Effect of in-season moisture on carbon, nitrogen and phosphorus in alkaline, semi-arid soils

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Abstract

An experiment was conducted to assess the influence of soil moisture on soil nitrogen and phosphorus dynamics in the absence of plants. Soil was collected on a 4 to 6 weekly basis over a seasonal cropping cycle, from 2 fallow microplot field experiments exposed to 3 soil moisture treatments. The sites selected were a Vertosol in the Wimmera district and a Calcarosol in the Mallee regions of Victoria. Soil analyses from these microplots indicated a complex relationship between soil type, moisture and air temperature and changes in microbial biomass N and C, nitrate and Colwell P, and to a lesser extent, resin P.

Key Words

Nitrate, microbial carbon, nitrogen and phosphorus

Introduction

Soil drying and re-wetting cycles occur throughout the crop growing season. These cycles result in changes in phosphorus (P), carbon (C) and nitrogen (N) in soil that ultimately determine the supply of nutrients to soil solution and thus the pool of nutrients available for plant uptake (Soinne *et al.* 2010). There is a balance between sufficient soil moisture that allows soil organisms to mineralize nutrients for plant absorption, and excess soil moisture that results potential loss of some nutrients e.g. through leaching (Tilman *et al*. 1996). While soil moisture is important, soil physical and chemical properties also strongly influence nutrient fluxes (Brady, 1990). This experiment aims to examine whether modifying soil moisture to mimic different seasonal conditions produced changes in the microbial biomass (C, N and P) and several indices of soil N and P supply over a cropping cycle.

Methods

Sixteen, 1m^2 fallowed microplots were established at Longerenong (-36^{o}40'S;142^{o}18'E) on a Vertosol and Walpeup (-35^{o}07'S;141^{o}59'E) on a Calcarosol, by removing the 0 - 10 cm layer of soil and lining the base with shade cloth. The soil was then thoroughly mixed (to minimize soil heterogeneity), replaced back into the plots and sampled on a 4 to 6 week basis. The microplots were laid out in a completely randomized design of 3 watering treatments ('dry sowing' – plots kept dry, using covers from April to June 2009, 'dry finish' – plots exposed to rainfall but kept dry using covers from October 2009 to February 2010, and 'seasonal conditions': no covers applied to microplots) x 4 replicates. Urea (25 kg N/ha) was broadcast applied to all microplots in May to simulate fertilizer application of N at sowing.

Soil samples from each site were initially characterized for total C, N and P, pH (H_2O and $CaCl_2$), exchangeable Ca, Mg, Na, and K, upper (-1500KPa) and lower (-10 KPa) storage limits, texture, electrical conductivity and bulk density using methods outlined in Rayment and Higginson (1992). Following each sampling (0 to 10 cm depth), soil nitrate and ammonium (2M KCl extractable ((Bremner and Keeney 1966)), chloroform extractable microbial C (Jenkinson and Powlson 1976), and N (ninhydrin method (Amato and Ladd 1988)), and hexanol extractable P (McLaughlin and Alston 1986), resin P (Kouno *et al.* 1995), and Colwell P (Colwell 1963) were determined.

Results

Both soils have similar pH (8.50 and 8.54), total N (0.10 mg/kg at both sites), total C (1.22 and 1.11 % w/w) and electrical conductivity (0.10 and 0.08 dS/m) (Table 1). Total P, exchangeable cations and upper and lower water storage were all higher in the Vertosol than in the Calcarosol.

Table 1: General soil characteristics of microplot soils at Longerenong (Vertosol) and Walpeup (Calcarosol)

Characteristic	Units	Vertosol	Calcarosol
Organic C	% w/w	0.67	0.99
Total P	mg/kg	195	84
Exchangeable cations (Ca, Mg, Na, K)	Meq/100g	48	21
-1500 KPa - -10 Kpa	% w/w	23 – 41	7 - 16
Bulk density	g/cm^3	1.09	1.25

Both the Vertosol and Calcarosol soils showed significant drying in response to the ‘dry start’ and the ‘dry finish’ treatments. The seasonal conditions treatment was initially dry (April) but soil moisture subsequently was maintained close to 80% of the upper storage limit from May 28th to November 2009.

Where plots were subjected to dry starts, microbial N and nitrate N concentrations initially lower compared to seasonal conditions (Figure 1). Following urea addition in late May (49 mg N/kg soil), soil nitrate increased significantly (P< 0.05) in the August sampling for all treatments in the Calcarosol but remained unchanged in the Vertosol, with the exception of the dry start treatment (following the removal of rain exclusion covers). These changes were strongly linked to changes in soil moisture. In the Calcarosol, microbial N increased from below detection limit in June to 36 ?g/g in October; nitrate N increased from 4 mg//kg (when soil moisture was 4%) to 70 mg/kg for the same period, as soil moisture increased to 10% in the ‘dry start’ treatment. Soil moisture varied less in the seasonal and dry finish treatments, and as a result, the increase in nitrate-N was also smaller (3 mg/kg in June to 34 mg/kg in October). The Vertosol ‘dry start’ treatment nitrate N remained at very low levels between April and June as soil moisture remained low, but then rapidly increased to 38 mg/kg in August when soil moisture was 33%, before declining rapidly and remaining low. By comparison the nitrate N in the seasonal and dry finish treatments remained low throughout the study period. No significant correlation was found between soil moisture and corresponding levels of microbial P (analysis not shown).

Microbial N follows similar trends to nitrate-N (with the exception of June’s sampling in the Calcarosol). The initial dry soil conditions at the start of the season coincided with low levels of microbial C, N and P at both sites. Microbial N and C increased markedly in early spring (following urea application in May) before declining towards grain maturity. In contrast, microbial P remained unchanged (P > 0.05) during the study period and was unaffected by moisture treatment. Both indices of plant available P (Colwell and Resin P) remained relatively stable at both sites during the early part of the season. However as the season progressed, there was a trend for Colwell P to increase although there was no clear effect of moisture treatment. There was a similar trend for Resin P to also increase from October onwards in the Calcarosol (Figure 1) but there was no significant (P > 0.05) change in the Vertosol.

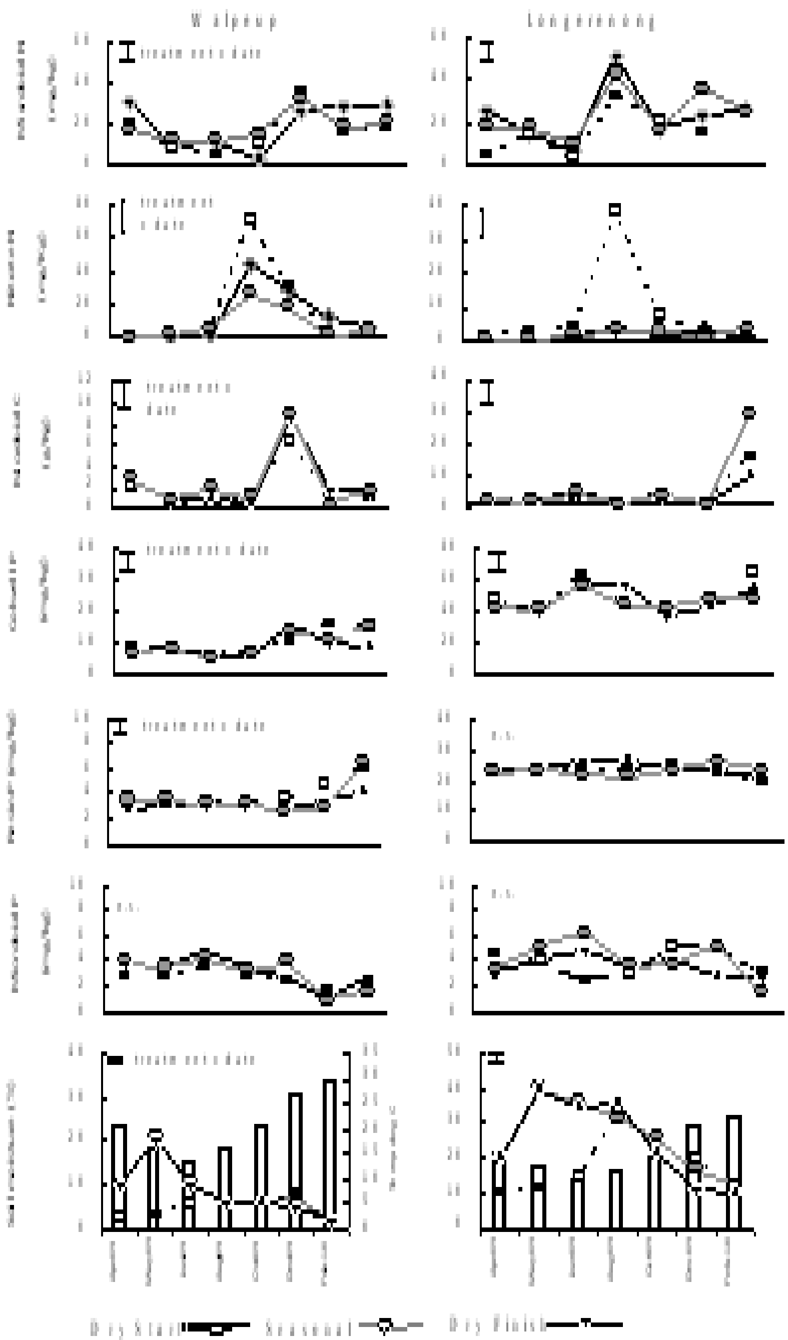

Figure 1 Measures soil microbial and chemically extractable N, C and P compared with soil moisture. Bars represent l.s.d. (5%). n.s. = not significant

Discussion

Following a dry fallow prior to the start of the study in April, there were rapid increases in soil moisture in treatments subjected to natural rainfall. Although there were relatively small changes in air (and presumably even smaller soil) temperature during this period, no major changes in most soil parameters measured were readily apparent until sufficient rainfall had occurred. The largest effect appeared to result from the application of urea in late May which corresponded to large increases in nitrate N and microbial

N and eventually microbial C rather than changes in soil moisture *per se* (once sufficient rainfall had occurred to allow fertilizer granule dissolution and wet the initially dry soil which resulted in increased microbial activity). The effect of this urea application on soil nitrate was greatest in the 'dry start' treatment at both sites where there was an 18-fold increase at Walpeup and 13-fold increase in nitrate N levels between June (when the rainout covers had been removed) and August. Subsequent declines in soil nitrate N as the season progressed may be due to a range of N loss mechanisms such as immobilization or denitification as the relatively dry finish leading up to December makes leaching losses unlikely and plots were kept fallow i.e. no plant uptake. Overall this experiment did not identify any clear significant statistical correlation between soil moisture and the different soil indices measured. This may in part reflect the comparatively large gaps (up to 6 weeks) between sampling events, especially in the warmer months when even large rainfall events (eg. 47 mm at Longerenong during early February) did not produce significant differences in soil moisture at the next sampling time. In contrast to N, the different indices of plant available P as well as microbial P were relatively more stable over time and less affected by soil moisture treatment. There was however small but significant changes, especially in Colwell P at both sites towards the end of the trial. To what extent this represents mineralization of organic P is unknown but these changes are important as they may affect predictions about P fertilizer requirements.

Acknowledgements

Our thanks to the Grains Research and Development Corporation (Project DAV00095),the Australian Research Council (Project LP0882492) and the South Australian Grains Industry Trust for co-funding. Thanks also to Mel Munn, Ashlea Doolette and Colin Rivers for technical assistance.

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