CHAPTER - 5

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Introduction

The productivity of a crop plant is the result of the interaction between its genetic make-up and various environmental factors. Therefore, in crop production emphasis is given to improvement of yields through their proper manipulation.

Previously, low productivity of crops, particularly in underdeveloped countries like India, was due to the low yielding ability of available varieties coupled with the lack of capability of the farmers to provide optimum inputs, including fertilizers. However, yields have been increased substantially with the introduction of improved high yielding varieties that ushered in the "Green Revolution" in the sixties. With yields having reached a plateau once again, farm scientists are greatly perturbed about the future scenario as the accompanying population explosion shows no discernible sign of abatement.

Being a newly introduced and commercially less viable crop; triticale has received far less attention of farm scientists than most of the traditional cereals. In fact, the laudable achievements of the breeders responsible for producing and improving this crop
have not been matched by the plant physiologists and agronomists. None the less, the release of improved cultivars during the last two decades has been instrumental in spurning a few workers to determine their fertilizer requirement, particularly that of nitrogen (Ali and Rajput, 1978; Etchovers and Moraghan, 1978; Gagrado et al, 1978; Kalra and Dhiman, 1979; Bishnoi and Mugwira, 1980; Farnworth and Said, 1982; Bali et al. 1991). It may not be out of place to mention here that workers at Aligarh have also made substantial contribution in the field of nitrogen and phosphorus requirement of triticale (Afridi et al., 1977; Abbas, 1980; Alvi, 1984; Ashfaq, 1986; Moinuddin, 1987; Aziz, 1991; Aziz et al., 1994; Fatima, 1994; Shah, 1996). However, it must be admitted that no in depth study of potassium requirement has been undertaken here or elsewhere.

As this essential macro-nutrient is present in all types of plant materials being required for all phases of plant growth and development by playing a major role in influencing a number of physical, physico-chemical and metabolic pathways at the cellular level (Mengel, 1976). The present investigation comprising five experiments was carried out on triticale with the following aims.

1. To establish the optimum potassium dose under local agro-climatic conditions and to select a cultivar of triticale out of two originated from Mexico and India taking wheat as check.
2. To study the interaction effect of potassium with nitrogen in promoting the growth, yield and grain quality parameters of selected triticale.

3. To study the interaction effect of potassium with phosphorus on growth, yield and grain quality of the selected triticale.

4. To determine the efficacy of split application of nitrogen (basal and top dressing) with two doses of applied potassium on grain, yield and quality parameters of the selected triticale.

5. To test the efficacy of split application of nitrogen (basal and foliar) with two doses of applied potassium on grain yield and quality of the selected triticale and to determine if fertilizer economy could be effected without sacrificing yield and quality.

The data of these field tests are briefly considered below in the light of those of other researchers, working mainly on the potassium requirement of cereals but of course not of triticale.

**Growth characteristics**

The growth parameters selected for the first three experiments included some of the important morphophysiological attributes of a cereal crop. According to Gregory (1937) shoot
length and tiller production are a measure of meristematic activity, increase in leaf number at different stages indicates the degree of differentiation as well as photosynthetic rate while fresh and dry weight account for total productivity of the crop plant. Moreover, the span of the vegetative phase may have an important and direct bearing on grain yield (Bunting and Drennan, 1966; Yoshida, 1972).

$K_{20}, K_{40}, K_{60}$ and $K_{80}$ were applied (Experiment I) to assess the potassium requirement of Delfin, TL-419 and HD-2204 (check). In this cultivar-cum-potassium trial $K_{60}$ proved optimum for the various growth parameters studied (Tables 9-24), at the three samplings. The data thus confirm the well established role of potassium in augmenting cell division and expansion (Hewitt, 1963; Black, 1968; Mengel, 1978; Patnaik, 1987) which leads to enhanced shoot length and tiller number. The resulting increase in leaf number would be expected to provide greater surface area for harvesting solar energy. Enhanced production of photosynthates and their subsequent accumulation in the form of dry matter would thus be assured (Yoshida, 1972; Mengel, 1983).

Among the cultivars (Experiment I), Delfin performed best, followed by TL-419. The superiority of Delfin was manifested at the tillering stage itself and was maintained as growth progressed, resulting finally in its highest fresh and dry weight. In this respect
its better capacity for tiller and leaf production (Table 10 and 11), surpassing not only the other triticale but also the wheat check, points towards its improved genetic constitution. In fact, greater efficiency of absorption and retention of water exhibited by Delfin through its higher fresh weight accompanied with better utilization of essential nutrients absorbed from the soil, is also a clear indication of its superior genetic make-up. At present, sufficient information is available where genotypes (like the two triticale in the present study) have been found to differ considerably in the response of their physio-morphological characteristics to the surroundings, including their ability not only in the enhanced absorption of water and mineral ions but also in their translocation and accumulation in the plant. Such varietal differences are well known in the cereals including triticale (Millikan, 1961; Vose, 1963; Langer, 1966; Ashfaq, 1986; Moinuddin, 1987; Aziz et al., 1994).

In his early findings on the causes of variation in crop yield, Watson, (1951) concluded that variation in leaf area was an important factor. This has been reiterated by Yoshida (1972) who emphasizes that it is the area of leaf surface that intercepts solar radiations and is the most important factor in determining the yielding ability of a crop plant. The higher tiller and leaf number in Delfin is an obvious indication of greater surface area for higher dry matter accumulation.
Among the interaction effects, $K_{60} \times \text{Delfin}$ proved optimum for all growth characteristics, which is not surprising. It is however, noteworthy that the response to $K_{20} \times \text{Delfin}$ was at par with or even better than that of $K_{60} \times \text{TL-419}$ at most stages of growth for many of the growth parameters. Even $K_{60} \times \text{wheat}$ was at best found at par with $K_{20} \times \text{Delfin}$ and $K_{20} \times \text{TL-419}$ or even inferior to these combinations. These findings indicate the superiority of Delfin in extracting and utilizing potassium to its advantage during the vegetative phase, not only when the nutrient is present in sufficient quantities but also when it is deficient. This in-built superiority of triticale over wheat in better utilization of inputs coupled with greater harvesting of solar radiation makes it a good competitor as a future grain crop.

As in experiment 1, $K_{60}$ was found to be optimal for all growth characteristics of Delfin in Experiment 2 and 3, better growth response being observed as the applied potassium dose was increased from $K_{20}$ to $K_{60}$. However, luxury consumption resulted at the highest dose ($K_{80}$).

Basal dose of nitrogen, $N_{150}$, proved best for the growth of Delfin in Experiment 2. Like potassium, nitrogen is an essential macronutrient. It is involved directly or indirectly in almost all physiological activities of the plant (Hewitt, 1963; Steward and Durzan, 1965, Noggle and Fritz, 1986; Devlin and Witham, 1986; Salisbury and Ross, 1991).
As growth is a manifestation of the interplay of meristematic and metabolic processes, including cell division, elongation and expansion, metabolism and dry matter production which are responsible for meristematic activity, the application of nitrogen led to enhanced leaf production, tillering, elongation of shoot and increase in volume and weight in the present study. Thus in particular, leaf area was considerably increased confirming the findings of Humphries and Wheeler (1963) and Gardner et al. (1985), among others. Such an effect of nitrogen application corroborates the work done at Aligarh on several varieties of triticale including Delfin (Ashfaq, 1986; Moinuddin, 1987; Fatima, 1994 and Shah, 1996).

In experiment 3, the response of Delfin to four doses of potassium with three of phosphorus applied basally was studied. As in Experiment 1 and 2, the data confirmed that $K_{20}$ and $K_{40}$ were inadequate for the growth of Delfin, while $K_{60}$ proved optimum, $K_{80}$ was found wasteful (Tables 30-34). Among phosphorus doses $P_{60}$ proved more beneficial than $P_{30}$ and $P_{90}$ for shoot length, tiller number, leaf number, fresh weight and dry weight. (Table 30-34) at each of the three stages. These data confirm the well established role of phosphorus in cell division and expansion (Hewitt, 1963; Black, 1968; Patnaik, 1987). Adequate provision of nutrient at sowing through the application of $P_{60}$ promoted tissue and organ formation. The increased growth
activity culminated in enhanced leaf and tiller formation as noted for various crops by Tamhane et al. (1970). Expectedly, the resulting increased photosynthetic area would result in higher photosynthetic rate ascribed to phosphorus application in various plants by Natr (1972), Osman et al. (1977), Longstreth and Nobel (1980) and produce more dry matter which is regarded as the best measure of plant vigour.

Among the interaction effects, $K_{60} \times P_{60}$ (equalled by $K_{80} \times P_{60}$) proved the best combination for tiller production, fresh weight and dry weight at the three stages of growth. Further, $K_{80} \times P_{90}$ generally proved harmful for growth. Thus on the basis of satisfactory vegetative growth and dry matter production, $K_{60} \times P_{60}$ was established as the optimum combination, while the interaction effect of lower doses proved less effective and that of higher doses wasteful or even deleterious (Tables 30-34). These data justify the adoption of the factorial randomized design for the field trial. Interestingly, this is also applicable to the results of Experiment 2 on potassium and nitrogen requirement of Delfin in which $K_{60} \times N_{150}$ proved optimum (Table 20-24).

An interesting observation made in Experiments 2 and 3 is the differentiated response of the crop to nitrogen and phosphorus. Whereas, tiller number and leaf production showed a linear increase with age on nitrogen application (Table 21 and
22), these parameters showed a decline at the milky grain stage in the phosphorus trial (Experiment 3 - Table 31 and 32). However, the response with respect to shoot length, fresh weight and dry weight was linear for both nutrients.

**Yield characteristics**

Yield and its components are the ultimate measure of many important biophysical and biochemical functions dependent upon potassium. In cereals the number of ears per unit area, the number of grains per ear and average grain weight are the main yield determining parameters (Haeder and Beringer, 1981a). However, while studying yield physiology, it is desirable to consider not only the tissues involved in the storage of food (sink) but also the plant parts producing these photosynthates (source).

It may be recalled that in Experiment 1, 2 and 3 treatment $K_{60}$ proved optimum for all growth parameters including dry matter production. The logical expectation that this augmented source would lead to better development of the components of the sink was corroborated by the data in Tables 14-16, 25-27 and 35-37 wherein $K_{60}$ proved optimum for ear number, ear weight, spikelet number, grains per ear, 1000 grain weight, grain yield and straw yield.
It is well established that 90-95% of the carbohydrate in grain is derived from CO₂ fixation after anthesis, in which apart from other "sources", the flag leaf and the one next to it play a dominant role.

Adequate potassium application is known to safeguard the functioning of these 'sources' in the grain filling process, for example grain weight is severely affected by the loss of the flag leaf. Sufficient potassium supply reduces the loss (Forster and Beringer, 1981). Moreover losses in chlorophyll content of the upper internode of wheat plants during the final stage of grain filling were diminished by increasing K nutrition (Haeder, 1980).

Although the potential number of grains per year is largely fixed genetically, there is convincing evidence that adequate potassium supply contributes to increased formation of grains per ear. Forster (1982) concluded that a high level of K nutrition helped to control the loss of grain primordia in wheat and oats by encouraging stronger root growth during the milky grain and dough stages of grain ripening.

Haeder and Beringer (1981) attributed the yield response of wheat to K fertilization primarily to increased single grain weight and, to a lesser extent, to the number of ears per unit area and number of grains per ear. Increasing rates of K raised wheat yields
chiefly due to a striking rise in grain weight, but greater number of ears per plant and of grains per ear also contributed to the improved yield (Forster and Beringer, 1981).

Prolonged grain filling period is a very important requirement for the formation of larger grain. Haeder and Beringer (1981) found that K fertilizer lengthened the period of grain filling of wheat by both advancing anthesis and delaying senescence. Higher potassium was found by them to increase the intensity of grain filling or the rates of grain growth per day.

A higher level of K supply is believed to promote the formation of longer grain through more intensive and longer photosynthesis. Shrivelled and light weight grains are often formed by K deficiency (Vig and Das, 1977).

Considering varietal differences, in Experiment 1, Delfin performed better than TL-419 and even surpassed the local wheat check with regard to final yield (Table 16). The superiority of Delfin may be due to its better yield attributing parameters, including ear number, ear length, ear weight and grain number compared to the other two cultivars (Tables 14-16). The superior yielding ability of Delfin has also been reported earlier by Moinuddin et al. (1990 a,b); Aziz et al (1994); and Fatima (1994).
It is noteworthy that among the yield parameters wheat could surpass Delfin and TL-419 only in 1,000 grain weight (Table 15) which highlights its superiority in the production and translocation of photosynthates to the grains.

Since its inception in the year 1875, triticale has overcome a number of inferiority barriers through the consistent efforts of plant breeders, agronomists and plant physiologists. This progress has been ably reviewed by Inam (1992). He has remarked that triticale genotypes have either matched or surpassed wheat in various yield characteristics including grain yield. However, it has also been admitted that triticale still lagged behind in test weight, colour and boldness of the grain. So it is not surprising that Table 16 reveals that triticale cultivars Delfin and TL-419 were poorer in 1,000 grain weight when compared to the local wheat check. Such variations do exist in different cultivars due to their genetic make-up, as their efficiency for nutrient absorption and utilization with respect to various physiological aspects of grain yield differ considerably (Yoshida, 1972).

Ion transport processes also provide a basis for genotypic differences in nutrient utilization (uptake, transport across roots and release to the xylem) as discussed by Lauchli (1976). In the present study, genotypic variations were observed in terms of N, P and K concentrations in the leaves, indicating the pattern
observed in grain yield, that Delfin is an efficient harvester of potassium is also confirmed. The effect of combination $K_{20} \times Delfin$ being at par with $K_{40} \times HD 2204$. On the other hand $K_{20} \times HD-2204$ was superior to even $K_{60} \times TL-419$, indicating the superiority of wheat over this triticale. Interestingly, 1,000 grain weight of Delfin in the present study was noted to be improved by increasing the potassium dose. Thus $K_{20} \times HD-2204$ was at par with $K_{60} \times Delfin$ (Table 15).

The ameliorative role of nitrogen with regard to yield attributes (Experiment 2) was similar to that noted earlier for growth characteristics, wherein $N_{150}$ proved best. The observations summarized in Table 25-27 indicate the effectiveness of this optimum dose of nitrogen for maximisation of yield attributes leading to high grain yield. The improvement in yield characteristics is not unexpected as nitrogen is known to affect grain production favourably in a number of plants, including triticale.

Perusal of the $K \times N$ interactions shows that by increasing the K dose from $K_{40}$ to $K_{60}$ not only brings about significant increase in the grain yield of Delfin but also results in saving of the N ($N_{120}$ replacing $N_{150}$), indicating the utility of potassium in promoting nitrogen efficiency.

In Experiment 3, the effect of $P_{60}$ on yield characteristics was significantly higher than that of $P_{30}$ or $P_{90}$, the latter even
proving deleterious as it gave even lower yields than $P_{30}$ (Table 37). The involvement of phosphorus in the production of fertile tillers was reported among others by Sethi and Singh (1972), Sethi et al. (1979), Prasad and Singh (1983). The ear weight (Table 35) is a measure of partitioning of the photosynthate between vegetative and reproductive parts of the plant (Black, 1968). The data shows that $P_{60}$ produced heavier ears than $P_{30}$ thus indicating the involvement of phosphorus in the process. An increase in ear length due to $P_{60}$ compared to $P_{30}$ may be an indicator of the promotory role of phosphorus in cell division and expansion leading to increased vertical growth (Hewitt, 1963; Black, 1968; Patnaik, 1987). The treatment also promoted 1,000 grain weight, confirming the role of phosphorus in swinging the partitioning of photosynthates towards grain filling as noted in other cereal crops (Afridi and Samiullah, 1973; Qaseem et al. 1978; Giaqunta and Quebendeaux, 1980; Orphanos and Krentos, 1980). A similar observation has been made by Fatima (1994) in the case of triticale. In the present study, the effectiveness of $P_{60}$ in promoting vegetative growth (Tables 30-34) was reflected in enhancing the yield attributes (Tables 35-37). It is, therefore, not surprising that this treatment resulted in the highest grain and straw yield.

Unlike the $K \times N$ interaction effects (Experiment 2), noted above, interaction between $K$ and $P$ was not spectacular. However,
the grain yield was at par in $K_{60} \times P_{30}$ and $K_{40} \times P_{60}$. Thus $P_{60}$ may be replaced with $P_{30}$ by increasing $K_{40}$ to $K_{60}$, again proving a positive role of K in enhancing the utility of phosphorus like that of nitrogen noted above.

As mentioned earlier, judicious application of fertilizers is one of the most important concerns of the farmer as it guarantees the desired growth and yield of a crop. Not only the quantity but also the technique of its application should be such as to serve the plant to its advantage. Fertilizer is applied mostly in solid form and is broadcast, i.e. distributed uniformly over the soil, before sowing. For soils of poor nutrient status and those that strongly fix plant nutrients, split application of fertilizer is advisable. Loss of much of the nitrogen applied at the time of sowing (Anonymous, 1971) through various agencies also warrants split application. Top dressing with nitrogen in addition to a proper starter dose, after the crop has grown to a particular stage, has therefore, become a standard agricultural practice.

The data of Experiment 4, confirmed once again the superiority of $K_{60}$ over $K_{30}$ with regard to all yield attributes including grain yield.

Tables 40-42 also indicate that split application of nitrogen (basal + top dressing) proved better than the one-time basal
application of nitrogen alone. Thus, treatment $B_{N90} + T_{N30}$ was found optimum for all yield characteristics except ear weight. 

It is interesting to note that the higher dose of nitrogen ($B_{N120} + T_{N30}$) proved at par with $B_{N90} + T_{N30}$ for ear number, ear length, grain yield and straw yield while $B_{N120}$ (basal nitrogen alone) gave the lowest value for all the parameters considered, confirming the data of Experiment 2. The data thus indicate that although, if applied only once at sowing $N_{150}$ is the required dose for good yield, a saving of 30 kg N/ha together with higher yield could be obtained by split application of 120 kg N/ha as $B_{N90} + T_{N30}$. Fertilizer economy of nitrogen through top dressing is well established and has been achieved at Aligarh for various crops (Akhtar Noor, 1986; Abbas and Kumar, 1987).

Among interaction effect $K_{30} \times B_{N90} + T_{N30}$ was found to be at par with $K_{60} \times B_{N150}$ for grain yield (Table 42), proving that even low potassium ($K_{30}$) may bring about more efficacious nitrogen use, in case of split application. The basis of such synergistic effect of potassium and nitrogen has already been discussed.

As mentioned above, a large part of nitrogen fertilizer applied to the soil at the time of sowing is rendered unavailable to the crops, particularly at the late stages of development (Anon, 1971) which resulted in low yield. In recent years, the agricultural
utility of foliar application of mineral nutrients has received wide attention due to its proven efficacy under various constraints. A number of research workers have suggested split application of supplemental nitrogen through foliage, as a remedial measure to ensure maximum realization of the genetic potential of crops (Afridi and Wasiuddin, 1977).

In Experiment 5, as in the earlier experiments, $K_{60}$ proved superior to $K_{30}$ for all yield attributing characters and yield itself (Tables 45-47). Among nitrogen treatments the data confirmed that when applied at the time of sowing only, the crop did better with $N_{150}$ than with $N_{120}$ as in Experiments 2 and 4. However, the best results were obtained in $BN_{120} + FN_{10}$, containing a total of 130 kg N/ha. Here again, we have not only a saving of 20 kg N/ha but also higher yield than in any of the other treatment, confirming the findings of Experiment 4 and those of others, Inam, 1978; Akhtar Noor, 1986).

This spectacular efficacy of foliar spray was not unexpected. Spray of nitrogen at early heading which is considered a period of great metabolic activities, when setting and filling of grains started, ensured a better supply of readily available nitrogen spray. Similar increase in grain yield by nitrogen spray has been reported by Evans (1952), Reeves (1954), Finney et al. (1957), Sadaphal and Das (1966), and by Alvi (1984), Ashfaq (1986), Fatima (1994) in triticale.
It is well established that from germination onwards, growth is controlled not only by the amount of assimilates produced but also by their partitioning among the various parts of the plants (Langer, 1967). It seems that even when the experimental plants had received up to 150 kg N/ha at sowing, they become somewhat deficient in nitrogen by the time grains were set and required fresh supply of the nutrient for optimal morpho-physiological activity, including the formation of reproductive parts and the development of sink.

Regarding the K x N interaction effect it may be summarized that $K_{60} \times B_{N120} + F_{N10}$ followed by $K_{60} \times B_{N90} + F_{N10}$, proved the best treatment and ensured highest grain yield (Table 27) as a result of cumulative effect of other yield characteristics (Table 45-46). However, it is noteworthy that even $K_{30} \times B_{N90} + F_{N10}$ out yielded all treatments in which foliar application was not involved. These results highlight the efficacy of supplemental nitrogen spray on one hand and the role played by potassium (in the presence of phosphorus) in bringing out the full genetic potential of the crop, on the other, commending the adoption of this judicious combination of N, P and K for ensuring high return to the farmer. However, for those without spray facilities, $K_{60} \times N_{150} \times P_{60}$ should suffice.
Grain quality

Plants draw from the soil various essential mineral nutrients and water which they utilise not only for their growth and yield but also for the quality of their produce. If any of them is deficient, the quality of the crop is likely to be affected as they are involved in the biosynthesis of various metabolites. Cereals provide about 70-80% of the total calories and more than two third of the protein in human diet (Hulse and Spurgeon, 1974). As such, not only the grain yield but also the protein and carbohydrate content of the grain assume equal importance.

Potassium is often described as the "quality element" for crop production. With a shortage of potassium, photosynthesis, respiration, translocation and a number of enzyme systems may be disrupted, thereby causing reduction in crop quality (Evans and Sorger, 1966). It is therefore, not surprising that application of adequate quantities of potassium was found necessary for maintaining grain quality in all the present trials, $K_{60}$ proving optimum. Mengel et al. (1981) reported an indirect influence of potassium on grain protein formation through amino acid translocation from vegetative plant parts to the grain, which favoured synthesis of gluten and prolamine.

In Experiment 1, among the cultivars tested, Delfin proved inherently superior to TL-419 and wheat check for grain protein
content but TL-419 proved best for grain carbohydrate content (Table 17). Being an intergeneric hybrid of wheat and rye, triticale is known to combine high protein content of wheat and high lysine content of rye (Hulse and Spurgeon, 1974). Higher content of protein in triticale has also been reported by (Villegas et al., 1968). The findings of the trials are also in conformity with the findings of Sisodia (1971), Villegas (1973), Bronwer (1977), Fencik et al. (1980), Gill and Sandha (1980), Koleves and Khristove (1983), Alvi (1984), Vaulina (1987), Moinuddin et al (1990). While considering the protein and carbohydrate yield per hectare, it was noted that wheat (HD-2204) almost caught up with Delfin and was superior to TL-419 on both counts (Table 18). This was due to the higher grain yield of wheat compared to that of TL-419. These findings are in agreement with those of Moinuddin et al (1990 a, b) and Fatima (1994).

In Experiment 2, nitrogen treatment $N_{150}$ proved better than all other treatments for grain protein and carbohydrate content as well as yield (Table 28 & 29). In cereals, including triticale, beneficial role of applied N with regard to protein content of grain is well established as reported by a number of researchers, including McNeal and Davis (1954), Eck et al (1963), Singh and Gupta (1969). Jaisingham et al. (1970), Mc Neal et al (1971) and Afridi and Samiullah (1973) for wheat and barley and Kalra and

In Experiment 3, P$_{60}$ proved optimum for quality characteristics. The observed increase in grain protein content in this treatment may be due to the indirect effect of P in increasing the uptake of nitrogen as reported by Roy and Wright (1974) for sorghum. This assumption is supported by the high protein and carbohydrate contents in grains (Table 38). Moreover, although nitrogen is the chief constituent of protein, phosphorus is also involved in protein synthesis via supply of energy-rich ATP (Hewitt, 1963) which explains the data presented in Tables 38 and 39.

Grain carbohydrate content and yield were also significantly affected by phosphorus treatments. P$_{60}$ proved best for both quality parameters (Tables 38 & 39). It may be due to the importance of phosphorus through its role in energy-rich ATP and NADP, which are involved not only in the production of carbohydrate in the source but also in its conduction to the sink (grains). It may be added that these results are also in agreement with those of Fatima (1994).

The data of Experiments 4 and 5 on grain protein and carbohydrate content and yield (Tables 43, 44, 48 & 49) confirmed the earlier findings in this study (Experiment 2; Tables 28 & 29). However, the superiority of split application over one-time
nitrogen application (top dressing in Experiment 4 and foliar spray in Experiment 5) has also been established. Thus, we harvest better quality grain and also save costly fertilizer by adopting the technique of split application of nitrogen.

In cereals, a positive correlation of soil-applied nitrogen to protein content of grain is well documented (Mc Neal and Davis, 1954) and has been confirmed by later work including that on triticale undertaken at Aligarh. At the same time, it is also known that a major part of the nitrogen fertilizer applied to the soil at the time of sowing is rendered unavailable to the crops as they mature which results in low values of grain protein content.

In Experiment 5, where N was applied through foliar spray as a supplement to basal fertilization, results were much more pronounced than in Experiment 4 conducted under the same conditions. Thus, $B_{N120} + F_{N10}$ proved the most effective dose. The 130 kg N/ha thus supplied gave much higher values for all the quality characteristics than even $B_{N150}$ due to the ready availability of nitrogen during the grain setting and grain filling period as explained earlier while discussing grain yield.

These results on the efficacy of supplemental foliar spray of nitrogen are in line with those of a number of researchers, including Finney et al (1957), Sadaphal and Das (1966), Bhowmik

It was also observed that, where the data were significant, $K_{60}$ resulted in higher grain protein content when interacting with each nitrogen dose compared with $K_{30}$. This proves the effectivity of potassium in improving the quality of grain, as protein content is the main concern as far as human nutrition is concerned. It may not be out of place here to mention that cereals receiving good K supply absorbed more N during grain filling (Koch and Mengel, 1977). In the present study adequate K supply increased the utilization of N and P and not only resulted in higher grain yield and grain size but also produced grains with higher protein content. It may be mentioned here that, probably for this reason, crops with high yield potential also have high potassium requirements (Haeder and Mengel 1974, Forster 1976).