The partitioning of dry matter between root and shoot of a range of temperate annual and perennial pasture grasses

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Abstract

Relationships between dry matter production, shoot to root dry weight ratio (S:R) and leaf weight ratio (LWR) were examined in four cvs. of the annual ryegrass (*Lolium multiflorum*), six perennial grass species including *L. perenne* and two annual x perennial ryegrass hybrid species supplied with a range of nitrate (NO_3^-) concentrations (0.1 - 10 mol m^{-3}) in a glasshouse. For all grasses, total plant dry weight (DW) increased with increased applied NO_3^- concentration from 0.1 to 1-2 mol m^{-3} then changed little or decreased with additional NO_3^- thereafter. Also, for all grasses, LWR increased with increased applied NO_3^- from 0.1 to 2-4 mol m^{-3} then changed little with additional NO_3^- while S:R increased with NO_3^- supply over the entire range used. In general, at comparable applied NO_3^- concentrations, total plant DW was greater while S:R and LWR were lower for annual grasses than for perennial grasses. In the case of the hybrids, cv. Manawa was similar to the annual grasses while cv. Marsden was similar to the perennial grasses. It is concluded that greater growth of annual grasses in comparison with perennial grasses is not due to greater partitioning of dry matter to leaves or shoots.

Additional key words: *nitrate, shoot to root dry weight ratio, leaf weight ratio.*

Introduction.

Often, within plant families, growth rate is greater for annual species than for perennial species (Grime and Hunt, 1975; Tilman, 1988; Andrews *et al.*, 1991). Greater growth of annuals in comparison with perennials has been related to a greater investment in photosynthetic (usually leaf) tissue at the expense of the root and/or stem (Tilman, 1988). Growth rate is also dependent on nitrogen availability. This effect also has been related to differences in partitioning of dry matter between photosynthetic and non photosynthetic tissue (Andrews, 1992 and references therein).

Within the Poaceae, growth rate is usually greater for cereals than for perennial grasses at comparable stages of growth (Andrews *et al.*, 1991; Andrews *et al.*, 1992). For a range of temperate cereals, total plant dry weight (DW) was found to increase with increased applied nitrate (NO_3^-) concentration from 0.1 - 5 mol m^{-3} then change little or decrease with additional NO_3^- to 20 mol m^{-3} (Andrews, 1992; Andrews *et al.*, 1992). Shoot to root DW ratio (S:R) increased with additional NO_3^- over the entire range used. For pasture grasses commonly used in N.Z., growth (dry matter production) during the first year is usually greater for annual ryegrass (*Lolium multiflorum* Lam.) than for perennial ryegrass (*L. perenne* L.) and all other perennial species with the possible exception of *Bromus willdenowii* Kunth. (Hunt, 1971; Langer, 1975; Hume, 1991). In the present study, four annual ryegrass cvs., six perennial grass species including perennial ryegrass and two annual x perennial ryegrass hybrids were compared with respect to dry matter production and the partitioning of dry matter to leaf, pseudostem and root at different applied NO_3^- concentrations.

Materials and Methods

Seed of *Bromus willdenowii* cv. Grasslands Matua; *Dactylis glomerata* L. cv. Grasslands Wana; *Festuca arundinacea* Schreb. cv. Grasslands Roa; *L. multiflorum* cvs. Concord, Grasslands Moata, Grasslands Paroa and Grasslands Tama; *L. multiflorum x L. perenne* cv. Grasslands Manawa; *(L. multiflorum x L. perenne) x L. perenne* cv. Grasslands Marsden; *L. perenne* cv. Grasslands Nui; *Phalaris aquatica* L. cv. Grasslands Maru and *Phleum pratense* L. cv. Grasslands Kahu were obtained from Seedlands N.Z. Ltd, Timaru, N.Z.

Seeds were germinated on moist (distilled water) filter paper in an incubator at 25°C. Seedlings with a coleoptile length of 2 - 10 mm were transferred to 100 mm diameter x 200 mm tall pots (one plant per pot) containing vermiculite/perlite (1:1) soaked in a basal nutrient solution containing the appropriate NO_3^- concentration. The basal nutrient solution comprised $CaCl_2$ (3.0 mol m^{-3}), KH_2PO_4 (3.0 mol m^{-3}), K_2HPO_4 (0.3 mol m^{-3}), $MgSO_4.7H_2O$ (3.0 mol m^{-3}) and micronutrients as described in Andrews *et al.* (1984). There were seven different applied NO_3^- concentrations, 0.1, 0.5, 1.0, 2.0, 4.0, 6.0 and 10.0 mol m^{-3} NO_3^- added as potassium nitrate. Potassium was maintained at 13.6 mol m^{-3} by the addition of potassium sulphate as required. Pots were flushed with the appropriate nutrient solution every two days.

At harvest, plants were separated into leaves (laminae), pseudostem and root for DW determination. Dry weights were taken and the S:R (leaf DW + pseudostem DW : root DW ratio) and leaf weight ratio (LWR, leaf DW : plant DW ratio) were calculated.

The experiment was carried out in a glasshouse under natural autumn/winter daylight conditions with the 9 - 10 hour photoperiod extended to 14 hours with artificial lighting (high pressure mercury vapour lamps). The temperature was maintained between 15 and 25°C.

The experiment was a randomised complete block design with three replicates for all treatments. Analysis of variance was carried out on all data and effects discussed have a probability $P < 0.05$.

Results and Discussion.

Nitrate effects on total plant DW, S:R and LWR were similar for all grasses. Values for *L. multiflorum* cv. Tama and *Phleum pratense*, the grasses which showed the greatest and least DW respectively are shown as representative data (Fig. 1). For all grasses, total plant DW increased with increased applied NO_3^- concentration from 0.1 to 1-2 mol m^{-3} then changed little or decreased with additional NO_3^- thereafter. Also for all grasses, LWR increased with increased applied NO_3^- from 0.1 to 2-4 mol m^{-3} then changed little with additional NO_3^- thereafter while S:R increased with additional NO_3^- over the entire range used. For cereals also, S:R was found to increase with additional NO_3^- regardless of its effect on growth (Andrews 1992; Andrews *et al.*, 1992). Shoot to root DW ratio for herbaceous species usually increases with increased growth/development thus at least part of the NO_3^- effect on S:R of grasses is likely to have been an ontogenetic effect (Bastow Wilson, 1988). However, there is also a NO_3^- effect which is independent of growth as at a similar plant DW, at applied NO_3^- concentrations above and below that which gave maximum growth, S:R was greater at high than at low NO_3^- (Fig. 1). This effect is discussed by Andrews (1992).

At comparable NO_3^- concentrations, total plant DW was greater for all annual ryegrass cultivars than for all perennial grasses with the exception of *B. willdenowii* which had a similar DW to cvs. Moata and Paroa. In general, the S:R and LWR were lower for annual grasses than for perennial grasses at comparable NO_3^- supply. In

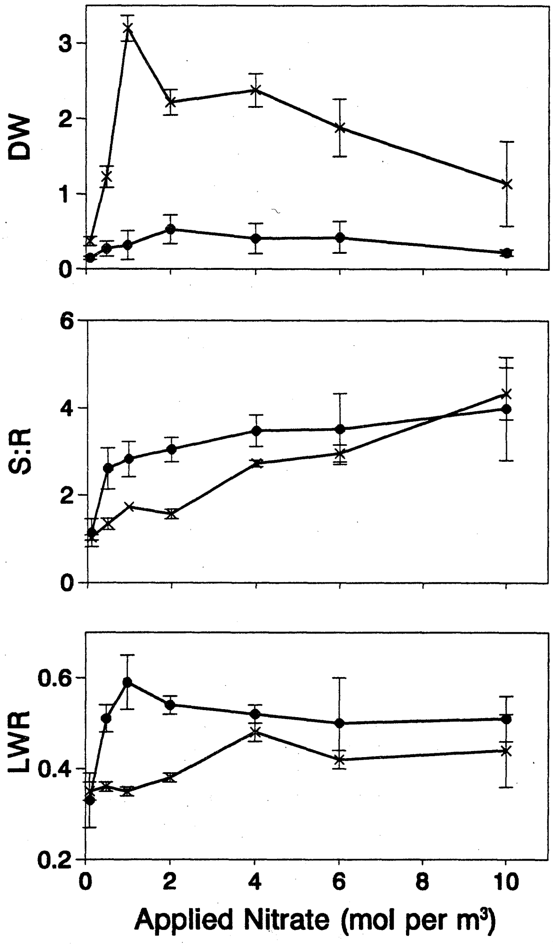

Figure 1. The effect of applied NO_3^- concentration on the dry weight (DW), shoot to root DW ratio (S:R) and leaf weight ratio (LWR) of *L. multiflorum* cv. Tama (•) and *Phleum pratense* (×). Vertical bars indicate SEM.

the case of the ryegrass hybrids, cv. Manawa was similar to the annual grasses while cv. Marsden was similar to the perennials. Values for total plant DW, S:R and LWR at the applied NO_3^- concentration which gave the greatest growth are shown for all grasses in Table 1. Greater growth of annual grasses in comparison with perennial grasses is as expected but this was not due to greater partitioning of dry matter to leaves or shoots as predicted by Tilman (1988). One possible factor determining growth is seed weight. Usually there is a positive correlation between area of the first few leaves and seed weight and this may affect subsequent growth (Nelson and Larson, 1984; DeMarco, 1990; Andrews *et al.*, 1991). However, seed DW was poorly correlated with total plant DW (Table 1). For example, seed DW was similar for *L. multiflorum cv.* Concord and *L. perenne* but total plant DW was twice as great for the annual species. Current experiments are comparing grasses with respect to photosynthetic rate, specific leaf area and aspects of NO_3^- assimilation.

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Table 1. Dry weight (DW), shoot to root DW ratio (S:R) and leaf weight ratio (LWR) of twelve temperate grasses at the nitrate concentration which gave the greatest plant DW. Values in parentheses are SEM.

Species	DW (g)	S:R	LWR	Seed DW (mg)
L. multiflorum cv. Tama	3.20 (0.17)	1.73 (0.11)	0.35 (0.01)	5.00
L. multiflorum cv. Concord	3.02 (0.27)	1.58 (0.11)	0.35 (0.02)	2.36
L. multiflorum cv. Moata	2.34 (0.18)	2.07 (0.30)	0.40 (0.01)	5.00
L. multiflorum cv. Paroa	2.06 (0.37)	1.66 (0.15)	0.42 (0.04)	2.16
L. multiflorum x *L. perenne* cv. Manawa	2.75 (0.13)	1.53 (0.26)	0.37 (0.02)	2.49
(*L. multiflorum* x *L. perenne*) x *L. perenne* cv. Marsden	1.25 (0.22)	2.14 (0.16)	0.41 (0.02)	2.10
L. perenne cv. Nui	1.17 (0.08)	2.16 (0.10)	0.45 (0.03)	2.25
D. glomerata cv. Wana	1.44 (0.15)	3.23 (0.48)	0.46 (0.02)	0.73
B. wildenowii cv. Matua	1.95 (0.46)	2.13 (0.15)	0.45 (0.01)	11.95
F. arundinacea cv. Roa	0.93 (0.10)	2.55 (0.16)	0.43 (0.02)	1.78
Phalaris aquatica cv. Maru	1.16 (0.06)	1.91 (0.06)	0.47 (0.02)	1.46
Phleum pratense cv. Kahu	0.53 (0.19)	3.05 (0.28)	0.53 (0.02)	0.37

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