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Can root biomass of grasses in NSW be predicted from shoot biomass yields?

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Abstract

We evaluated shoot and root biomass yields of four native grasses of NSW and an introduced species in order to establish if differences in shoot- and root-biomass yields as well as root:shoot ratios existed among the species. We also explored the potential to predict root biomass from shoot biomass of each species. The species were grown in trays with conical holes of volume 180 cm³ uniformly packed with sand (0.1 – 0.8 mm grain size) amended with potting mix (50/50 v/v) in a glasshouse experiment. The trays were arranged in a replicated randomised complete block design. After eight weeks, the shoots and respective roots of randomly selected plants per species were harvested and oven-dried for biomass determination. Data were subjected to ANOVA in R after square root transformation normalised the data. We found remarkable differences in shoot biomass, root biomass and root/shoot ratios among the species. *Microlaena stipoides* gave strongest positive linear relationship ($R^2 = 0.8$) between root biomass and shoot yield while *Austrodanthonia spp.* showed no significant relationship between the two variables. These interrelationships must be investigated under field conditions before root biomass can be meaningfully modeled from known shoot biomass yields, taking into consideration the implications of these differences for carbon storage.

Introduction

Differences in root/shoot biomass yields among grasses can shed light on photoassimilated carbon (C) allocation strategies and the relative importance of species in the cycling of terrestrial C and other nutrients. Species with extensive root systems can transfer up to 80% of their photoassimilated C (PAC) to roots, mainly for growth and maintenance (Kuzyakov and Domanski, 2000; Warembourg *et al.*, 2003). In the USA, Kaisi and Grote (2007) found that higher switch grass (*Panicum virgatum*) root biomass (averaging 14 Mg ha⁻¹) relative to shoot biomass yield (about 6 Mg ha⁻¹) was also associated with high SOC and large microbial biomass C. Similar results were reported on the North Western Slopes of NSW (Lodge and Murphy, 2006) and on the Central Tablelands of NSW (Guo *et al.* 2008).

Studies pertaining to roots are tedious, time-consuming and are associated with soil disturbance, which often introduce artifacts to measurements (Metcalfe *et al.*, 2007). Even with the most recent methodological advances in root sampling, it is practically impossible to remove all the biomass from the soil. Practically feasible alternatives must be employed to strike a balance between adequate root recovery and the need to include root data in models of root production and turnover. We (i) evaluated species of five selected pastures common on the Northern Tablelands of NSW for differences in root/shoot biomass yields and (ii) examined relationships between root biomass and shoot yields among the species.

Materials and Methods

A glasshouse experiment was conducted to evaluate root- and shoot-biomass yields and to explore root:shoot yield relationships among five grasses between September 05 to November 05, 2009, namely; (i) barnyard grass (*Echinochloa crus-gali*) an introduced species, (ii) weeping rice grass (*Microlaena stipoides*) a C₃ shade-loving species, (iii) wallaby grass (*Austrodanthonia spp.*) a C₃ sun-loving species, (iv) red grass (*Bothriochloa macra*) a C₄ shade-tolerant species and (v) tall windmill grass (*Chloris ventricosa*) a C₄ sun-loving species. All the latter four species of grasses are native to the Northern tablelands of NSW (Kahn *et al.*, 2003).

Seedlings were raised in trays packed with sand (0.1 – 0.8 mm grain size) homogenised with Searles Premium Potting Mix (50:50 v/v) at a rate of one seedling per hole (of an estimated

capacity of 180 cm³). Growth conditions in the glasshouse were maintained at 20 °C and 80% RH, with an automated sprinkler irrigation system. Eight weeks after germination, plants were harvested for biomass determination. Shoots were clipped off at the base and roots flushed out of the soil using two root washing drums connected to a hosepipe, followed by manual picking of roots trapped on the 0.5-mm sieves and cleaning the roots of any debris and soil. Both harvested shoots and roots were oven-dried to constant mass at 40 °C.

Data were subjected to ANOVA in R (version 1.10.1) after normalising by square root transformation. We used contrasts to answer the questions of interest and conducted simple linear regressions to explore the relationship between root biomass (as a response variable) and shoot biomass (as a predictor variable) for each of the species.

Results and Discussion

Yield parameters of the five species of the grasses of NSW

Shoot and root biomass yields and root/shoot ratios varied significantly ($P = 0.01$) among the grasses (Table 1). *Echinochloa crus-gali* yielded the highest shoot biomass (SB) (155.1 mg plant⁻¹), significantly higher ($P = 0.004$) than the average of the four native grasses but it had a significantly lower ($P < 0.001$) root /shoot ratio (RSR) than the average of the native species. Between the sun-loving and shade-loving species, there were no significant differences in SB and root biomass (RB) ($P = 0.565$ and 0.849 , respectively). However, the RSR of the sun-loving species significantly exceeded ($P = 0.023$) that of the shade-loving species. Shade-loving species, *Microlaena stipoides* (C₃ species) and *Bothriochloa macra* (C₄ species) did not differ significantly in RB ($P = 0.346$) and RSRs ($P = 0.446$). However, *B. macra* yielded significantly higher SB ($P = 0.033$) than *M. stipoides*. The RB and RSR of the two sun-loving species i. e. *Austrodanthonia spp.* (C₃ grass) and *Chloris ventricosa* (C₄ grass) varied highly ($P < 0.001$), with *Austrodanthonia spp.* out-yielding *C. ventricosa*.

The superiority of exotic grasses to native species in terms of shoot biomass yield is in agreement with the findings of Lodge and Murphy (2006) and Guo *et al.* (2005). This may be attributed to disproportionate allocation of photoassimilated carbon (PAC) to shoots. On the contrary, native grasses may have, through repeated selection pressures, evolved adaptation mechanisms to cope with the wide-ranging stresses common in their environments, by investing more of their PAC to root production and maintenance. Such species can expend up to 80% of their PAC in the growth

and maintenance of roots (Kuzyakov and Domanski, 2000; Warembourg *et al.*, 2003). These differences in C allocation strategies should be evaluated for their implications with regard to C sequestration belowground (Kaisi and Grote, 2007)

Table 1. Shoot and root biomass yields (mg plant⁻¹) and root:shoot ratios of five grasses of NWS

Species	Shoot weight (mg plant ⁻¹)	Root weight (mg plant ⁻¹)	Root:Shoot ratio
Barnyard grass	155.1	83.9	0.528
Weeping rice grass	98.3	95.6	0.913
Red grass	136.2	110.7	0.806
Wallaby grass	117.5	141.7	1.413
Windmill grass	102.8	69.9	0.762
s.e.d _{0.05}	17.51	15.94	0.1389

Relationship between the root and shoot biomass yield

All the species showed a positive linear relationship ($P < 0.001$) between RB and SB with the exception of *Austrodanthonia spp.* whose RB could not be explained ($P = 0.74$) by its SB. RB (Rootb) for each of the species under the conditions in which this study was conducted can be predicted from respective SB (Shootb) using equations 1 – 4 for: *Bothriochloa macra* (Bothrio), *Chloris ventricosa* (Chlori), *Echinochloa crus-gali* (Echino) and *Microlaena stipoides* (Microl), with respective coefficients of determination of: 0.72, 0.59, 0.66 and 0.8. Thus, 80% of the RB of *M.stipoides* (Fig. 1) could be explained by its SB with a 95% confidence that each 1.0-mg increase in SB of *M.stipoides* increases RB by 0.8 to 1.42 mg. Such a relationship suggests a disproportionate partitioning of photoassimilated C in favour of roots, which could be a major survival strategy for this species.

$$\text{Bothrio}_{\text{Rootb}} = 10.71 + 0.73\text{Bothrio}_{\text{Shootb}} \dots\dots\dots 1$$

$$\text{Chloris}_{\text{Rootb}} = 10.90 + 0.26\text{Chloris}_{\text{Shootb}} \dots\dots\dots 2$$

$$\text{Echino}_{\text{Rootb}} = 29.40 + 0.35\text{Echino}_{\text{Shootb}} \dots\dots\dots 3$$

$$\text{Microl}_{\text{Rootb}} = -15.55 + 1.12\text{Microl}_{\text{Shootb}} \dots\dots\dots 4$$

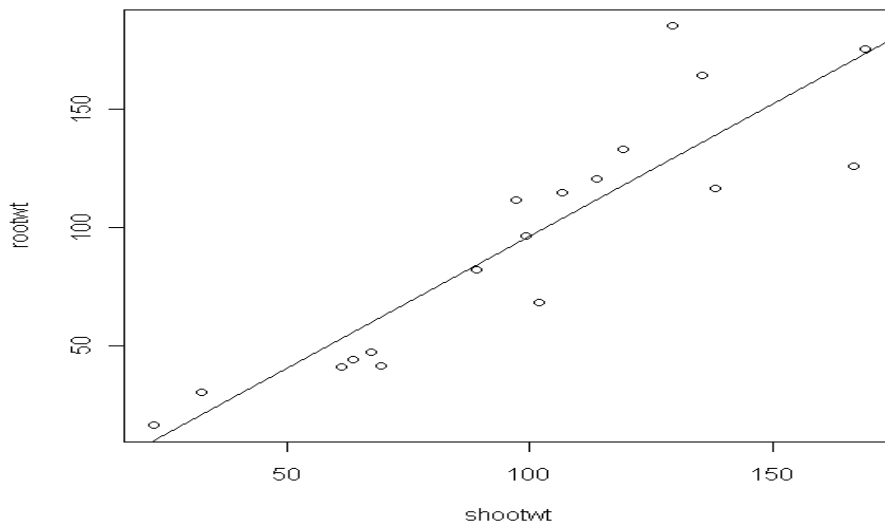


Fig 1. The relationship between fine root biomass (rootwt) and shoot biomass (shootwt) of *Microlaena stipoides* (mg plant^{-1})

Conclusion

These interrelationships should be investigated under field conditions over a range of environmental conditions, particularly soil types and climate, before the models can be applied to predict root biomass from shoot yields before root biomass, taking into consideration the implications of these differences with regard to carbon storage.

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