# Nitrogen effects on early growth of Otane wheat: Possible advantages and disadvantages of adding fertiliser nitrogen at sowing

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## Abstract

Effects of different external nitrogen (N) concentrations on early growth of Otane wheat were examined under controlled environment, glasshouse and field conditions. At 60 mm sowing depth under controlled environment conditions, increased applied nitrate ($NO_3^-$) from 0 to 1.0 or 10 mol/m$^3$ had no effect on shoot length but caused increases in shoot fresh weight and dry weight prior to emergence. Additional $NO_3^-$ also caused a decrease in emergence percentage. Under glasshouse conditions, increased applied $NO_3^-$ from 0 to 1.0 or 10 mol/m$^3$ resulted in increases in extension rate, final length and final area of main-stem leaves 2 to 4 and greater tillering at the 5-leaf stage. Final area of leaf 1 was also greater with additional $NO_3^-$. At a mean sowing depth of 51 mm in the field, additional N as urea (100 kg N/ha) did not affect emergence percentage or final area of main-stem leaves 1 and 2 but resulted in greater area of main-stem leaves 3 and 4 and greater tillering at the 5-leaf stage. Possible advantages and disadvantages of adding fertiliser N at sowing are discussed.

***Additional key words:*** Triticum aestivum *L., nitrate, urea, seedling growth, emergence percentage, leaf growth*

## Introduction

In most agricultural soils, low nitrogen (N) availability is the major nutrient factor limiting growth and yield of wheat (*Triticum aestivum* L.) and the economic return from the use of N fertiliser is usually substantial (Wibberley, 1989). The primary effect of additional N on wheat is to increase crop photosynthesis by increasing leaf area index (LAI) and leaf area duration (Wibberley, 1989; Hay and Walker, 1989). Increased LAI results from increases in rate of leaf expansion, individual leaf area and total number of leaves due to increased tillering (Wibberley, 1989; Hay and Walker, 1989; Andrews *et al.*, 1991).

There is some inconsistency in the literature with regard to the developmental stage at which external N affects main-stem leaf growth of wheat. In pot experiments, Radin (1983) found that day-time leaf extension rate for leaf 3 was only 19% lower at 0.5 mol/m$^3$ nitrate ($NO_3$) then at 5 mol/m$^3$ $NO_3^-$ while Lawlor *et al.*, (1988) obtained similar rates of extension and final area of leaves 1 to 4 for low and high N treatments. In the field, additional N was found to have little effect on final area of main-stem leaves 1 to 3 but it caused a 50% approx. increase in final area of leaf 4 (Bunting and Drennan, 1966). In a different field experiment, additional N was found to almost double extension rate of leaf 4 (Kemp and Blacklow, 1982). Although addition of N fertiliser usually results in greater growth of wheat, care must be taken if application is made at sowing. Placement of fertiliser N close to the seed can cause dehydration of seedlings and result in reduced emergence and establishment (Varvel, 1982).

The present study examined N effects on shoot growth of Otane wheat up to the time of full expansion of main-stem leaf 4. Pot trials were carried out in order that zero N treatments could be obtained. A field trial was carried out to determine the relevance of the findings to the agricultural situation.

## Materials and Methods

Seed of Otane wheat obtained from Pyne Gould Guinness, Christchurch, was used in all experiments.

### Experiment 1

Seed of weight 43-49 mg was placed 60 mm deep in 100 mm diameter, 200 mm tall pots (5 per pot) containing a vermiculite/perlite (1:1) mixture soaked with basal nutrient solution (Andrews *et al.*, 1989) containing the appropriate $NO_3^-$ concentration. The treatments were 0, 1.0 and 10 mol/m$^3$ $NO_3^-$ (added as $KNO_3^-$) replicated 18 times. In all treatments, potassium was maintained at 23.6 mol/m$^3$ by the addition of $K_2SO_4$ as required. Pots were placed in a completely randomised design in a controlled environment chamber. The experiment was carried out in darkness and the temperature ranged from 5-10°C during each 24 h period. All pots were flushed twice weekly with the appropriate nutrient solution. Six replicates of each treatment were harvested 21 days after sowing when mean shoot length for all treatments was slightly less than sowing depth. Shoot length, fresh weight (f.wt) and dry weight (d.wt) were determined for all plants. The dried material was then ground and an aqueous extract of a 30 mg approx. sample analysed for $NO_3^-$ content (MacKereth *et al.*, 1978). A count of emerged plants was carried out on twelve replicates of each treatment 6 weeks after planting. Seed which failed to result in emerged seedlings was examined to determine if germination had occurred. Coleoptile length of all plants was measured at this time.

### Experiment 2

Pot size, rooting medium, $NO_3^-$ treatments and experimental design used in this experiment were as in Experiment 1. Seeds were germinated on moist towels (distilled water) in the glasshouse then seedlings with a coleoptile length of 5-10 mm were transferred to pots (1 plant per pot). Plants were grown under natural autumn daylight with photoperiod extended to 14 hours by the use of high pressure mercury fluorescent lamps. Temperatures ranged from 11 to 26 °C during the experiment. Plants were fed every 2 days.

Length of main-stem leaves was measured every 2 days commencing 1 day after planting. Leaf length was taken as leaf tip to substrate for leaf 1, leaf tip to point of leaf emergence from coleoptile for leaf 2 and leaf tip to the ligule of the leaf two positions below in the case of leaves 3 and 4. Leaves were considered fully extended when ligules formed. On completion of extension of leaf 4, tiller number was determined and individual leaf area was measured using a Lambda, model LI 3100, area meter.

Leaf growth (extension) was modelled using variates derived from a generalised logistic curve:

$$y = \frac{C}{(1 + Te^{-b(x-m)})^{\frac{1}{T}}}$$

where C is the final size; b and m are constants; and T is a shape parameter. Curves were fitted using the Maximum Likelihood Programme from Rothamsted (Ross *et al.*, 1979). The growth variates used for data analysis were: maximum growth rate ($bC/(T+1)^{(T+1)/T}$); weighted mean absolute growth rate ($bc/2(T+2)$); and duration or time required for the majority of growth ($2(T+2)/b$). These variates were derived from curve parameters as described in Dennett *et al.*, (1978).

### Experiment 3

The field experiment was carried out between 18 May and 17 August 1990 in a Wakanui silt loam at Lincoln University. The previous crop on the site was chickpea (*Cicer arietinum* L.) and prior to that ryegrass/white clover (*Lolium perenne* L./*Trifolium repens* L.) pasture. The ground was ploughed on 16 May and Dutch harrowed and rolled on 17 May. Seed was drilled on 18 May 1990. Seed was sown at 150 kg/ha (15 cm row spacing) with a cone seeder. This seed showed 93% germination and had a mean seed weight of 44.71 mg. The trial was a randomised complete block design replicated six times with N treatments as plots. The N treatments were 0 and 100 kg N/ha added by hand as urea prior to drilling. Each plot was 7.5 x 2.5 m. A 2.5 m strip was sown around the entire trial to act as a guard area.

On 5 June, five plants close to emergence (50 mm length approx.) were sampled from a randomly placed 0.1 m$^2$ quadrat in each plot for $NO_3^-$ determination as described above. On 28 June, when the majority of plants were at the 2-leaf stage, plant population was determined from counts of plants in two randomly placed 0.5 m$^2$ quadrats in each plot. At this time, mean sowing depth was determined as 51 mm by sampling the central five plants from two randomly placed 0.1 m$^2$ quadrats in each plot. Plants were sampled for shoot growth analysis on 17 August 1990. The central five plants from each of three randomly placed quadrats (0.1 m$^2$) in each plot were sampled. Area of main-stem leaves 1 to 4, length of main-stem leaf 5 and number of tillers were measured.

### Data analysis

An analysis of variance was carried out on all data. All effects discussed have a probability $P < 0.01$. Means stated as significantly different in text are on the basis of an LSD ($P < 0.05$) test.

## Results and Discussion

### Experiment 1

Under controlled environment conditions, 21 days after sowing (DAS), shoot $NO_3^-$ concentration increased with increased applied $NO_3^-$ concentration (Table 1). For all treatments, $NO_3^-$ concentration in the shoot was substantially greater than that applied. At this time, mean shoot length was unaffected by $NO_3^-$, and for all treatments, was slightly less than the sowing depth. Shoot f.wt and d.wt were greater at 1 or 10 mol/m$^3$ $NO_3^-$ than at zero $NO_3^-$. Forty two DAS, emergence percentage decreased with increased applied $NO_3^-$ concentration (Table 1). This effect was not due to decreased germination percentage which was > 90% for all treatments (Table 1). It was also not due to dehydration of seedlings as has been reported in the field (Varvel, 1982) as shoot f.wt and percentage water were greater with additional $NO_3^-$ (Table 1). In more detailed experiments to that described here, it was found that additional $NO_3^-$ caused a decrease in emergence percentage at 60 - 120 mm sowing depths but had no effect on emergence percentage at 30 mm sowing depth (Andrews, Scott and McKenzie unpub.). Also, at 30 mm sowing depth, $NO_3^-$ stimulated shoot growth in the dark after emergence. In the present study, additional $NO_3^-$ had no effect on shoot length but caused an increase in shoot f.wt and d.wt prior to emergence (Table 1). As coleoptile length for all treatments was less than 30 mm (Table 1), this indicates that within the substrate $NO_3^-$ caused greater expansion of leaf 1. It is proposed that this greater expansion of leaf 1 was the primary cause of decreased emergence with additional $NO_3^-$ in the present study. Increased expansion of leaf 1 will result in a more open leaf structure which will fold more easily and be more prone to damage before emergence.

### Experiment 2

Under glasshouse conditions, regardless of applied $NO_3^-$ concentration, maximum and mean growth rate increased with increased leaf number (Fig. 1A, B). For all leaves, maximum and mean growth rate increased with increased applied $NO_3^-$ 0 to 1.0 mol/m$^3$ but a further increase to 10 mol/m$^3$ $NO_3^-$ had no effect. The effect of $NO_3^-$ increased with increased leaf number. For example, increased applied $NO_3^-$ from 0 to 1.0 mol/m$^3$ caused increases in maximum growth rate from 9.6 to 12.6 mm/day for leaf 1 and from 17.8 to 44.6 mm/day for leaf 4. In general, duration of growth decreased with increased applied $NO_3^-$ concentration 0 to 1.0 mol/m$^3$ then changed little with a further increase to 10 mol/m$^3$ (Fig. 1C). For all $NO_3^-$ treatments, duration of growth was greater for leaves 1-3 than for leaf 4.

Without $NO_3^-$, final leaf length increased with leaf number 1 to 3 then decreased for leaf 4 (Fig. 2A). For these plants, area was similar for leaves 1-3 but decreased for leaf 4 (Fig. 2B). At 1.0 and 10 mol/m$^3$ applied $NO_3^-$, leaf length and area increased with increased leaf number. Length and area of all leaves increased with increased applied $NO_3^-$ 0 to 1.0 mol/m$^3$ but changed little with a further increase to 10 mol/m$^3$. The effects of $NO_3^-$ increased with increased leaf number. For example, increased applied $NO_3^-$ from 0 to 1.0 mol/m$^3$ caused increases in area from 296 to 362 mm$^2$ for leaf 1 and from 178 to 1274 mm$^2$ for leaf 4. Although increased applied $NO_3^-$ from 1.0 to 10 mol/m$^3$ had little effect on growth of main-stem leaves 1-4, it did cause an increase in tiller number (Fig. 2C). In concurrent work, $NO_3^-$ was found to have similar effects on growth of main-stem leaves 1-4 of Atlas wheat, barley (*Hordeum vulgare* L. cv. Triumph), oat (*Avena sativa* L. cv. Amuri), rye (*Secale cereale* L. cv. Rapaki) and triticale (*x Triticosecale* cv. Salvo) (Andrews *et al.*, 1991). The reason for previous

**TABLE 1: Effect of different applied $NO_3^-$ concentrations on shoot $NO_3^-$ content, length, f.wt and d.wt of shoots 21 days after sowing, and emergence percentage, germination percentage and coleoptile length 42 days after sowing Otane wheat 60 mm deep.**

| Applied $NO_3^-$ (mol/m$^3$) | Shoot $NO_3^-$ (mol/m$^3$) | Length (mm) | F.wt (mg) | D.wt (mg) | Emergence (%) | Germination (%) | Coleoptile length (mm) |
|---|---|---|---|---|---|---|---|
| 0 | 0.9 | 54 | 64 | 8.2 | 88 | 96 | 25 |
| 1 | 10.4 | 56 | 85 | 9.4 | 72 | 93 | 27 |
| 10 | 26.5 | 53 | 83 | 9.3 | 66 | 100 | 24 |
| SEM | 0.9 | 2 | 2 | 0.2 | 2 | 3 | 2 |

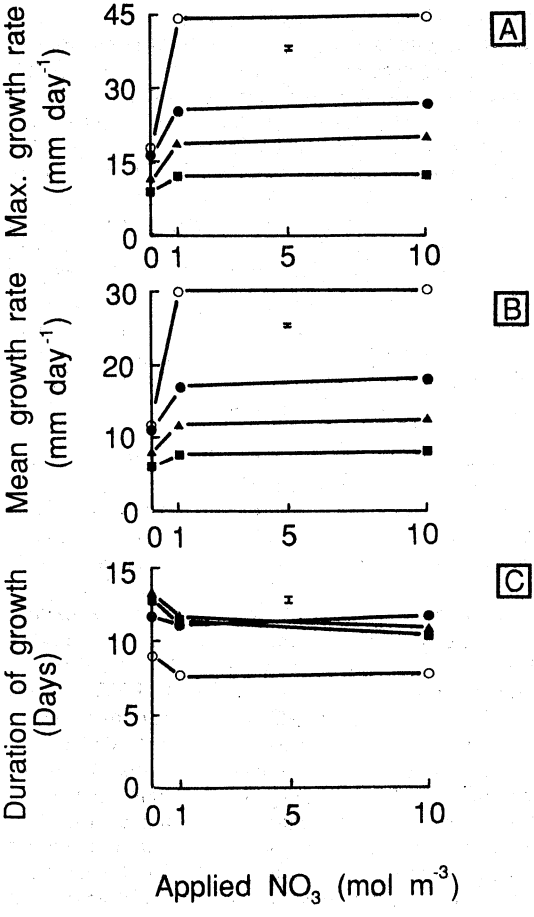

**Figure 1:** **The effects of different concentrations of applied NO$_3^-$ on extension growth of leaves 1 (■), 2 (▲), 3 (●) and 4 (○) of Otane wheat. Bars indicate SEM.**

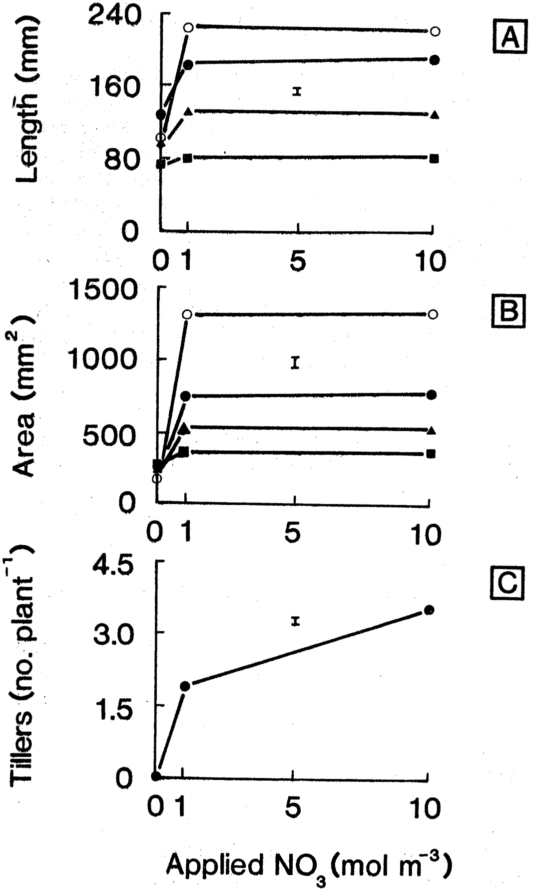

**Figure 2:** **The effects of different concentrations of applied NO$_3^-$ on final length and area of leaves 1 (■), 2 (▲), 3 (●) and 4 (○), and tiller number of Otane wheat at the 5-leaf stage. Bars indicate SEM.**

findings of little effect of additional NO$_3^-$ on early growth of wheat in laboratory experiments (Radin, 1983; Lawlor *et al.*, 1988) is likely to have been the use of a low N-treatment which in reality was high enough to give maximum or near maximum growth. Similarly, little effect of additional N in the field (Bunting and Drennan, 1966) was probably due to high concentrations of endogenous soil NO$_3^-$ (Russell, 1973; Haynes *et al.*, 1986).

### Experiment 3

During the field experiment, monthly mean values for mean daily air and grass minimum temperatures were, in general, slightly greater than for long term means (Table 2). Soil temperatures at 10 cm were similar to long term means while rainfall was lower than average during most of the study. Data for solar radiation were unavailable from June to August.

**TABLE 2:** **Monthly mean values for mean daily air temperature, grass minimum temperature, soil temperature at 10 cm depth, rainfall and solar radiation during the period of study in 1990 compared with long term means[1].**

| | Daily temp. (°C) | | Grass min. (°C) | | Soil temp. (°C) | | Rainfall (mm) | | Solar radiation ($MJ/m^2/day$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual | Mean | Actual | Mean | Actual | Mean | Actual | Mean | Actual | Mean |
| May | 10.3 | 8.7 | 1.6 | 0.9 | 6.8 | 6.9 | 1.1 | 2.3 | 6.5 | 7.3 |
| June | 7.0 | 6.2 | 0.1 | -1.6 | 4.6 | 4.5 | 1.4 | 2.0 | -[2] | 5.5 |
| July | 6.5 | 5.7 | -0.2 | -1.3 | 4.3 | 4.0 | 0.6 | 2.2 | -[2] | 6.3 |
| August[3] | 7.0 | 6.7 | -0.9 | -0.6 | 4.5 | 5.2 | 3.4 | 2.0 | -[2] | 9.6 |

[1] Long term means are for the periods 1967-77 for air temperature, 1976-86 for grass minimum temperature, soil temperature and solar radiation, and 1930-81 for rainfall.

[2] Values not available.

[3] Mean values up to harvest date, 17 August.

In the field, $NO_3^-$ concentration in the interstitial water of non-fertilised agricultural soil is often likely to be 1 $mol/m^3$ or greater shortly after cultivation and hence during seedling development (Russell, 1973; Barber, 1984; Andrews *et al.*, 1986; Haynes *et.al.*, 1986). Endogenous soil $NO_3^-$ was probably greater than 1 $mol/m^3$ in the field experiment here, as shoot $NO_3^-$ concentration prior to emergence from unfertilised plots was similar to that at 10 $mol/m^3$ applied $NO_3^-$ in Experiment 1 (Tables 1, 3). In the pot trials of Experiments 1 and 2, increased $NO_3^-$ from 0 to 1.0 $mol/m^3$ gave maximum response with regard to shoot growth prior to emergence and growth of main-stem leaves 1 to 4 after emergence. Thus, in the field, it is unlikely that additional N will have a substantial effect on pre-emergence growth or growth of main-stem leaves 1 to 4. This was found to be the case with the addition of 100 kg N/ha having no effect on emergence percentage or final area of main-stem leaves 1 and 2 and causing only a slight increase in final area of main-stem leaves 3 and 4 (Table 4). Also, in the field, length of leaf 5 was unaffected by additional N. As leaf 5 had not fully expanded in any plant examined, additional N clearly did not affect rate of development of the main stem. Although in Experiment 2, additional $NO_3^-$ from 1.0 to 10 $mol/m^3$ did not affect growth of main-stem leaves 1 to 4, it did cause an increase in tiller number (Fig. 2C). In the field also, additional N was found to increase tiller number substantially. These data indicate that even in soils where $NO_3^-$ levels are high enough to achieve maximum growth of the main stem up to leaf 5, additional N at sowing can have a positive effect on growth during this period, via increased tiller production.

## Conclusions

In pots, with a zero N treatment as control, additional N can cause increased shoot growth prior to emergence and increased growth rate and final area of main-stem leaves 1-4 after emergence. Additional N can also result in increased tillering by the 5-leaf

**TABLE 3:** **Effect of additional N (urea) on shoot $NO_3^-$ concentration prior to emergence and plant population at the 2-leaf stage of Otane wheat.**

| Additional N (kg/ha) | Shoot $NO_3^-$ ($mol/m^3$) | Plant population ($plants/m^2$) |
|---|---|---|
| 0 | 24 | 241 |
| 100 | 39 | 240 |
| SEM | 3 | 5 |

**TABLE 4:** **Effect of additional N (urea) on area of main-stem leaves 1 to 4, length of leaf 5 and number of tillers of Otane wheat at harvest.**

| Additional N (kg/ha) | Leaf area ($mm^2$) | | | | Length (mm) | Tillers per plant |
|---|---|---|---|---|---|---|
| | L1 | L2 | L3 | L4 | L5 | |
| 0 | 305 | 441 | 766 | 1340 | 111 | 2.7 |
| 100 | 320 | 477 | 847 | 1583 | 113 | 3.8 |
| SEM | | 24 | | | 9 | 0.2 |

stage. At sowing depths of 60-120 mm but not 30 mm, increased shoot growth prior to emergence is associated with decreased emergence percentage. In the field, because of reasonably high N availability after cultivation, it is unlikely that additional N will have an effect on emergence percentage. Also, rate of development and total area of main-stem leaves 1-4 is likely to be at most, only slightly affected by additional N. However, in the field, it is likely that additional N will stimulate tiller production by the 5-leaf stage.

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