Legume shoot and root N accumulation under water stress

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Abstract

Nitrogen derived from N_2 fixation of legumes is an essential component of most dryland grain production systems in Australia and an accurate knowledge of the contribution they make to soil N reserves is essential to assessing long term sustainability. Accurate quantification of total plant N content remains elusive due to the difficulty of accounting for the finer root and rhizosphere fractions of plant root systems. The effect of deteriorating soil water conditions on legume shoot and root total nitrogen of mungbean (*Vigna radiata* cv Emerald) and peanut (*Arachis hypogaea* cv Florunner) was determined. Increasing drought intensity reduced both shoot and root N significantly for the two legumes. However the effect on mungbean root N as a proportion of the total plant N remained constant at 35 to 40 % while peanut root N consistently increased from 24 to 44 %.

Key words

Drought survival, shoot:root partitioning, sustainability, cereal.

Introduction

Soil fertility has declined throughout the Central Queensland Cereal Belt as a result of continuous cereal cropping (1). Two strategies have been suggested to arrest or reverse this trend; (*i*) chemical fertiliser addition and (*ii*) incorporate N_2 fixing legumes into the farming systems. However grain yield and protein content responses in following cereal crops have been inconsistent, largely a result of either variability in fertiliser uptake, or poor legume performance due to unreliable rainfall. Small scale investigations over the past decade have shown that the inclusion of legumes in farming systems for only one year can improve soil fertility (2). These investigations however do not differentiate between the legume above and below ground tissue N and their potential contribution to soil N status; this shortcoming is addressed in the current investigation.

Methods

Drought treatments

Legumes were cultivated with an open downs cracking clay (Halpic, self mulching vertisol) typical of Central Queensland in regulated glasshouse conditions. Three soil moisture treatments were imposed; well watered, and moderate and severe drought. The moderate drought treatment was designed to impose soil moisture conditions as experienced *on farm* when legume crops are planted on a full profile of soil moisture conditions yet receive follow up rainfall only late in crop development. The severe drought treatment was designed to represent a catastrophic drought event.

Determination of legume AGN and BGN

Legume shoot N was calculated by determining shoot dry weight and % N at harvest. Legume root N was determined using a ^{15}N isotopic technique. Legumes were foliar labelled at 28, 35 and 42 days after sowing (das). Each labelling event applied 3 ml of 0.25 % w/w urea, 98.61 atom % ^{15}N. At harvest, the ^{15}N content and dry weight of soil explored by the labelled legume was determined. The g tot N:g$^{15}N_{root}$ ratio of recovered macro root tissue at 10-20 cm was then measured. Legume root N was calculated as follows, Root N (mg) = ((atom % ^{15}N x %N)$_{soil, t=1}$ – (atom % ^{15}N x %N)$_{soil, t=0}$) x g tot N/g^{15}N$_{root}$ x soil dry weight (g)/10. Where the subscripts soil t = 1 and soil t = 0 refer to measurements of soil taken at harvest and prior to planting respectively.

Results and discussion

Water was withheld from moderately and severely droughted legumes for 14-18 and 27-31 days respectively. No difference in pot soil water content was observed between the two legume species at any of the soil water treatments (P>0.01) except for 54-55 days after sowing for severely droughted peanut.

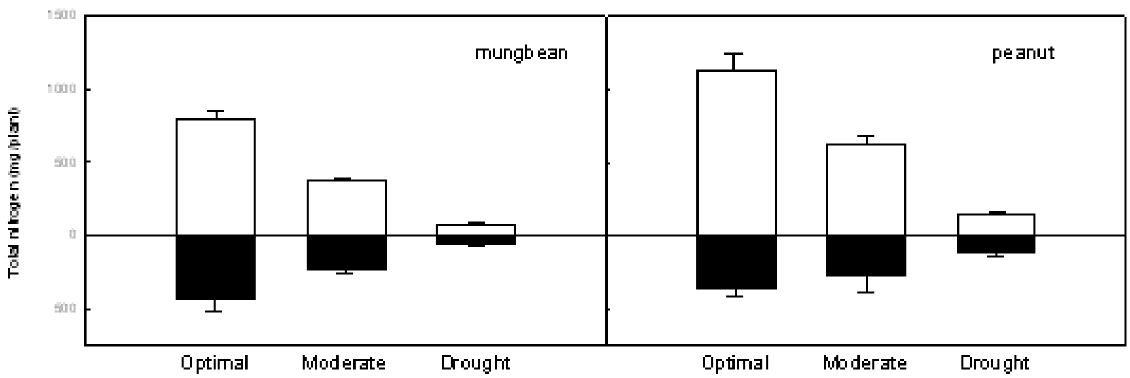

Figure 1. Effect of drought intensity on of legume nitrogen in shoots (open) and roots (solid). Data are means (? s.e.m.), n = 5

The proportion of legume N located in roots of well watered plants of the current investigation are consistent with similar previous studies where root N of a number of commercially cultivated legumes has been shown to account for 28 to 52% of total plant accumulated N (3, 4, 5, 6). In all treatments estimated legume total N content was significantly greater when root N was included compared to values based on shoot tissues alone (Fig. 1). Under increasing drought intensity mungbean and peanut invoked significanly different shoot:root N partioning responses. For example droughted mungbean did not increase the proportion of N resources to the root system to ameliorate the effects of reduced soil water availability. By comparison, peanut consisistently increased the allocation of plant N to root N stores with increasing drought intensity. The different shoot N:root N partitioning ratios exhibited by mungbean and peanut are consistent with drought survival strategies of escape and avoidance respectively (7).

Results presented here have significant implications for the current efforts undertaken to determine the ability of legumes to contribute to soil N fertility under the prevailing climatic conditions encountered *on farm*. The significantly greater estimates of legume N (shoot N + root N) in comparison to estimates based on shoot N alone, and as conventionally determined, suggests previous studies have underestimated the ability of legumes to contribute to soil N reserves. Further, the consistent underestimation of legume N for both legumes and at all three soil water regimes suggests that previous investigations may have underestimated legume N for a range of farming systems and agronomic conditions. In addition, the greater proportion of legume N located within roots with increasing drought intensity for peanut but not mungbean suggests the choice of legume for incorporation into farming systems may also depend on the requirement to maintain or improve soil N fertility for the farming system under consideration.

References

(1) Henzell, E. F. and Daniels, J. D. 1995. Review of nitrogen research, development and extension in Northern NSW and Queensland for the Grains Research and Development Corporation, Northern Panel. GRDC, Canberra.

(2) Armstrong, R. D., Kuskopf, B. J., Millar, G. and Whitbread, A. M. 1999. Aust. J. Exp. Agric., 39: 445-456.

(3) Russell, C. A. and Fillery, I. R. P. 1996. Aust. J. Agric. Res., 47: 1047-59

(4) McNeill, A. M., Zhu, C. and Fillery, I. R. P. 1998. Aust. J. Agric. Res., 49: 427-36.

(5) Rochester, I. J., Peoples, M. B., Constable, G. A. and Gault, R. R. 1998. Aust. J. Exp. Agric., 38: 253-60.

(6) Khan, D. F., Peoples, M. B., Chalk, P. M. and herridge, D. F. 2002. Plant and Soil., 239: 277-289.

(7) Ludlow, M. M. 1989. Strategies of response to water stress. In: Structural and functional responses to environmental stresses: water shortage. Eds Kreeb, K., Richter, C. and Hinckley, T. p269-281. SPB Academic Publishing: The Hague