THE EFFECT OF SUBSOIL MINERAL NITROGEN ON GRAIN PROTEIN CONCENTRATION OF WHEAT

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Thesis submitted for the degree of
Doctor of Philosophy

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December 1996

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SUMMARY

In the ley farming system traditionally used in the cereal zone of southern Australia, nitrogen (N) input for cereal production was largely derived from that added by legume-based pastures. In recent years cropping has increased, the importance of pastures has diminished in many areas and pastures have been replaced with grain legumes and oilseed crops. As a consequence input of biologically fixed N into the farming system has declined and the use of N fertiliser increased. Nitrogen deficiency is a major factor limiting productivity and quality (grain protein concentration) of wheat in some areas.

Subsoil nitrate (NO_3-N) may be a useful N reserve for field crops when N in the surface layer is unavailable or not accessible because the soil is dry. Leaching of N mineralised in, or applied as fertiliser to, the surface layer of soil appears to be the main avenue of NO_3-N build-up in the subsoil. There is some evidence to suggest that, under the farming conditions of southern Australia, NO_3-N leached deeply into the soil profile, but still in the active root zone, may be taken up by wheat crops late in the growing season and thus may constitute a potential source of N for enhancement of grain protein concentration (GPC). Preliminary measurements in the field at the Waite Institute showed a loss of mineral N from the surface horizon of the soil during the growing season, part of which was attributed to leaching to the deeper layer.

This project examined the uptake of mineral N from the subsoil after anthesis and its effect on the GPC of wheat. The overall objective of the studies was to examine the importance of subsoil mineral N and investigate the ability of wheat to take up N from the subsoil late in the season under different conditions of N supply and soil water availability. Greenhouse experiments were designed to investigate the importance of subsoil mineral N availability on GPC of wheat and the factors that contribute to the effective utilisation of N. The recovery of N from subsoil, the effect of split N application on GPC and short term N uptake by the wheat at different rooting densities were studied.

The first experiment examined the ability of wheat plants to take up subsoil mineral N and the subsequent effect on GPC. Wheat was grown in pots 105 cm deep using a soil

that was sandy and very low in N. Samples of wheat were taken during the season to measure shoot and root weight, root length, concentrations of NO_3-N, total N, grain yield and GPC. Two weeks after anthesis, 150 mg N (equivalent to about 150 kg N ha^{-1}) as KNO_3 was added in solution to the treatment pots at a depth of 60 cm and its fate was examined. Application of N after anthesis significantly increased root growth at the site of N placement in subsoil. Grain yields, N uptake per unit root length and GPC were increased. The apparent recovery of applied N in plant tops was high (about 72%). The amount of N remobilised after anthesis from the roots and shoots in the control plants was high, equivalent to 81% of the N in the grain, while only 27% was remobilised in the N-treated plants. The results from this experiment support the hypothesis that subsoil mineral N may be taken up late in the season and contribute to GPC.

The second pot experiment considered the effects of depth, time and amount of N application, as well as soil water regime on GPC. A single post-anthesis application of N was compared with treatments where the N was placed in the topsoil or subsoil during the early part of the season under different water treatments. The experiment was designed to simulate possible conditions in the field *i.e.* subsoil N derived from decomposition of organic material or from fertiliser applied early in the season and leached into the subsoil. There were five N treatments applied as KNO_3: (N0) no N; (N1) 150 mg to topsoil at sowing; (N2) 75 mg to topsoil and 75 mg to subsoil at sowing; (N3) 150 mg to subsoil at sowing; (N4) 75 mg to topsoil at sowing and 75 mg to subsoil one week after anthesis. When the wheat reached anthesis, water treatments were introduced to provide (1) well-watered control ; (2) dry topsoil but ample water supply in the subsoil. The plant and soil measurements were the same as the first experiment. An additional series of pots in which 150 mg N was applied at sowing (N1), was established and watered as for the well-watered treatment to follow the leaching of N from the topsoil. When the fate of the N was followed down the profile in these pots during the pre-anthesis period, it was found that one month after N application some NO_3-N was leached in to the subsoil.

Application of N significantly increased the yield and GPC irrespective of the depth or the time of application and the recovery of N was similar in all treatments. This shows that placement of N had no effect on N uptake by plants. The plant yield and GPC responses to the different N treatments were not affected by restricting the supply of water during the post-anthesis period. The GPC of plants treated with 150 mg in the topsoil at sowing (N1) was comparable with N2, N3 and N4 treatments suggesting that as long as the N is not leached beyond the root zone, it has an equivalent effect as an application to the subsoil. Root growth increased at the site of N placement in the subsoil. The ability of wheat to recover N from subsoil was high (about 70%). Nitrogen fertiliser increased the water use and water use efficiency compared with the control.

A further experiment was conducted to test the hypothesis that a split application of N has an equivalent effect on GPC as a subsoil N reserve which is used after anthesis. Wheat was grown in a sandy loam soil in pots 105 cm deep. There were four N treatments applied as KNO_3: (N0) no N; (N1) 150 mg to topsoil at sowing; (N2) 75 mg to topsoil at tillering and 75 mg to topsoil at booting; (N3) 150 mg to subsoil after anthesis. Water treatments were applied as in the previous experiment. Drying of the topsoil decreased grain yield but increased the GPC of wheat. Placement of 75 mg N in the topsoil at tillering and 75 mg N topsoil at booting or 150 mg N at 60 cm depth after anthesis produced higher GPC than the control. The effect of the split N application (N2) on GPC was comparable to the subsoil N application after anthesis (N3), due to the leaching of the N into the subsoil where it was taken up after anthesis. Root growth increased at the site of N placement in the subsoil. N fertiliser increased the efficiency of water use compared with the control.

Root length density declines with depth and in some cases root growth in the subsoil is poor. It may not be sufficiently large to utilise N effectively, or it may limit the ability of the plant to take advantage of transient increases of available N from mineralisation or exploit subsoil N reserves. Therefore it is important to examine the effect of different root length densities on N uptake from the soil. Short term (48 hour) N uptake by wheat at different rooting densities with different levels of plant demand (imposed by the use of shading treatments) was studied in 2 experiments. This experiment examined the importance of root density and plant growth rate on the rate uptake of N by wheat.

Wheat was grown in 2.4 kg sandy loam soil in pots 20 cm deep. The two rooting densities were produced by planting 3 or 9 seeds per pot. There were four N treatments applied as KNO_3: (a) no N; (b) 50 mg per pot; (c) 100 mg per pot; (d) 150 mg per pot to topsoil four weeks after sowing. After applying N, shade treatments were introduced to provide (1) non-shade or (2) shade. A second experiment also included a treatment which reduced effective leaf area (LA) by covering the basal half of each leaf with foil at the time that shade treatment were imposed. Two sets of plants were harvested, before and after the N and shade treatments were imposed.

Shading had no significant effect on root dry weight or root length, but average shoot dry weight of shaded plants was lower than that of non shaded plants after the 48 hour period. The rate of N uptake increased when 50 mg N was applied but was not increased further by higher rates of application. This response to N was independent of root length density. Restricting the growth of the plants by shading or decreasing the area of leaf exposed to light had no effect on the response of the plants to 50 mg N, but it decreased the ability of the plant to respond to higher levels of N. These results show that the ability of plants to exploit transient increases N in soil depended more on the shoot growth rather than rooting density. The rate of uptake was not affected by the density of roots but was sensitive to shoot growth. Therefore a transient increase in subsoil mineral N due, for example, to mineralisation and leaching, may improve the N uptake by plant, but the ability of the plant to respond to this N will depend on its growth rate.

The findings from this work showed that the subsoil mineral N is potentially a good N reserve for the wheat late in the season when there is no water available in the topsoil for the plant. The ability of plant roots to recover N from the subsoil is high and N uptake from subsoil after anthesis can increase the GPC of wheat. The results also showed that as long as the N is not leached from the root zone topsoil N application at sowing or split N application at tillering and booting has an equivalent effect as application to the subsoil. Results provided a sound basis for field work to investigate the effect of subsoil mineral N on GPC of wheat.