IMPACTS OF GRAZED PASTURES ON SOIL WATER AND NITROGEN STATUS IN CROPPING SYSTEMS

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ABSTRACT

In southern Australia pastures precede wheat in many rotations. In recent years the quality (legume content) of many pastures has declined and the value of pastures in rotation with cereals has been questioned. This research aims to develop a more complete understanding of the impact of pastures on crop production through greater knowledge of the below ground processes of soil water and soil inorganic nitrogen. In this study, the impacts of annual barley grass (Hordium leporinum) and barrel medic (*Medicago truncatula*) pastures on soil water and inorganic nitrogen status at the start of a subsequent wheat growing season were investigated in an existing field study located at Roseworthy, South Australia. Gravimetric contents of water, nitrate-N and ammonium-N were measured for eight depth layers within the 0-180 cm soil profile and converted to a volumetric basis. The amounts of water and nitrate-N in the soil at the start of the next growing season were significantly higher after medic pasture than grass pasture. Soil nitrate-N following a legume dominant pasture (87 kg nitrate-N ha^{-1}) was more than double the amount following a grassy pasture (42 kg nitrate-N ha^{-1}) in the top 60 cm of soil. Soil water was greater following legume pasture, particularly at depths greater than 60 cm. No significant effect of pasture type was noted on ammonium-N or the total inorganic-N fraction (nitrate-N + ammonium-N).

KEYWORDS

soil, water content, nitrate, ammonium, pasture, rotation

INTRODUCTION

Two major constraints limiting cereal grain production in southern Australia are availability of water and nitrogen. Water limitations are imposed by climatic characteristics and the extent of water use by the previous crop. Nitrogen fertilisation rates are typically low (<20 kg N ha^{-1}) and biological N fixation from legume pastures and grain crops represents an important N input into farming systems.

In southern Australia the land area devoted to the production of legume pastures and grain legumes has been estimated at 30 M ha and 1.5 M ha, respectively. Peoples and Herridge (1989) reported expected annual biological N fixation rates in pasture legume shoots on the order of 40-80 kg N; however, values reported by Bolger et al. (1995) for *Trifolium subterraneum* pasture shoots ranged from 50-125 kg N ha^{-1}. Given the extensive land area devoted to the production of legume pastures and their potential to fix significant quantities of N, the observation that grain yields are often limited by poor quality pastures (low legume content) is of concern, especially when it is considered that the technology to achieve legume dominance in pastures is available for most situations.

The objective of this study was to assess the impact of a grazed annual barley grass (*Hordeum leporinum*) pasture and a grazed annual barrel medic (*Medicago truncatula*) pasture on the water and inorganic nitrogen status of the soil profile at the start of the subsequent growing season.

MATERIALS AND METHODS

The study site was located at Roseworthy, South Australia (34°32'S, 138° 45'E) and utilised the annual barley grass and medic plots included in a larger experiment examining the impacts of grass and legume pastures and grain legume production on a range of soil properties and subsequent cereal (wheat followed by barley) production. The plots were 0.5 ha in area (50 m x 100 m) and the pasture plots were grazed by sheep at a stocking rate of 10 DSE ha^{-1}. Apparent shoot net primary productivity, measured by collecting biomass samples within and outside grazing cages, was estimated at 6.8 and 6.1 t ha^{-1} for the medic and grass pasture, respectively, for the 1995 growing season (Apr-Oct rainfall = 305mm).

The soil was a Red-brown earth (Soil Taxonomy Classification: Xeralf) with a variable depth to the argillic B horizon, calcrete layers and an underlying heavy clay layer. Soil samples were collected from plots which had produced a grass or medic pasture during the 1995 growing season. Samples were collected at the start of the 1996 wheat growing season (12 June) with a 71 mm inside diameter push tube from the 0-10, 10-20, 20-40, 40-60, and 60-80 cm layers and with a 35 mm inside diameter push tube from the 80-100, 100-140, and 140-180 cm layers. The push tubes were inserted into and removed from the soil using a hydraulic ram mounted on the rear of a gantry with a 5 t axle weight. Samples were collected in such a way that estimates of the average bulk density of each layer could be obtained. All samples were dried to constant mass at 40°C in a fan forced oven.

Gravimetric water content at the time of sampling was determined by measuring the mass loss during drying and correcting for residual moisture content. Gravimetric water contents were converted to volumetric water contents using the measured bulk density values. The dried samples were crushed to <1 mm, extracted with 2M KCl (10 g soil and 50 cm^3 2M KCl) and the contents of NO_3-N and NH_4-N in the extracts determined with a Alpkem Flow Solution III autoanalyser system (NO_3-N by cadmium reduction and NH_4-N by indolphenol reaction). The contents of NO_3-N, NH_4-N, and total inorganic N in units of mg N g^{-1} soil were calculated and converted in to µg N cm^{-3} soil using bulk density values. From these values, the total amount of water in units of mm and inorganic N in units of kg ha^{-1} contained in each soil layer and the total profile were calculated (Table 1).

The experimental plots were arranged in a complete randomised block design with three blocks and one treatment replicate per block. In the analysis of variance the treatment structure was set up in a pasture type by soil depth, 2 x 8, factorial design with blocks. In Figure 1 and Table 1 the term "treat" corresponds to the pasture type treatment and "depth" corresponds to the soil depth layers. Data were transformed where required to ensure homogeneity of variances in all analyses of variance.

RESULTS AND DISCUSSION

It is important to emphasise that the results collected pertain to soil profile conditions at the start of the growing season subsequent to the year in which the pasture treatments were applied. Soil volumetric water content increased with depth for both types of pastures, but the soil previously supporting medic pasture contained more water than where grass was previously grown (P=0.07, Fig. 1a).

Although the pasture treatment by depth interaction was insignificant, it would appear that the increased water content of the medic pasture soil resulted from higher water contents at depth (>60 cm). In the top 80 cm of the soil profile, the volumetric water contents corresponded to approximately 30% of the total pore space calculated using bulk density values. With increasing soil depth, this value increased to 50, 70 and 100% for the 80-100, 100-140, and 140-180 cm layers, respectively, indicating that the soil at the bottom of the sampled profile was saturated despite only having a volumetric water content in the vicinity of 0.35.

When the total amount of water contained in each soil layer was calculated and summed for the soil profile, soil from the medic treatment was found to contain more water than that from the grass treatment due to the increased water held in the deeper soil depth layers (P=0.07, Table 1).

Nitrate-N contents, on a volumetric basis (Fig. 1b), changed significantly with depth irrespective of the previous type of pasture. The largest changes occurred in progressing from the 0-20 cm region to the >20 cm depth soil layers. Growing a medic pasture enhanced soil nitrate-N content relative to growing a grass pasture, especially in the upper 40 cm of soil. In the upper 20 cm of soil the standard deviations associated with the mean nitrate-N contents were large, typical of field studies with grazing animals.

The total content of nitrate-N contained in each soil layer and the entire 0-180 cm soil profile are presented in Table 1. After medic pasture, the amount of nitrate-N present in the soil profile was approximately 1.6 times that observed after grass pasture (144 versus 88 kg NO_3-N ha^{-1}).

The largest differences in the amount of nitrate-N in the various soil layers between the two pasture treatments were confined to the 0-60 cm depth, the zone of active grass and medic root growth in the previous season (Crawford et al., 1997). Within the 0-60 cm depth, the amount of nitrate N found after medic pasture was 2.0 times that found after grass pasture (88 versus 43 kg ha^{-1}).

The extra 45 kg ha^{-1} of nitrate-N contained in the 0-60 cm layer of the medic soil would provide approximately one third of the total N requirement estimated for a 4 t/ha wheat crop with 10-12% protein, a harvest index of 0.5 and a root:shoot ratio of 0.2. The elevated nitrate content in the root zone of the medic pasture may have resulted from a reduced utilisation of inorganic N supplies (sparing effect) and/or an increased deposition and mineralisation of medic root derived N.

In contrast to the nitrate-N contents, ammonium-N contents on a volumetric basis (Fig. 1c) were not affected by the pasture treatment and the variations with depth, although almost significant (P= 0.07), were not as large. There was some indication of an increased ammonium-N content in the 140-180 cm soil layer relative to the rest of the soil profile. The amount of ammonium-N contained in the various soil layers and the entire 0-180 cm soil profile was not influenced by pasture treatment (Table 1); however, when summed over the entire 0-180 cm profile ammonium-N accounted for a similar amount of N as noted for the nitrate-N in the grass treatment.

For the medic treatment, the amount of ammonium-N was approximately one half of the amount of nitrate-N. The majority of the ammonium-N (74%) found after grass and medic pasture was located below 60 cm outside of the major zone of root activity in the grass and medic pastures and thus may or may not be available to the subsequent wheat crop.

When the nitrate-N and ammonium-N contents were added together to give a total inorganic-N content on a volumetric basis, the effect of pasture treatment was not significant, but the changes with depth were (Fig.1d). The standard deviations of the mean total inorganic-N contents were greater than those associated with the nitrate-N and ammonium-N contents and undoubtedly contributed to the lack of a significant pasture treatment effect on total inorganic-N content. The total amount of inorganic N contained in each depth layer is given in Table 1. The total amount of inorganic-N contained in the 0-180 cm soil profile was 170 and 208 kg N ha^{-1} with roughly one third present in the surface 0-20 cm region.

Soil conditions following a legume dominant pasture were more favourable for subsequent wheat production compared to soil conditions following a grassy pasture. In particular, the amount of nitrate-N located in the major zone of root activity (0-60 cm) following annual medic was double that following barley grass pasture. Other differences were detected in soil water, particularly at depth; however, any benefits associated with the increased water availability would depend on the ability of the wheat crop to extract water from deep (>60 cm) in the soil profile. A significant amount of ammonium-N was detected at depths greater than 60 cm. The implications of these pasture generated soil conditions on subsequent wheat growth and grain yield will be reported elsewhere.

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Figure 1
Influence of grass and medic pasture on the volumetric contents of (a) water, (b) nitrate-N, (c) ammonium-N, and (d) total inorganic-N in soil layers at the start of the subsequent growing season. Error bars represent the standard deviation associated with each mean.

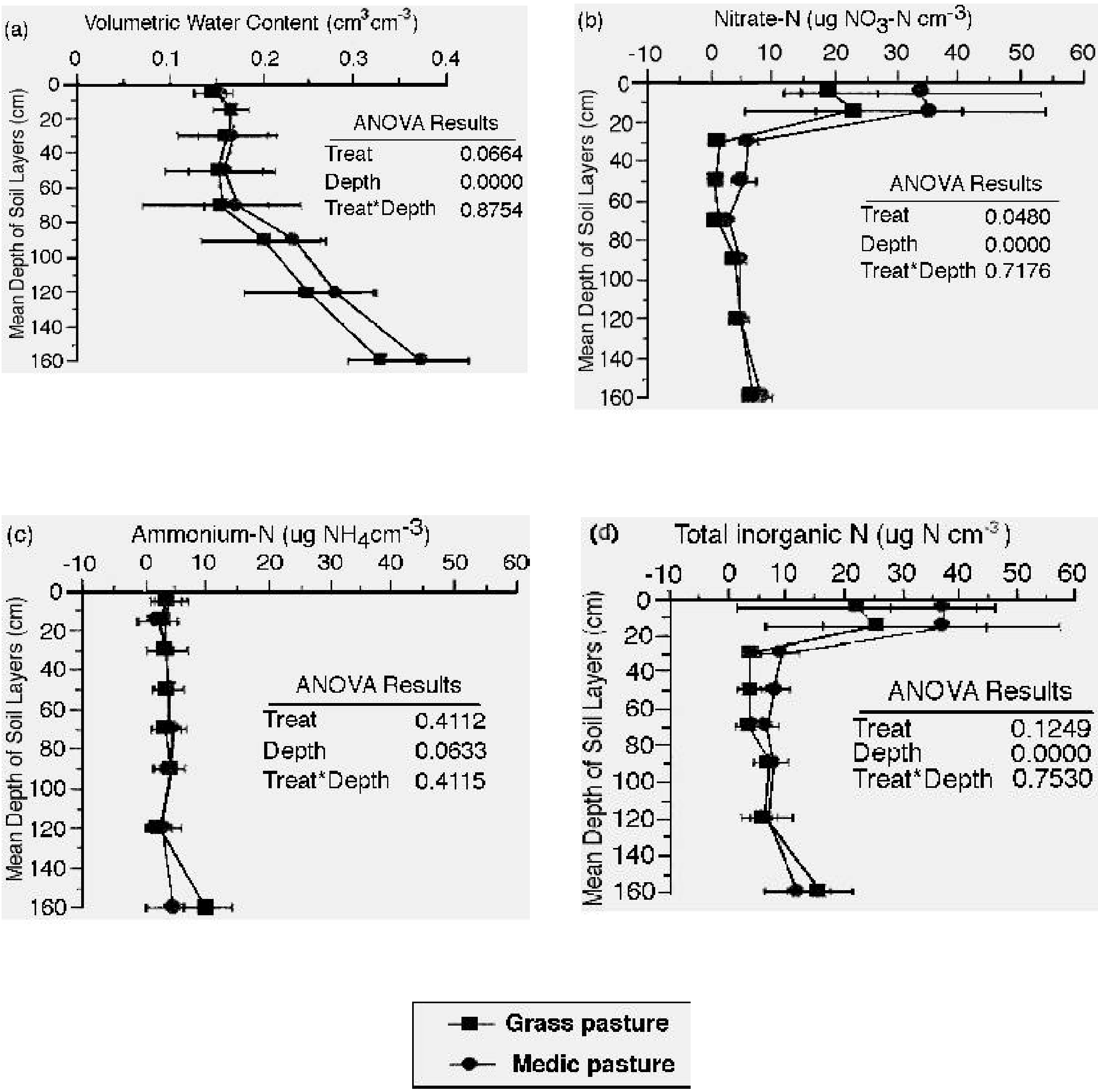

Table 1
Influence of grass and medic pasture on the amount of water, nitrate-N, ammonium-N and total inorganic-N contained in each soil layer sampled and in the 0-180 cm soil profile at the start of the subsequent growing season. Standard deviations of means are given in parentheses.

Depth (cm)	Water (mm) Grass	Water (mm) Medic	Nitrate-N ($kg\ ha^{-1}$) Grass	Nitrate-N ($kg\ ha^{-1}$) Medic	Ammonium-N ($kg\ ha^{-1}$) Grass	Ammonium-N ($kg\ ha^{-1}$) Medic	Total Inorganic-N ($kg\ ha^{-1}$) Grass	Total Inorganic-N ($kg\ ha^{-1}$) Medic
0-10	14.9 (0.7)	15.1(1.5)	18.4 (7.0)	32.7 (18.9)	3.5 (3.1)	3.(2.2)	21.9 (8.7)	36.5 (20.4)
10-20	16.6 (0.3)	16.7 (1.8)	22.7 (17.5)	34.9 (18.4)	3.0 (2.6)	2.1 (0.6)	25.7 (20.2)	37.1 (18.8)
20-40	32.3 (7.2)	33.5 (10.7)	1.4 (0.7)	10.9 (3.2)	6.5 (6.6)	7.1 (2.6)	7.8 (6.6)	18.1 (1.6)
40-60	30.8 (8.2)	31.6 (11.7)	0.5 (0.3)	8.6 (3.5)	7.5 (4.9)	7.2 (0.9)	8.0 (4.8)	16.0 (4.2)
60-80	31.0 (6.8)	33.9 (17.0)	0.8 (0.1)	4.1 (0.9)	6.7 (4.0)	8.7 (4.9)	7.5 (4.0)	12.8 (5.4)
80-100	40.2 (6.4)	46.0 (12.7)	6.0 (0.7)	7.9 (2.1)	8.4 (4.9)	7.5 (4.2)	14.5 (5.3)	15.3 (6.0)
100-140	99.8 (15.3)	111.0 (27.4)	15.3 (5.8)	15.5 (4.9)	8.1 (11.1)	10.5 (7.1)	23.4 (17.0)	26.0 (9.6)
140-180	130.2 (19.1)	147.7 (14.1)	23.2 (6.4)	28.8 (6.8)	38.6 (18.4)	17.6 (15.3)	61.8 (22.6)	46.4 (22.2)
Total (0-60)	94.6 (16.3)	96.9 (25.4)	43.0 (22.4)	87.3 (6.1)	20.4 (13.1)	20.2 (4.2)	63.4 (24.8)	107.5 (6.3)
Total (0-180)	395.5 (61.3)	435.6 (93.1)	88.2 (17.8)	143.5 (9.2)	82.3 (30.5)	64.4 (27.6)	170.6 (13.8)	208.6 (34.3)

ANOVA Results for the Pasture Treatment by Depth (2 x 8) Factorial Arrangement

Effect	P-Value	Effect	P-Value	Effect	P-Value	Effect	P-Value
Treat	0.0691	Treat	0.0122	Treat	0.2353	Treat	0.2368
Depth	0.0000	Depth	0.0000	Depth	0.0000	Depth	0.0000
Treat*Depth	0.7324	Treat*Depth	0.8456	Treat*Depth	0.1150	Treat*Depth	0.6519