LONG-TERM RESIDUAL EFFECTS OF 6 DIFFERENT CROPS ON YIELD AND PROTEIN OF WHEAT

G. J. Crocker

NSW Agriculture, Tamworth Centre for Crop Improvement, Tamworth, NSW 2340

Abstract

Six rotations were each superimposed on ?long-term rotation trials on a black earth and a red clay soil at Tamworth in 1988. The 6 rotations consisted of 3 years of lucerne (Medicago sativa), subclover (Trifolium subterranean) or snail medic (Medicago scutellata) followed by 3 years of wheat; alternate years of chickpea (Cicer arietinum)/wheat or long fallow/wheat and 6 years continuous wheat grown from 1988 to 1993. All plots were again sown to wheat in 1994 a nd 1995 and this paper examines the effects of these rotations on wheat in 1995. Plots were split for 0, 60 or 120 kg N/ha as urea. Lucerne and subclover increased yield, protein and grain N uptake of wheat over chickpea, long fallow and continuous whe at treatments on both soil types in the absence of N fertiliser, 5 years after the last pasture was grown. While long fallow and continuous wheat gave the lowest yields and N uptake on both soils, they responded most to N fertiliser. Medic and chickpea effects were intermediate on wheat yield and protein in the absence of N fertiliser on both soils. On the black earth soil, without N fertiliser, wheat protein level increased from % following fallow, continuous wheat and chickpea to 11.8% following lu cerne. While protein levels were increased for each rate of N for each treatment, N uptake was increased following only the 3 non-pasture legume treatments. On the red clay where N fertiliser was applied it increased protein for the continuous wheat tr eatment from 9% to 11.4% and wheat following lucerne from 9.9 to 14.1%. Grain N uptake increased from 24.1 to 60.3 kg/ha for continuous wheat compared to 39.5 to 64.8 kg/ha for wheat following lucerne.

Key words: Residual effects, pasture legumes, chickpea, long fallow, protein and N uptake.

The long-term trend in wheat yields and protein levels in northern NSW is downward due to declining soil fertility caused by the number of years of cultivation (3). ?Economic viability has dictated that farmers crop continuously which has led t o a decline in soil fertility. It has been shown that cultivation greatly reduces total organic C and total and mineralisable N (2). The push towards sustainable economic viability has meant that farmers are looking for alternate crops or methods to ma intain soil fertility and ways of reducing input costs. ?One way to do this is by using pastures which increase organic matter, soil aggregate stability and nutrient cycling and reduce soil erosion (3).

Lucerne is the main perennial pasture grown for rotation with cereal cropping in northern NSW. Most of the soils are neutral to alkaline, and annual medics (Medicago species) are also well adapted to this area. Subclover is the predominant legu me pasture grown in the south of the State. Chickpea is the main grain legume grown in northern NSW and is being used because some farmers have few stock or returns from grain are more profitable. Long fallowing has traditionally been practised to cons erve soil moisture and accumulate soil N through mineralisation, however, this leaves the soil exposed to erosion in this summer dominant rainfall area especially when weeds are controlled by cultivation.

Six pasture and crop rotations were superimposed on two long-term rotation trials located on a black earth and a red clay soil at the Tamworth Centre for Crop Improvement. The effects of these treatments on wheat yield and protein during the rotations h ave been reported by Holford and Crocker (5) and changes in soil moisture, soil N and organic carbon have been reported by Holford et al. (6). Wheat was grown over the whole site in 1994 (a low rainfall year) and results have been reported by Crocker and Holford (1).

This paper reports the residual effects of the rotations that were measured on a wheat crop grown in 1995, two years after the rotations had been completed.

Materials and methods

In 1988 six treatments were superimposed on 2 long-term trials on adjacent black earth and red clay soils at Tamworth. The 6 treatments lasted for 6 years (1988-93) and consisted of 3 years of lucerne, subclover or snail medic followed by 3 years of whe at; alternate years of chickpea/wheat, long fallow/wheat and continuous wheat. Plots were grazed by sheep immediately after harvest (December) and then weeds are controlled with chemicals until cultivation in March-April when stubble is incorporated wi thout burning. Janz wheat was sown without N fertiliser over all plots in 1994.

Hartog wheat was sown over all treatments on May 30 on the red clay and June 25, 1995 on the black earth soil. Seed was sown with a conventional combine using 18 cm rows at 45 kg/ha with superphosphate (8.8% P, 11% S) at 75 kg/ha. Plots were split f or N which was applied as urea (46% N) at 0, 60, or 120 kg N/ha with 6 replications in a Latin square design in plots measuring 15.2 x 27.4 m on the red soil and 11.3 x 30.5 m on the black soil. Wheat was machine harvested on November 29 by taking 1.5 x 21.5 m and 1.5 x 24.5 m samples. Grain protein was analysed by the NIR method.

Long fallow was 18 months where weeds were controlled by grazing, cultivation and herbicides. Rainfall in 1995 was 655 mm compared to an average of 675 mm, but only 415 mm in 1994. Available soil water was determined in April 1995 to a depth of 60 cm pr ior to sowing.

Analysis of variance of the data was performed as a factorial trial in a Latin square layout to provide standard error of the difference between means to determine sign- ificant effects. Crop sequences are shown in Table 1.

Table 1. Crop sequences for 6 treatments from 1988 - 1995.

Treatment	1988	1989	1990	1991	1992	1993	1994	1995
Subclover	Subclover	Subclover	Subclover	Wheat	Wheat	Wheat	Wheat	Wheat
Lucerne	Lucerne	Lucerne	Lucerne	Wheat	Wheat	Wheat	Wheat	Wheat
Medic	Medic	Medic	Medic	Wheat	Wheat	Wheat	Wheat	Wheat
Chickpea	Chickpea	Wheat	Chickpea	Wheat	Chickpea	Wheat	Wheat	Wheat
Long fallow	Long fallow	Wheat	Long fallow	Wheat	Long fallow	Wheat	Wheat	Wheat
Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat

Results

Wherever treatments are mentioned such as lucerne, medic or chickpea, it refers to their effect on the 1995 wheat crop. On the black earth in the absence of N fertiliser, wheat yields following the 3 pasture legumes were significantly higher than after the other 3 treatments. When 120 kg N/ha was applied, long fallow and continuous wheat treatments yielded more than lucerne, and long fallow more than chickpea. There were no treatment differences when 60 kg N was applied. This rate gave maximum yield for all treatments, except long fallow, but 60 kg N was not significantly better than the unfertilised clover or lucerne treatments (Table 2).

Nitrogen uptake was superior for the 3 pasture legumes, with lucerne and clover being greater than medic which was greater than all other treatments in the absence of fertiliser N, a reflection of the higher yield and grain protein. While N fertiliser i ncreased uptake for all treatments at 60 kg N/ha, at 120 kg N/ha only the 2 non-legume crops were increased further.

On the red clay in the absence of N the 3 pasture legume treatments also outyielded the other 3. With 60 kg N, the medic treatment yielded more than lucerne, wheat and chickpea treatments, while with 120 kg N, long fallow and medic yielded significantly more than chickpea and lucerne treatments.
Each rate of N fertiliser significantly increased protein levels for each treatment and the 3 pasture legume treatments were higher than the 2 non-legume ones at all rates of N. Protein levels on the red clay were lower than on the black earth at all le vels of N. Protein levels for the clover and lucerne treatments increased significantly with increasing rates of N and were greater than all other treatments at all rates of

N. Protein levels for long fallow and continuous wheat treatments were not incr eased by 60 kg N/ha and these 2 treatments had the lowest protein levels at 120 kg N. Medic and chickpea treatments were better than long fallow and continuous wheat but inferior to clover and lucerne treatments.

On the red clay the 3 pasture legumes had greater N uptake than all other treatments at all rates of N, except lucerne at the highest rate of fertiliser. However, lucerne was still higher, although not significantly, than the other 3 treatments. All rat es of fertiliser N significantly increased N uptake for all treatments.

Plant available water was only measured to 60 cm and this was of insufficient depth to explain all treatment differences. However, plant available water did increase from 36 mm/60 cm for lucerne to 50 and 58 mm for wheat and long fallow on the black soi l and from 29 mm/60 cm for lucerne to 37 mm for long fallow on the red soil.

Table 2. The residual effects of 6 rotations on yield, protein and N uptake of wheat at 3 rates of nitrogen in 1995.

Treatment	Nitrogen Rate kg/ha	Black Earth Yield kg/ha	Black Earth Protein %	Black Earth N Uptake kg/ha	Red Clay Yield kg/ha	Red Clay Protein %	Red Clay N Uptake kg/ha
Clover	0	2760	10.8	55.7	2560	9.8	44.6
	60	3020	13.6	71.5	2910	11.4	58.2
	120	2720	14.9	71.2	2990	13.4	70.0
Lucerne	0	2760	11.9	58.3	2280	9.9	39.5
	60	2820	13.2	64.8	2690	12.2	53.2
	120	2560	14.5	66.5	2590	14.1	64.8
Medic	0	2530	10.1	44.5	2100	9.1	33.8
	60	2980	12.6	65.7	2990	10.6	54.4
	120	2800	14.6	74.3	3040	12.7	67.3
Chickpea	0	1950	9.7	33.3	1760	8.7	27.1
	60	3060	11.4	61.0	2610	10.1	46.4
	120	2690	13.9	65.3	2750	12.7	60.9
Long Fallow	0	1630	9.1	26.0	1500	8.6	22.7
	60	3100	10.2	55.8	2810	9.0	44.3
	120	3160	13.0	71.4	3130	11.4	62.4
Continuous Wheat	0	1770	9.6	30.1	1530	9.0	24.1
	60	3080	10.9	56.8	2670	9.5	44.5
	120	3000	13.2	70.4	3000	11.4	60.3
sed		184	0.46	4.26	138	0.34	2.84

Discussion

Lucerne was estimated to have produced 350 kg N/ha on the red soil and 400 kg/ha on the black soil during the 3 years growth (5). Clover produced about 200 kg/ha and medic about 150 kg N/ha over the same time. This is the possible reason for the 3 pastu re legumes increasing yields, protein and grain N uptake of wheat even though they were grown 5-7 years previously. Lucerne and subclover generally had a larger effect than the medic treatment because they produced the most dry matter. Long fallow and continuous wheat consistently resulted in the lowest yields and quality without N fertiliser. The other 2 treatments were intermediate. ?Chickpea contributed some N to the system and provided a disease break, but much of the N fixed by grain legume s is removed in the grain and generally leaves little stubble behind which rapidly breaks down due to its higher N content than cereal stubble.

Application of 60 kg N/ha removed any treatment effects on the black earth and reduced treatment effects on the red clay. Some of the highest wheat yields in the absence of N followed lucerne, but the lack of any further N response indicates that ot her factors (most likely water) are limiting yield. This is supported

by data showing that long fallow and continuous wheat which had the most available water at planting, gave the largest response to applied N. Lucerne not responding to the highest ra te of N, and long fallow increasing in yield from lowest without fertiliser to highest yielder with 120 kg N, shows the effect of soil moisture on yield. The lucerne treatment fixed the most N (5) and earlier work by Holford and Doyle (4) showed lucerne to dry the profile out the most to more than 2 metres, while the long fallow treatment stored the most moisture (6). While 60 kg N/ha increased yields over all unfertilised treatments, only the 2 non legume treatments responded to 120 kg N relative to 60 kg N.

The residual effect of pasture is clearly demonstrated in wheat protein levels with all 3 pasture legumes producing the highest protein levels at all rates of N on both soils. A minimum of 10% protein is required for wheat to be accepted as Australian P remium White and 13% for Prime Hard wheat. The 3 pasture legume treatments on the black earth were the only ones to exceed 10% without N fertiliser. These same 3 treatments plus the grain legume were also the only treatments to exceed 10% on the red cl ay soil with 60 kg N/ha. Lucerne and clover were the only 2 treatments to exceed 13% protein at 60 kg N/ha on the black earth and 120 kg N on the red clay soil (Table 2).

Grain N uptake was also greater for the 3 pasture legumes at all rates of N (except 120 kg N) on the black earth. While N fertiliser did not increase wheat yield following the pasture legume treatments as much as after the 2 non-legume treatments, it di d increase protein to higher levels. This is an added bonus of pasture legumes and it may be because the N is leached down the profile or takes longer to mineralise, and the crop takes it up later in the season, lifting the protein levels.

Conclusions

The residual effects of pasture legumes grown from 1988 to 1990 were evident in wheat sown in 1995. ?Wheat yields following these legume treatments were increased 30-70% over chickpea, long fallow and continuous wheat treatments in the absence of N fertiliser on the black earth and 20-70% on the red clay. The addition of 60 kg N/ha removed most treatment differences.

Protein levels of wheat were also much higher following the pasture legumes, especially for lucerne and subclover which were 1 to 2 units higher than long fallow and continuous wheat treatments on both soils in the absence of N fertiliser. Wheat pro tein following lucerne and subclover, exceeded the prime hard quality levels with 60 kg N/ha on the black soil and 120 kg N/ha on the red soil, and was at least 2 units higher than long fallow and continuous wheat.

On the red soil, protein levels for lucerne and clover were almost 1 unit higher than the 2 non- legume crops in the absence of N fertiliser and 1.5-3 units higher with 60 kg N/ha and the protein level of wheat, only following the clover and lucerne tre atments exceeded the premium grade wheat standard of 13% with 120 kg N/ha.

While lucerne increased yield and N uptake and reduced fertiliser N requirement in subsequent wheat crops it does have the disadvantage of drying out the soil profile which can restrict yields when other factors are not limiting. A maximum yield of arou nd 3 t/ha was achieved at both sites except in the lucerne treatment.

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