Pulse crops improve productivity of crops in rotations involving various residue management strategies in the High Rainfall Zone of western Victoria – a case study example for grower decision support.

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Abstract

Unlike the semi-arid environment of north-western Victoria, crops in the High Rainfall Zone (HRZ) are often limited more by nitrogen than water. This work studies the effect of rotation and stubble management on wheat nitrogen management, as part of a collection of fact sheets being formulated to assist growers to achieve yield potential in the HRZ of south-eastern Australia. A simulation modelling approach was used to compare the nitrogen dynamics of two rotations comprising, wheat-canola-barley (WCB) and wheat-canola-faba bean (WCFb) and stubble management methods of standing, mulching, incorporating and burning. Simulations indicate that including faba beans in the rotation contributed, on average, an additional 70-80 kg N/ha of soil mineral nitrogen (SMN) for the subsequent wheat crop, compared with where barley was sown instead of the pulse crop. This additional SMN translated to less pre-anthesis wheat N-stress and yields were 2.2 t/ha more than for the non-pulse rotation (WCB), (8.4 v 6.2 t/ha). The N benefit of the pulse crop was restricted to the first following crop, thereafter levels of SMN were equivalent across both rotations. The simulated impact of stubble management was that the removal of faba bean stubble, by burning, reduced SMN levels by 10 kg N/ha compared with stubbles incorporated, mulched or left standing, which translated into lower wheat yields. Overall, these results show that rain-fed cropping in the HRZ would benefit from the inclusion of a pulse crop in the cropping sequence, through the reduction of nitrogen stress in subsequent cereal crops.

Key Words

Cropping, rotation, wheat, fact sheet

Introduction

Crop rotation and stubble management affect physical, chemical and biological properties of the soil. They also have a bearing on pest and disease pressure and the ease with which cultural practices can be conducted. The long-term retention of stubble can enhance soil structure, plant available water content, trafficability and reduce erosion risk by wind and water of arable soils (Hoare 1992; Bescansa et al. 2006). In regions of high growing season rainfall (> 550 mm annually), large volumes of crop residues can be produced (10 to 15 t/ha), which may negatively impact on subsequent crops through nitrogen tie-up. Crop choice within a rotation influences the nitrogen dynamics of the system. For example, rotations dominated by cereal and oilseed crops have a high demand for nitrogen and rely on supply from both soil reserves and applied N. Crop yield under such systems may be limited by nitrogen, particularly in regions of higher rainfall. In contrast, crop rotations where a pulse or pasture legume is included provide the opportunity to save and/or boost soil nitrogen, reduce cereal soil-borne diseases, control grass weeds and thus potentially increase yields of subsequent cereal crops (Armstrong 1997). Under high levels of high C/N ratio crop residues, nitrogen tie-up can occur when micro-organisms break down organic matter and use mineral nitrogen for their growth and survival. This tie-up is exacerbated on residues that have a high C/N ratio (ca 60-120), for example wheat or canola stubble, thus limiting immediate crop access to available N. Nitrogen tie-up may be of greatest risk if large quantities of residue are incorporated close to sowing (Baldock 2006).

Methods

The crop simulation model, APSIM-WHEAT (Version 6) (Keating et al. 2003) was used to examine the impact of crop rotation and stubble management on the nitrogen stress and yield of wheat crops growing in the high-rainfall zone. Model error (RMSE), based on validations from seven sites across south-western Victoria, Tasmania and south-eastern South Australia, was 731 kilograms of grain per hectare (R. Harris per comms). Two rotations, wheat (cv. Mackellar), canola (cv. Charlton), barley (cv. Gairdner) (WCB) and wheat (cv. Mackellar), canola (cv. Charlton), faba bean (cv. Fiord) (WCFb) were compared; rotations lasted 15 years prior to resetting soil mineral N, surface residue (10 t/ha) and stored soil water (PAWC sowing: 30mm). Three sets of simulation with starting years offset by 1 year were run to eliminate any seasonal effect and used soil data and 120 years (1889 – 2008) of historical climate records for Dunkeld, in south-west Victoria. For the Dunkeld site, two soil types occurred in the vicinity of the case study site, principally due to the occurrence of gilgai mounds and gilgai depressions. In the gilgai depressions, the soil is a vertic, mottled-subnatric grey Sodosol and in the gilgai mounds, the soil is a vertic, petroferric grey Sodosol. Topsoil properties are summarised in Table 1. Within the simulations, initial soil mineral N levels were set at 100 kg/ha and a total of 100 kg N/ha fertiliser (NO_3-N) was applied (25 kg/ha at sowing, 50 kg N/ha at floral initiation and 25 kg N/ha at GS39. The faba bean crop received no sowing nitrogen.

Stubble management treatments

- stubble standing – within APSIM the surface organic matter file was set at 10,000 kg, CN: 80 and 50% of stubble was left standing, as at 15 Jan.
- stubble incorporated – within the APSIM management folder, “tillage on a fixed date” was set for a disc to incorporate 70% of surface residue to 50 mm on 1 Feb.
- stubble mulched – within APSIM the surface organic matter file was set at 10000 kg, CN: 80 and 20% of stubble was left standing, as at 15 Jan.
- burnt standing – stubble incorporated – within the APSIM management folder “tillage on a fixed date” was set for burn_90 on 25 Mar.

Output file variables selected and reported here were soil NO_3-N (0-160 cm), % photosynthesis and grain yield; they were calculated daily. Percent photosynthesis is a measure of the plant nitrogen stress where 1.0 is no stress. Values presented are means for 120 years of simulation.

Results

Soil nitrate

Crop rotation had a greater influence on soil nitrogen than the method of stubble management (Figure 1). Including a pulse crop in the rotation instead of barley contributed an additional 70-80 kg N/ha for the subsequent wheat crop. The nitrogen contribution of the pulse crop was restricted to the first subsequent crop (wheat) and in the second year, when canola was sown, the levels of soil nitrate were equivalent across both rotations. The effect of burning faba bean crop residues was to reduce the soil nitrate levels by 25 kg N/ha, compared with stubbles that were incorporated, mulched or left standing. There was no evidence of nitrogen immobilization and N tie-up linked with variation in crop residue management.

Table 1 : Soil properties for the top 10 cm layer prior to sowing in 2008.

Bulk density (kg/m^3)	Total organic carbon %	Initial mineral nitrogen (mg/kg)	Colwell phosphorus (mg/kg)	pH ($CaCl_2$)	pH (H_2O)
0.93	2.71	58	22	4.6	5.5

Crop nitrogen stress

Crop rotation had the greatest effect on wheat N-stress during the growing season. For the wheat-canola-barley (WCB) rotation, substantial wheat N-stress occurred around GS31 (Figure 2). Similar patterns of

N-stress occurred, irrespective of the method of stubble management of crops. In contrast, the wheat-canola-faba bean (WCFb) rotation produced less wheat N-stress, although for this rotation the burning of the pulse crop residues produced higher levels of wheat N-stress compared with where stubbles were retained or incorporated. Evidently, differences in simulated stubble management within the WCB rotation did not produce a large variation in N-stress due to nitrogen tie-up, although the onset of wheat (and canola) N-stress occurred earlier where stubbles were standing, incorporated or mulched compared with where they were burnt.

Crop yields

Wheat yield varied substantially with rotation but less with method of stubble management (Figure 3). The yield of wheat following faba bean, was on average 8.4 t/ha, 35% greater than if wheat followed barley (6.2 t/ha) in the rotation. In the year following the wheat crop, the impact of faba bean disappeared, when canola yields were 2.0 and 2.1 t/ha for the WCB and WCFb rotations, respectively. Yield of barley crops following canola averaged 4.5 t/ha, compared with 3.4 t/ha for faba bean crops following canola. The 1.1 t/ha penalty associated with growing faba bean may be off-set against the grain price differences compared with barley, and the nitrogen contribution provided by the pulse crop which subsequent benefits the following wheat crop.

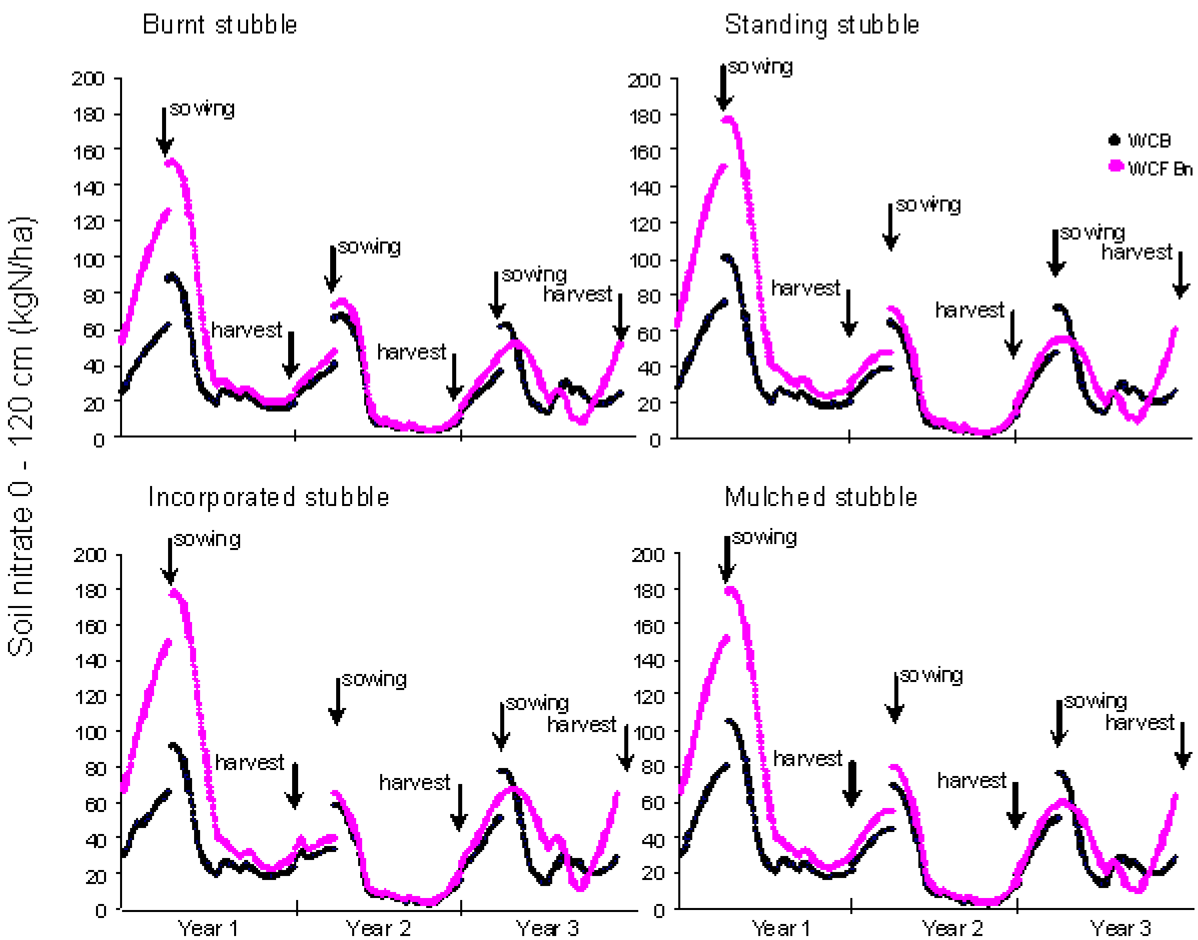

Figure 1. Simulated soil nitrate (kgN/ha) to 120 cm as affected by rotation and method of stubble management at Dunkeld. Year 1 is wheat, year 2 is canola and year 3 is barley or faba bean. The break in lines is where nitrogen was applied at sowing.

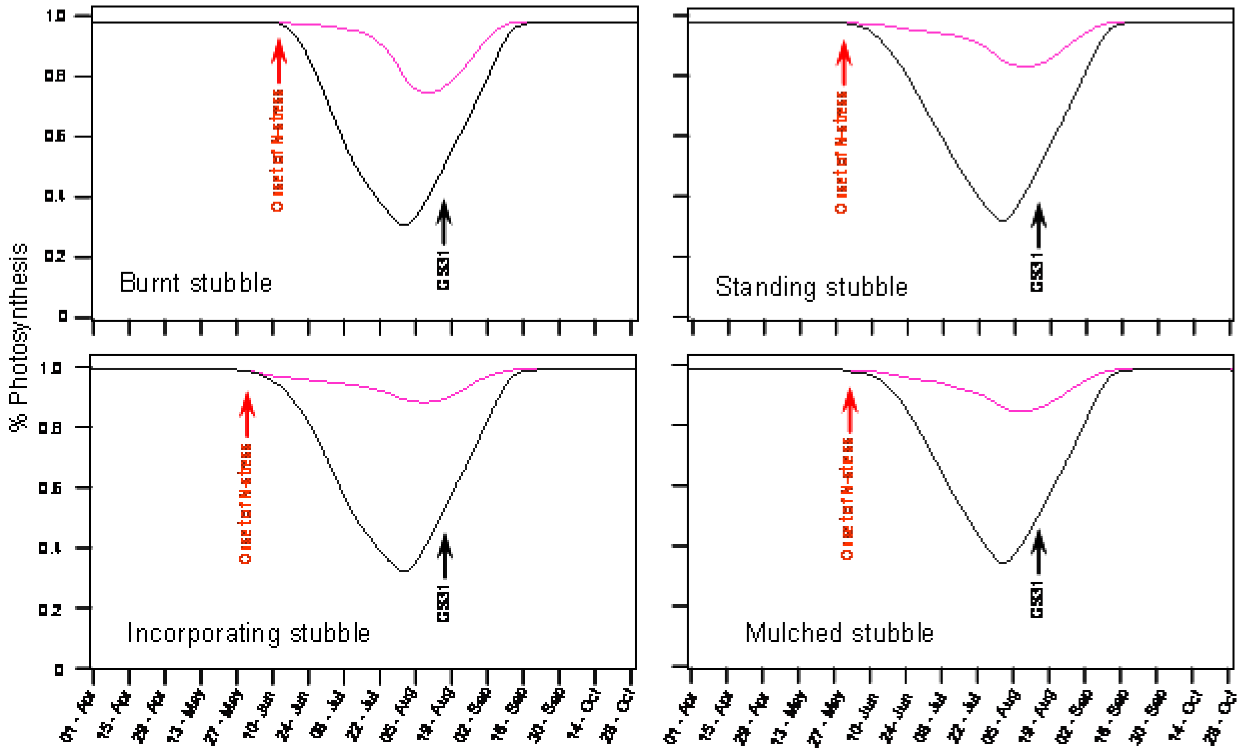

Figure 2. Nitrogen stress (% photosynthesis where 1 is no N limitation) of wheat during the growing season at Dunkeld, Victoria as affected by stubble management and rotation.

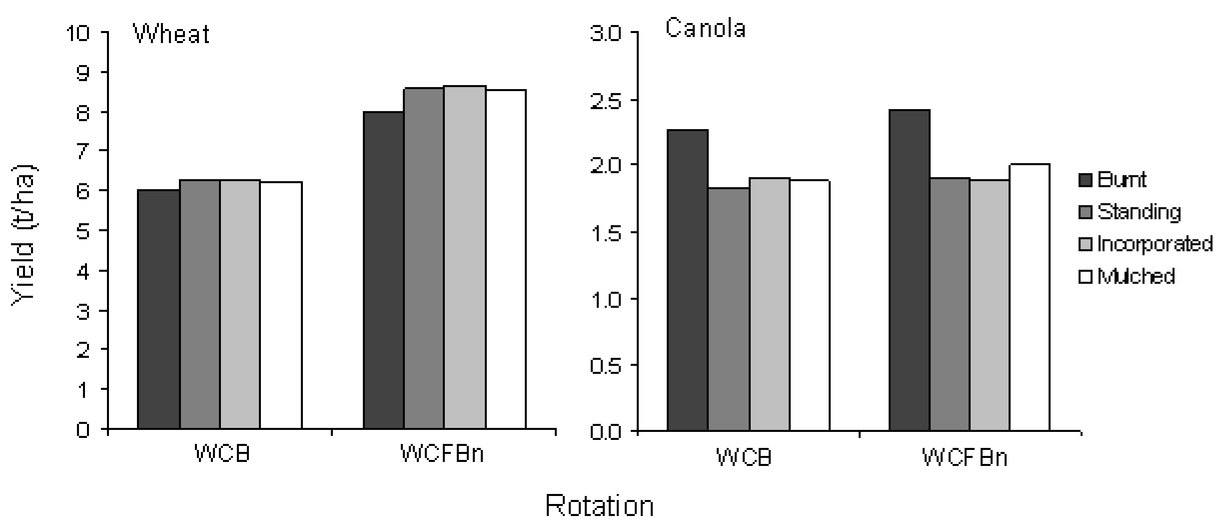

Figure 3. Simulated grain yield (t/ha) of wheat and canola as influenced by rotation and method of stubble management.

Conclusion

The simulations estimated that soil N levels were more affected by the previous crop than by the method of stubble management. The model estimated that a pulse (faba bean) crop can boost the soil mineral nitrogen content of the soil by between 70-80 kg N/ha, as nitrate. Consequently, N-stress levels in subsequent wheat were reduced. Early N stress in wheat was greater where legume stubbles were removed (burnt) compared with stubbles were left standing, mulched or incorporated, but according to simulations this did not translate into a yield penalty. Burning wheat stubble prior to the canola phase produced an increase in yield compared with stubbles left standing, mulched or incorporated. The simulations estimated that a pulse (faba bean) phase could potentially boost subsequent wheat grain yields by up to 2.2 t/ha, compared with wheat grown after barley. These simulated results suggest that cropping systems within the HRZ, where N is more likely to be limiting than water, will reduce the dependence on artificial N-fertiliser application while increasing production of cereal crops. Overall, these simulated scenarios, which were set using a participatory action research (PAR) process, assist growers in understanding the effects of various agronomic management options on production and help growers approach yield potential in the HRZ of south-eastern Australia.

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