all the stages.

Highest content of leaf-NPK was recorded in Delfin at all the stages, except at heading stage for leaf-P content and at milky grain stage for leaf-N content where Tigre "S" proved best, with Delfin being equal to it in each case. Bronco 90, rye, Juppa "S" and Mula "S" showed poorest performance with regard to the content of one or the other of the leaf-nutrients tested at different stages.

Among the various yield characters, the value for ear number, ear weight, ear length and 1,000 grain weight was highest in Delfin. Spikelet and grain number was maximum in rye and Tigre "S" respectively; but Delfin followed each of these varieties closely. Grain yield and harvest index were maximum in wheat; but Delfin was at par with wheat. Tigre "S" was also at par with wheat in grain yield. Straw yield was maximum in
TL 419. On the other hand, rye, Bronco 90, Juppa "S", Mula "S" and wheat gave lowest value for one or the other parameter at different stages.

Delfin proved best for all the quality parameters. However, Tigre "S" and wheat reached parity with Delfin in grain protein content, grain protein yield and grain carbohydrate yield. On the contrary, Bronco 90 gave lowest protein content and protein yield, while Badger PM 118 and rye were poorest in carbohydrate content and carbohydrate yield respectively.

Thus, of the eight triticales, better performing ones, namely TL 419, Tigre "S", Muskox "S" and Delfin were selected for the next three experiments conducted subsequently.

Experiment 2 (1983-84)

The design of this experiment was factorial randomised. Four triticle cultivars, selected on the basis of the data of Experiment 1, along with wheat and rye, were sown on four dates (25 October, 10 November, 25 November and 10 December) to determine the optimum sowing date for these cultivars.

Among all the dates, sowing on 10 November resulted in the highest number of plants/sq m, while 10 December proved poorest in this respect. Of the varieties, rye, followed by wheat and Delfin, in that order, showed highest population
density. TL 419 gave poorest performance. The interaction 10 November x rye proved best. 10 December x TL 419 gave the lowest value.

Considering the growth characters, 10 November proved best while 10 December gave poorest results for all the parameters at each stage. Delfin gave the best and rye, the poorest performance with regard to all the parameters, except shoot length, which was maximum in rye and minimum in TL 419 at all the stages. Interaction was significant for leaf number at heading stage and for all the growth parameters, except shoot length, at milky grain stage. 10 November x Delfin proved invariably best, while 10 December x rye showed lowest value for all significantly affected parameters, except leaf number at heading stage and tiller number at milky grain stage, where 10 December x TL 419 gave poorest value in both the cases.

10 November proved best and 10 December gave poorest value for leaf N, P and K contents at all the stages. Among the varieties, Delfin proved best for leaf N, P and K contents, at each stage except (i) leaf-N at tillering stage, which was maximum in wheat, (ii) leaf-P at heading stage and (iii) leaf-K at milky grain stage, which were highest in Tigre "S". Contrarily, rye, TL 419 and Muskox "S" gave poorest results for one or the other leaf-nutrient content at different stages. 10 November x Delfin proved best for all the leaf-nutrients when results were significant. Leaf-P at heading stage was, however,
highest in 10 November x TL 419 and leaf-K at milky grain stage, in 10 November x Muskox "S". On the other hand, lowest values were given by rye, Muskox "S" or TL 419 for one or the other leaf-nutrient at different stages.

Regarding yield attributes, 10 November proved invariably optimum while 10 December gave lowest value for all the parameters. Among the cultivars tested, Delfin proved best for all the parameters, except spikelet number, grain number and straw yield, which were maximum in rye, Tigre "S" and TL 419 respectively. Rye gave poorest performance with regard to all the attributes, except spikelet number which was minimum in wheat. The interaction 10 November x Delfin proved best for all the parameters, except spikelet number, grain number and straw yield, which were maximum in 10 November x rye, 10 November x Tigre "S" and 10 November x TL 419 respectively.

10 November proved best and 10 December gave lowest value for all the quality characters, except grain protein content for which 25 October, equalled by 25 November and 10 December, resulted in poorest performance. Delfin exhibited highest value for each parameter. Rye gave the minimum value for all the characters, except grain protein content for which Muskox "S" gave poorest performance. Interaction was significant for all quality parameters, except grain carbohydrate content. 10 November x Delfin invariably proved optimum. Conversely, 10 November x Muskox "S", equalled by 25 October x Muskox "S" and
10 December x rye, gave lowest value for grain protein content. The interaction 10 December x rye proved poorest for protein, as well as carbohydrate, yield of grain.

Experiment 3 (1983-84)

In a factorial randomised field trial, the effect of five seeding rates (50, 75, 100, 125 and 150 kg seed/ha) was observed on the performance of the same four selected triticales and one check each of wheat and rye, so as to determine the optimum seeding rate. The crop was sown on 10 November with a uniform basal fertiliser dressing of N\textsubscript{150}P\textsubscript{30}K\textsubscript{30}.

Plant population progressively increased with increasing seeding rates. Rye, followed by wheat and Delfin, in that order, resulted in maximum number of plants/sq m, while TL 419 was poorest in this regard. The interaction 150 kg seed/ha x rye gave the maximum and 50 kg seed/ha x TL 419 (equalled by 50 kg seed/ha x Muskox "S"), the minimum plant density.

Values for all the growth characteristics gradually decreased with increasing seeding rate from 50 to 150 kg seed/ha. Delfin gave best response for all the growth characters, except shoot length which was maximum in rye at each stage. The effect of interaction was significant for all the parameters, except shoot length at each stage and fresh and dry weight at tillering
stage. The interaction 50 kg seed/ha x Delfin proved optimum for all parameters, except shoot length for which 50 kg seed/ha x rye proved optimum at each stage and leaf number at milky grain stage for which the best combination was 50 kg seed/ha x Tigre "S". On the other hand, rye, TL 419, Muskox "S" and wheat gave poorest results with 150 kg seed/ha for one or the other parameter at different stages.

Like growth characters, leaf-nutrient content decreased with increasing seeding rate from 50 to 150 kg seed/ha. Among the varieties, Delfin invariably proved best for the content of all three leaf-nutrients. Rye, TL 419, Muskox "S" and wheat gave lowest values for leaf-NPK at one or the other stage. Interaction was significant for all three leaf-nutrients, except for leaf-N at each stage and for leaf-P at milky grain stage. 50 kg seed/ha x Delfin exhibited maximum value for leaf-N and P each at tillering and heading stage, while 75 kg seed/ha x Delfin (equalled by 50 kg seed/ha x Delfin) proved best for leaf-K at milky grain stage. Contrarily, rye, TL 419, Muskox "S" and wheat showed lowest value with 150 kg seed/ha at different stages.

As regards the yield attributes, increasing the seeding rate from 50 to 150 kg seed/ha decreased the values for ear number, ear weight, ear length and spikelet number. More or less the same trend was shown by grain number and 1,000 grain weight also. In contrast, grain and straw yield were increased
with increasing seeding rates up to 125 kg seed/ha; but both got sharply decreased at the highest seeding rate (150 kg seed/ha) which gave the lowest value. However, in grain yield, 50 and 75 kg seed/ha were also at par with 150 kg seed/ha. Harvest index was highest at 125 kg seed/ha and lowest at 75 kg seed/ha (equalled by 50 kg seed/ha). Regarding varieties, Delfin proved best for all the yield attributes, except spikelet number, grain number and straw yield, which were maximum in rye, Tigre "S" and TL 419 respectively. However, wheat was at par with Delfin in harvest index. Interaction was significant for all the yield parameters, except ear number and spikelet number. 50 kg seed/ha x Delfin proved best for ear weight, ear length and 1,000 grain weight. Highest grain number was given by 50 kg seed/ha x Tigre "S". Best results for grain and straw yield were given by 125 kg seed/ha x Delfin and 125 kg seed/ha x TL 419 respectively. Moreover, 125 kg seed/ha x wheat, equalled by 125 and 75 kg seed/ha x Delfin, gave highest value for harvest index. On the other hand, rye, Muskox "S", TL 419 and wheat gave lowest values with 150 kg seed/ha for one or the other parameter at different stages.

Effect of seeding rate was significant for all the quality parameters, except grain protein content. 75 kg seed/ha, equalled by 50 and 100 kg seed/ha, gave maximum carbohydrate content of grain, whereas grain protein and carbohydrate yield were highest with 125 kg seed/ha. Lowest value was invariably
given by 150 kg seed/ha for all significant quality parameters. Delfin proved best, while rye gave minimum value for all the quality parameters. Interaction was significant for all the quality attributes, except grain protein yield. 50 and 75 kg seed/ha x Delfin proved best for grain protein content. 100 kg seed/ha x Delfin (equalled by 125 kg seed/ha x Delfin) and 125 kg seed/ha x Delfin proved optimum for carbohydrate content and carbohydrate yield respectively. Whereas 50 kg seed/ha, with TL 419 and rye, gave the lowest values for protein content and carbohydrate yield of grain respectively, 150 kg seed/ha x rye was poorest for carbohydrate content.

**Experiment 4 (1984-85)**

This factorial randomised field experiment was aimed at working out the optimum of the nine possible combinations of basal nitrogen and phosphorus for the selected triticales and checks, taking $N_{150}$, $N_{200}$ and $N_{250}$ as nitrogen levels and $P_{30}$, $P_{40}$ and $P_{50}$ as those of phosphorus. The crop was sown on 10 November with 125 kg seed/ha, that was noted to be optimum in Experiments 2 and 3.

Maximum number of plants/sq m was noted for $N_{200}P_{40}$ equalled by $N_{200}P_{30}$, $N_{150}P_{40}$ and $N_{150}P_{50}$. The lowest value was given by $N_{250}P_{40}$, which was equalled by $N_{250}P_{30}$ and $N_{250}P_{50}$. Rye, followed by wheat and Delfin, in that order, gave highest population density, while TL 419 showed the lowest value. Interaction effect was non-significant in this regard.
$N_{200P40}$ proved best, while $N_{150P30}$ gave poorest results for all the growth characteristics at each stage. Regarding varietal response, Delfin showed highest value for all the growth characters, except shoot length (maximum in rye), at each stage. Interaction was significant for all the parameters, except leaf number and dry weight at tillering stage and for tiller number at milky grain stage. $N_{200P40}$ proved best with Delfin for all the growth parameters at all the stages, except for shoot length (optimum in $N_{200P40}$ x rye at each stage) and dry weight (optimum in $N_{200P40}$ x Tigre "S" at milky grain stage), on the other hand, $N_{150P30}$ gave the poorest performance with rye, wheat and Muskox "S" for one or the other parameter at different stages.

Doses containing 250 kg N ($N_{250}$) with $P_{30}$, $P_{40}$ or $P_{50}$ gave best results for leaf N, P or K content at different stages, while $N_{150P30}$ showed poorest value for all three nutrients at each stage. Regarding varietal performance, Delfin proved best for all the leaf-nutrients, except for leaf-P and K at heading stage (where wheat and Tigre "S", followed by Delfin, gave highest value) and for leaf-N at milky grain stage (where Tigre "S" proved best). Rye gave lowest value for all the leaf-nutrients, except for leaf-N at heading and milky grain stage (minimum in Muscox "S"). Interaction was significant for leaf-N at milky grain stage and for leaf-K each at tillering and milky grain stage. Tigre "S" with each dose containing $N_{250}$ and with
$N_{200P_{40}}$ gave highest leaf-N content at milky grain stage. Whereas $N_{200P_{40}} \times$ Delfin (equalled by $N_{250P_{30}} \times$ Tigre "S") at tillering stage and $N_{200P_{40}} \times$ Delfin at milky grain stage gave maximum value for leaf-K. Rye and TL 419 gave the lowest values with $N_{150P_{30}}$ at different stages.

As regards nitrate reductase activity (NRA), $N_{200P_{40}}$ proved invariably the best and $N_{150P_{30}}$ the poorest treatment. Among varieties, Delfin either proved best or was at par with the variety giving the highest value in this regard. Wheat gave the lowest value of NRA for all the types of leaf, except for second leaf at tillering and heading stage, where Muskox "S", equalled by wheat and/or TL 419, gave the poorest results. $N_{200P_{40}}$ was found to give the highest values for NRA with Delfin, Tigre "S" and rye in different leaves at various stages, with $N_{200P_{40}} \times$ Delfin being included in each case.

With regard to yield attributes, $N_{200P_{40}}$ proved invariably optimum, while $N_{150P_{30}}$ gave the lowest value for each parameter. Of the cultivars tested, Delfin proved best for all the yield attributes, except spikelet number, grain number and straw yield, which were maximum in rye, Tigre "S" and TL 419 respectively. As against it, rye showed poorest performance with regard to all the yield characteristics, except spikelet number (minimum in wheat). Among interactions, $N_{200P_{40}} \times$ Delfin proved best for all the parameters, except ear number (which was non-significant) and spikelet number, grain number, straw yield
and harvest index, for which \( N_{200P30} \times \text{rye} \), \( N_{200P40} \times \text{Tigre "S"} \), \( N_{250P50} \times \text{TL 419} \) and \( N_{250P40} \times \text{wheat} \) gave maximum value respectively. On the other hand, rye, TL 419 and wheat gave poorest values with various doses, with \( N_{150P30} \times \text{rye} \) being included in most cases.

Moreover, regarding grain yield, it may be added that positive correlations, worked out between grain yield and growth and yield parameters as well as between grain yield and leaf-NPK content and between grain yield and leaf-NRA, indicate that growth and yield attributes as well as leaf-NPK and NRA in different leaves, are associated with the final yield of the crop; and that grain yield can be predicted even at vegetative growth stages on the basis of growth characters, leaf-NPK content and NRA in various leaves.

As regards the quality characters, \( N_{200P40} \) proved optimum, while \( N_{150P30} \) gave lowest value for each parameter. Among varieties, Delfin proved invariably best and rye gave lowest value for all the parameters, except grain protein content, for which Muskox "S" gave the poorest performance. Regarding interaction, \( N_{200P40} \times \text{Delfin} \) proved optimum and \( N_{150P30} \times \text{rye} \) gave the lowest values for all the quality parameters, except grain carbohydrate content (non-significant) and grain protein content (lowest value recorded for \( N_{150P30} \times \text{Muskox "S"} \)).
In relation to grain quality, it may be added that positive correlations, worked out between quality parameters and NR in flag and second leaf, confirm the role of NRA in maintaining the grain quality; and that grain quality of different cultivars may be predicted at various growth stages of the crop by determination of NRA in different leaves.

In conclusion, $N_{200}P_{40}$ (with $K_{30}$) proved to be the optimum fertiliser dose, 10 November the best sowing date and 125 kg seed/ha the appropriate seeding rate for triticale, in general, and for Delfin in particular, for obtaining the superior vegetative growth and, ultimately, the desirable yield and quality of the grain. Moreover, correlation studies revealed that growth and yield characters as well as leaf-NPK and NRA in flag leaf and second leaf were attributive to the final yield of triticale and its parents, indicating that the grain yield of the cultivars tested could be predicted even at an early growth stage by determination of growth characters and leaf-NPK as well as NRA in leaf. Similarly, leaf-NRA might be utilised as a predictive tool to assess the grain quality of triticale and its parents.