TRENDS IN CROP PRODUCTION AND SOIL PROPERTIES IN A LONG-TERM TRIAL AT TARLEE, SOUTH AUSTRALIA

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Summary. After 17 years of monitoring a crop rotation trial, trends in various crop and soil factors are indicating which practices contribute to sustainable production. Important factors to consider are: wheat yields - highest in rotations which maintain soil fertility and control soil-borne diseases; nitrogen fertiliser - increases productivity in all rotations; soil fertility - increases with legume pastures, stubble retention, no-till, and nitrogen fertiliser; wheat grain protein - declines in intensive cropping rotations; and soil pH - declines where high rates of nitrogen fertiliser are applied. Continuous cropping has been more profitable than ley farming in recent years but declining soil fertility, wheat protein and soil pH are warning signals that yield and profitability losses may occur in the future in some production systems.

INTRODUCTION

The dryland farming system involving cereal crops and pastures (ley farming) became widely adopted in the cereal belt of temperate Australia in the 1950s. This ley farming system became a relatively stable pattern of land use which restored both the productivity of previously degraded soil and the profitability of farming. However, by the mid 1970s cropping intensity had increased on many farms as a result of economic pressures that required increased farm output, and favoured grain over livestock production, and a surge in interest in grain legume crops was just beginning. Against this background the Tarlee rotation trial was established in 1977 to monitor the long-term effects of intensive and traditional rotations on crop production and soil properties.

MATERIALS AND METHODS

The trial is located at Tarlee, 80 km north of Adelaide, on a hard-setting red-brown earth soil with a sandy loam texture (Northcote (1979) classification - Dr 2.13; Soil Taxonomy classification - fine, mixed, thermic calcic palexeralf). Before the trial began, the site had been farmed on a cereal-pasture rotation, as a means of restoring soil fertility and structure following an earlier period of intensive cropping in a cereal-fallow rotation. Some soil properties (0-10 cm) at the start of the trial were: organic carbon, 1.00%; total nitrogen, 0.10%; available phosphorus, 54 ppm; pH, 6.8; and clay content, 14%. The long-term mean annual rainfall is 475 mm and the growing season (April - October) rainfall is 355 mm. Further details are given in (1).

The experiment comprises eight 2-year rotations in factorial combination with 3 stubble/tillage treatments and these plots (6 m x 40 m) are split for 3 rates of nitrogen (N) fertiliser. There are 2 phases, so that each crop is grown each year, and 2 replicates.

The eight rotations are: (i) continuous wheat (W-W), (ii) wheat-barley (W-B), (iii) wheat-field peas (W-P), (iv) wheat-lupins (W-L), (v) wheat-field beans (W-Be), (vi) wheat-volunteer annual pasture (W-VP), (vii) wheat-sown legume pasture (W-SP), and (viii) wheat-fallow (W-F). The 3 stubble/tillage treatments, over the period 1978-1987, were: (i) stubble burned, (ii) stubble incorporated into the soil, and (iii) stubble chopped and retained as a surface mulch. All of these were cultivated for weed control and seed-bed preparation. In 1988 treatment management was modified to eliminate burning and to include direct drilling with narrow points (no-till). The treatments became: (i) stubble removed/cultivation (Rem/CC), (ii) stubble retained/cultivation (Ret/CC), and (iii) stubble retained/no-till (Ret/NT). The changes were made to keep treatments relevant to contemporary farm practices. The 3 rates of N fertiliser are 0, 40, and 80 kg/ha of N as ammonium nitrate applied to the wheat phase and to wheat and barley in the alternate crop phase.

Plant and soil parameters measured throughout the trial are crop dry matter and grain production, grain protein, and the effect of the treatments on soil fertility (eg organic C, total N and pH). The trial site is also being used to study soil structure, earthworms, soil biota and soil water. Rainfall, class A pan evaporation and air and soil temperature are recorded near the site.

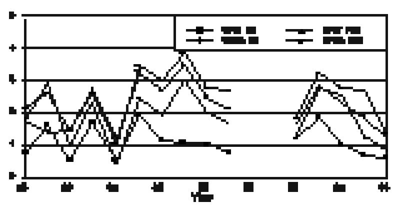
RESULTS AND DISCUSSION

Wheat yields

Wheat yields from 1978 to 1994 consistently show beneficial effects from rotation and N fertiliser but the stubble/tillage treatments have relatively small, variable effects (2). The highest wheat yields were obtained where wheat alternates with grain legumes or with sown legume pasture. Yields after lupins and beans were better than after peas, and sown pasture resulted in better wheat yields than volunteer pasture. Yields of wheat in W-F rotation were high for many years but appear to be declining now. Wheat yields in continuous cereal rotations are now relatively low and declining, even where 80 kg/ha of N is applied each year. There were N responses in all rotations but the second increment of N fertiliser gave only small and uncertain benefits. The yield differences between wheat following grain legumes (and sown legume pasture) and wheat in continuous cereals could not be made up completely by N fertiliser at 80 kg/ha N annually, indicating that N rates were insufficient for demand or that other factors (probably disease control) are involved.

Fig. 1 shows the yield trends from 1978 to 1994 for four different treatments, representing four different levels of production. The seasonal effect (year to year variation in yield) is similar for all treatments. In 1988 and 1989, all treatments were cut for hay to help control herbicide-resistant ryegrass.

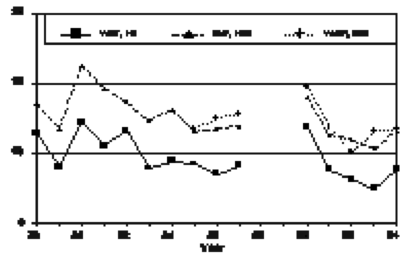
Figure 1 Wheat yields (t/ha) from 1978 to 1994 in four different treatments.



Wheat protein

Wheat protein ranged from 7.4% to 11.5% in 1993 and 8.5% to 11.8% in 1994, depending on rotation and N fertiliser rate. Nitrogen fertiliser raised wheat protein in all rotations. Over the period of the trial, wheat protein has gradually declined (Fig. 2). The total harvest of grain protein (grain yield X % protein) from 1985 to 1994 averaged 94 kg/ha/year (range 50 - 161) for W-W, N_0; 297 kg/ha/year (147 - 442) for W-P, N_{80}; and 313 kg/ha/year (187 - 435) for W-SP, N_{80}.

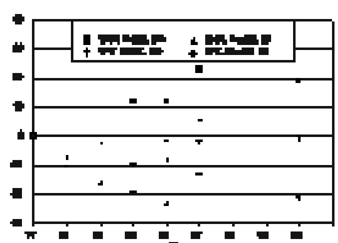
Figure 2 Trends in wheat grain protein percentages for three treatments.



The soil fertility index

The soil fertility index expresses the mean change in organic C and total soil N over a period of time as a percentage. This one value then indicates the extent (either positive or negative) by which the soil fertility has changed over the time interval being assessed. The W-SP rotation has a positive effect on the index, and this effect is maximized when crop and pasture residues are retained and N fertiliser is applied to the wheat. In continuous cropping rotations, much of the decline in soil fertility can be prevented by using stubble retention/no-till practices and N fertiliser. Trends in the soil fertility index from 1977 to 1993 for six treatments are shown in Fig. 3. The index has diverged to give current values up to 20% above and below the initial soil fertility, depending on the combination of crop rotation, stubble/tillage treatment and N fertiliser application.

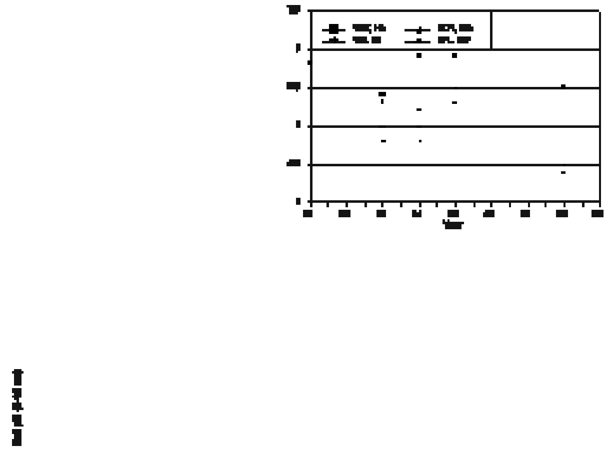
Figure 3 Trends in the soil fertility index from 1977 to 1993 for six treatments.



Soil pH

Soil pH has declined from its starting value (6.8) in all treatments. The biggest effect has been due to the use of N fertiliser. In continuous cereals, where the N fertiliser is added every year, soil pH is down to 5.3 and 5.2 for W-W, N_{80}, and W-B, N_{80}, respectively, and in W-L, with N added to the wheat crops only, soil pH is as low as 5.1. Fig. 4 shows the trend in soil pH over the period of the trial, for W-W and W-L, with 0 and 80 kg/ha of N as ammonium nitrate fertiliser.

Figure 4 Trends in soil pH for four different treatments.



CONCLUSIONS

Yield results from the Tarlee rotation trial show that with the right management, it is possible to sustain continuous cropping for a number of years. However, herbicide resistance and the decline in soil fertility, wheat protein and soil pH are threatening future productivity of some production systems and should be regarded as warning signals with respect to long-term sustainability.

The best farming system for an area will always allow flexibility to respond to agronomic needs and market forces. In a modern conservation-based farming system, the occasional burning of stubble or the occasional year of fallow will do little harm. They are old techniques which can still be effective against specific problems, eg weeds. Similarly, novel approaches to weed control being developed by organic farmers (eg wide row spacing to permit inter-row tillage) may well be justified in conventional systems. The trial has highlighted the value of legume-dominant pastures in maintaining or improving soil fertility. It is likely that even those farmers who now devote their whole farm to cropping enterprises will again include pasture in their rotations when profitability returns to the pasture phase because of the undisputed increase in sustainability when legume pastures are part of the farming system.

ACKNOWLEDGMENTS

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