Seed reserve mobilization and the partitioning of dry matter in barley seedlings prior to emergence.

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Abstract

The effects of nitrate (NO_3^-), ammonium (NH_4^+) and chloride (Cl^-) on rate of endosperm reserve mobilization and shoot to root dry weight ratio (S:R) were examined in barley (*Hordeum vulgare*) prior to emergence. Caryopsis dry weight (d.wt) decreased while shoot d.wt, S:R and shoot and root NO_3^- content increased with increased NO_3^- applied over the range 0 - 20 mol m^{-3}. At an external concentration of 5 mol m^{-3}, nitrogen uptake and assimilation were as great with NH_4^+ as with NO_3^- but NH_4^+ did not affect the rate of reserve mobilization or S:R. Addition of 5 mol m^{-3} Cl^- increased the rate of reserve mobilization and S:R. Shoot fresh weight and percentage water of shoot and root increased with additional NO_3^- or Cl^- but did not change with additional NH_4^+. It is proposed that NO_3^- or Cl^- causes increased water uptake by seedlings which results in increased water entering the caryopsis hence a greater rate of reserve mobilization. Increased S:R with NO_3^- or Cl^- appears to be related to increased rate of mobilization of endosperm reserves.

Additional key words: Hordeum vulgare *L., nitrate, ammonium, chloride, shoot:root*

Introduction

For barley (*Hordeum vulgare* L.) cultivated in darkness, application of either a full nutrient solution or 5 mol m^{-3} potassium nitrate (KNO_3) plus 5 mol m^{-3} calcium nitrate instead of distilled water caused a 45 to 65% increase in shoot dry weight (d.wt) within 7 days of planting (Nátr, 1988a,b). Increased shoot growth was due to a greater rate of endosperm reserve mobilization and to a greater allocation of reserves to the shoot at the expense of the root. For barley sown at 70 mm depth, addition of 20 mol m^{-3} nitrate (NO_3^-) as KNO_3 to an otherwise complete nutrient solution caused increases in endosperm reserve mobilization and the proportion of reserves allocated to the shoot prior to emergence from the substrate (Andrews, Lieffering and McKenzie, 1991). The NO_3^- concentrations used in these studies are at the upper end of the range found in agricultural soils (Barber, 1984; Haynes *et al.*, 1986; Wild, 1988). In the present study, relationships between applied NO_3^- concentration, rate of reserve mobilization and the partitioning of dry matter between shoot and root were examined in barley prior to emergence from the substrate. In addition, NO_3^-, ammonium (NH_4^+) and chloride (Cl^-) were compared with regard to their effect on seedling growth.

Materials and Methods

Seed of barley (*Hordeum vulgare* L. cv. Triumph) was obtained from the Crop Research Division of the Department of Scientific and Industrial Research, Lincoln, New Zealand. Individual seed weight was 44±1, 46±1 and 48±1 mg in Experiments 1, 2, and 3 respectively. Seed showed 98% germination and was not chemically treated.

All experiments were carried out in the dark at 10±1°C in a controlled environment chamber. In all experiments, seed was placed at 70 mm depth in 80 mm diameter, 180 mm tall pots (20 per pot) filled with a vermiculite/perlite (1:1) mixture soaked in basal nutrient solution (Andrews, Love and Sprent, 1989) containing the appropriate treatment. In all treatments, potassium was maintained at 23.6 mol m^{-3} using potassium sulphate as necessary. Pots were flushed with the appropriate nutrient solution every 2 days. Seedlings were harvested 21 days after sowing and fresh weight (f.wt) of the shoot and root determined. The shoot, root and caryopsis were then dried at 70°C for 4 days for d.wt determination.

In Experiment 1, plants were supplied 0, 1.0, 5.0 or 20.0 mol m^{-3} NO_3^- as KNO_3. Dried shoot and root material was ground and an aqueous extract of a 10 - 30 mg sample was analysed for NO_3^- content as described by Mackereth, Heron and Talling (1978). There were three nitrogen (N) treatments in Experiment 2: 0 N, 5.0 mol m^{-3} NO_3^- and 5.0 mol m^{-3} NH_4^+ added as ammonium sulphate. Nitrate, NH_4^+ (Mackereth *et al.*, 1978) and total N (Europa Scientific CN analyser) content of all plant parts were determined. In Experiment 3, plants were supplied 0 N, 5.0 mol m^{-3} NO_3^- or 5.0 mol m^{-3} Cl^- as potassium chloride.

Each experiment was a randomised complete block design. Experiment 1 had five replicates while Experiments 2 and 3 had six replicates. An analysis of variance was carried out on all data. All effects discussed have an F ratio with a probability $P<0.05$ and were obtained in repeat experiments. Means stated as significantly different are on a basis of an LSD ($P<0.05$) test.

Results and Discussion

Previously, application of 20 mol m^{-3} NO_3^- was shown to increase the rate of mobilization of endosperm reserves and the shoot to root d.wt ratio (S:R) of barley seedlings prior to emergence from the substrate (Andrews *et al.*, 1991). In Experiment 1, the magnitude of the NO_3^- effect on mobilization of seed reserves was shown to be dependent on external NO_3^- concentration as caryopsis d.wt decreased with increased applied NO_3^- over the entire range used (Fig. 1a). Also, shoot d.wt increased with decreases in caryopsis d.wt but root d.wt changed little thus S:R increased with increased applied NO_3^- throughout. Shoot and root NO_3^- content increased with increased applied NO_3^- concentration over the entire range used (Fig. 1b). At applied NO_3^- concentrations of 1 - 20 mol m^{-3}, NO_3^- content was greater in root than in shoot. Values for NO_3^- content of shoot and root in the present study were greater than those obtained for mature plants grown on comparable NO_3^- supply in a previous study (Andrews *et al.*, 1992).

No report was found of the extent of NO_3^- assimilation in temperate cereals prior to emergence from the substrate. Barley seedlings grown in the dark have been shown to have nitrate reductase activity (Aslam and Huffaker, 1982) and therefore may assimilate NO_3^- prior to emergence. In Experiment 2, the effect of NH_4^+ on seedling growth and the relationships between N uptake, N assimilation, mobilization of endosperm reserves and S:R were examined. Additional NO_3^- caused a decrease in caryopsis d.wt and increases in shoot d.wt and S:R as in Experiment 1, but additional NH_4^+ did not affect d.wt of shoot, root or caryopsis (Table 1). However, N uptake was as great with NH_4^+ as with NO_3^-. Also, as NH_4^+-N and NO_3^--N constituted only a small proportion (<1%) of total N in seedlings supplied NH_4^+, then N assimilation was as great with NH_4^+ as with NO_3^-. The N containing products of NO_3^- and NH_4^+ assimilation are likely to be the same (Layzell, 1990). Thus, although NO_3^- effects

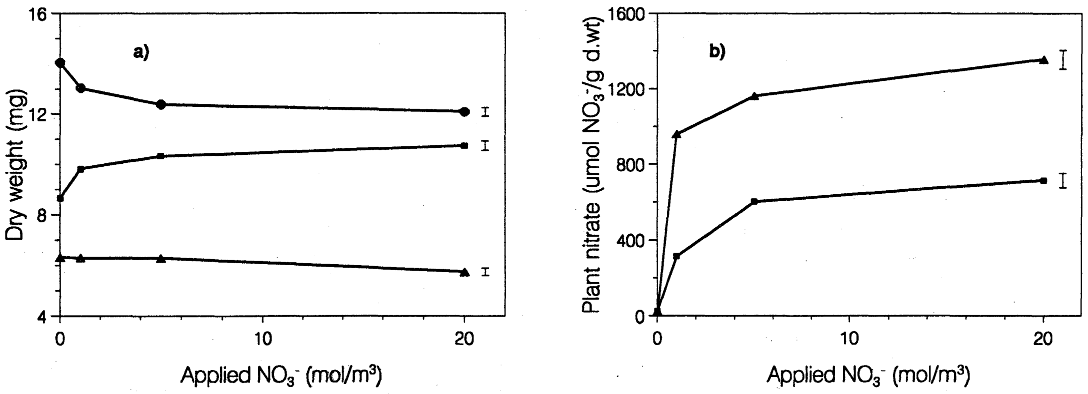

Figure 1. Effect of different concentrations of applied NO_3^- on a) shoot (■), caryopsis (●) and root (▲) d.wt and b) NO_3^- content of the shoot and root of barley prior to emergence from the substrate. Vertical lines indicate SEM.

Table 1. **Effect of 5 mol m^{-3} applied NO_3^- or NH_4^+ on shoot (S) and root (R) f.wt and d.wt, caryopsis (C) d.wt, S:R, shoot and total N, NO_3^--N and NH_4^+-N content of barley prior to emergence from the substrate.**

	D.wt (mg)				F.wt (mg)		N (µg $seedling^{-1}$)		
Applied N	S	C	R	S:R	S	R	Total N	NO_3^--N	NH_4^+-N
nil	8.67	14.06	6.38	1.36	94.4	97.6	610.5	5.1	0.5
NH_4^+	8.36	14.51	6.02	1.39	99.1	90.3	920.2	4.6	1.4
NO_3^-	10.31	12.46	6.33	1.63	138.5	107.8	976.9	185.2	0.7
SEM	0.37	0.41	0.14	0.06	4.3	5.2	15.4	10.2	0.5

on barley seedlings appear to be related to the amount of NO_3^- taken up (Fig. 1a,b), they do not appear to be related to products of NO_3^- assimilation such as proteins/enzymes, as is the case with mature plants (Khamis and Lamaze, 1990; Zhen and Leigh, 1990).

In Experiment 2, shoot f.wt and percentage water of shoot and root increased with additional NO_3^- but did not change with NH_4^+ (Table 1). It is possible that the NO_3^- effects on reserve mobilization and S:R ratio are related to water uptake. Chloride is an ion which is readily taken up by plants but which is not assimilated (Clarkson and Hanson, 1980). Addition of Cl^- at concentrations of 5 or 20 mol m^{-3} can result in substantial increases in percentage water of shoots (Andrews *et al.*, 1989). In Experiment 3, addition of Cl^- caused increases in shoot f.wt and percentage water in shoot and root (Table 2). Chloride also caused increases in the rate of mobilization of endosperm reserves and S:R. These data, in conjunction with those obtained in Experiments 1 and 2, indicate that NO_3^- effects on seedlings prior to emergence are osmotic effects. It is proposed that NO_3^- causes increased water uptake by seedlings which results in increased water entering the caryopsis and hence a greater rate of reserve mobilization. If NO_3^- accumulates in the endosperm reserves then this would have a more direct effect on water uptake by the caryopsis. The increase in S:R with additional NO_3^- or Cl^- appears to be related to the increased rate of reserve mobilization. Studies are currently under way to determine the relationships between rate of reserve mobilization, and NO_3^- and water content of the caryopsis.

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Table 2. Effect of 5 mol m^{-3} applied NO_3^- or Cl^- on shoot (S) and root (R) f.wt and d.wt, caryopsis (C) d.wt and S:R of barley prior to emergence from the substrate.

	D.wt (mg)				F.wt (mg)	
Treatment	S	C	R	S:R	S	R
nil	9.98	17.57	6.41	1.55	105.6	121.5
NO_3^-	12.67	14.37	6.34	1.99	148.5	127.5
Cl^-	11.93	15.36	6.24	1.91	139.5	128.9
SEM	0.52	0.25	0.20	0.07	4.8	4.5

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