3.1 Comparison of different green manure crops as tools for renovation cropping and evaluating economic benefits at Mullewa on a heavy soil

Why do the trial?

This research determines to assess the benefits (economic and environmental) of a green manure phase under current cropping systems in areas with a poor nutritional status. The aim of this trial is to evaluate crop types and incorporation techniques to rejuvenate poor performing soils, as well as to identify and evaluate the potential longevity of benefits.

Treatments

Several crops including field peas, lathyrus, vetch, oats, oat/vetch mix, mustard and canola were evaluated in 1998 for their potential as a green manure crop. Treatments were imposed at flowering in September 1998, following the application of a broad-spectrum herbicide to ensure crop death. Crops were either green manured (disced), brown manured (sprayed and left standing) or mulched green (slashed).

Yield and quality response to imposed treatments, have been assessed by comparing results to a more conventional harvested field pea or chemical fallow treatment over a five year rotation (Trial phase: Wheat: Wheat: Field Pea: Wheat) from 1998 to 2002.

Trial design and statistical analysis

This trial was sown in a randomised split-split-block design. Statistical analysis of data (ANOVA) was performed using Genstat version 6.1.

Trial: 98MW31	
Location	
State: Western Australia	
District: North, E of Geraldton	
Town: Mullewa RSU, Paddock C	
Location: 347024 mE, 6836239 mN	
Rainfall	
Winter dominant	
Avg. annual total: 341 mm	
1999 GSRF: 323 mm (213 mm)	
2000 GSRF: 277 mm (167 mm)	
2001 GSRF: 234 mm (124 mm)	
2002 GSRF: 133 mm (23 mm)	
Paddock History	
2002: Wheat	
2001: Field peas	
2000: Wheat	
1999: Wheat	
1998: Renovation crops (various)	
Soil (initial)	
Type: Sandy loam (clay at depth)	
pH: 5.4 $CaCl_2$	
Org. Carbon: 0.45%	
P (Colwell): 35 ppm	
Significant crop diseases?	
Root: Nil	
Leaf: Minor	
Research plot size, replicates	
10m x 1.8m, 3 replicates	
Other significant factors?	
Below average growing season rainfall in 2000, 2001 and 2002. Poor fertility site with low nitrogen status and low organic carbon levels.	
Yield (after harvest pea treatment)	
1999 potential yield:	4.26 t/ha
Actual yield (wheat):	2.13 t/ha
2000 potential yield:	3.34 t/ha
Actual yield (wheat):	2.03 t/ha
2001 potential yield:	NA
Actual yield (peas):	NA
2002 potential yield:	0.46 t/ha
Actual yield (wheat):	0.49 t/ha
Water Use Efficiency	
1999 (wheat):	10 kg/mm
2000 (wheat):	16 kg/mm
2001 (field peas):	NA
2002 (wheat):	21 kg/mm

1998 RESULTS

Seeding Details in 1998

In 1998, the following crops were sown in order to determine any future benefits in grain yield and quality parameters.

- Sowing date: 29th May 1998
- Crop, variety, seed rate: Mustard (347.6.3.1.3) @ 6 kg ha
  Canola (Narendra) @ 6 kg ha
  Vetch (Languedoc) @ 65 kg ha
  Oats (Pallinup) @ 80 kg ha
  Vetch (75%):Oats (25%) @ 65kg ha
  Field peas (Dundale) @ 110 kg ha
  Lathyrus (Chalus) @ 60 kg ha
  Fallow (chemical)
- Base Fertiliser: 120kg/ha Super at seeding and 50kg/ha Urea topdressed
- Site management: Site tickled after early rain on approximately 10th May
- Herbicides: Sprayseed applied twice prior to seeding at 1L ha
  Oat, mustard and canola received 500mL Dicamba + 200mL Lontrel
  Vetch, lathyrus and oat/vetch received 40g Broadstrike

Field peas received 250g Lexone
Roundup @ 2L ha on 7th Spetember on renovation treatments

- Renovation: Mulching was done using a Fieldmaster mulcher
  Green manuring was done using a Weston plough

Soil Properties in 1998

Soil properties were sampled and characterised at the site prior to the implementation of treatments (Table 1) to identify and assess constraints to production. Initial measures for soil bulk density (dry) indicated a site value of 1.55 Mg/m^3 and a soil porosity value of 41% by volume. A slow infiltration rate (steady state flow) typical of poorly structured loams was measured at 28.4 mm per hour (Peverill et al., 1999).

Table 1. Soil properties for 98MW31, prior to the implementation of treatments in 1998 on a loam soil at Mullewa. Data is the site average.

Depth (cm)	Nitrate (mg/kg)	Ammonium (mg/kg)	Phosphorous (mg/kg)	Potassium (mg/kg)	Sulphur (mg/kg)	Organic Carbon (%)	Iron (mg/kg)	EC (dS/m)	pH ($CaC1_2$)
0-10	9.2	14.7	34.7	431.8	4.5	0.4	676.5	0.058	5.4
15-30	5.0	7.0	8.8	198.1	4.5	0.2	824.0	0.046	6.0
30-45	2.8	7.5	4.3	186.2	9.8	0.2	855.5	0.108	6.5

These results indicate the site is rated low-very low for salinity (Peverill et al., 1999) and suitable for wheat production. The site was determined to be nitrogen responsive (Mason, unpublished data), with sufficient phosphorous and very high potassium levels.

Trial Results in 1998

Potential nitrogen contributions were assessed from the dry weight and nitrogen content of the green manure crops in 1998. Forty per cent of the total above ground nitrogen was assumed to be available at seeding in 1999 (Table 2).

Crop biomass and tissue nitrogen (%) were the primary factors in determining the potential nitrogen contribution for different crops (Table 2). Legume crops had the highest tissue nitrogen and subsequently, total nitrogen of all treatments. There were no significant differences (P=0.05) measured in crop dry matter between incorporation treatments (data not presented).

Table 2. Average potential nitrogen contribution from green manure crops established in 1998 at Mullewa, calculated using crop biomass (dry weight) at anthesis and tissue nitrogen (%).

Crop Species	Tissue N content (%)	Plant dry matter (t/ha)	Total N (kg/ha)	Likely additional N at seeding in 1999 (kg/ha)**
Canola	0.61	2.7	16.6	6.6
Fieldpea	2.71	5.4	146.6	58.6
Lathyrus	3.94	3.2	128.1	51.2
Mustard	0.76	2.6	20.0	8.0
Oats	0.40	6.4	25.8	10.3
Oats/Vetch	1.55	3.8	58.7	23.5
Vetch	3.19	3.0	94.4	37.8
LSD(P=0.05)		*0.9*	*21.3*	

** Based on 40 per cent of nitrogen being available at seeding

Oats had the highest biomass but were extremely low in tissue nitrogen. Therefore the benefits from this type of crop, would be largely associated with the contribution of organic carbon to the soil. Emergence of both canola and mustard was poor, whilst lathyrus and vetch competed poorly with weeds due to slow initial growth. These crops may otherwise have resulted in higher amounts of biomass.

The percentage of undecomposed material remaining on the soil surface at seeding in 1999 varied depending on crop and method of incorporation. Residue levels remaining at seeding ranged from approximately 20% of the original dry matter, to complete decomposition. In general, the crops with higher tissue nitrogen content broke down more rapidly. This indicates the decomposition of legume residues is likely to be faster than for crops with lower nitrogen.

An evaluation of soil properties was carried out three months (Table 3) and again eight months after implementing renovation techniques. Results indicate an initial build up of nitrate nitrogen (N) under fallow treatments (3 months post implementation). Early changes under renovation techniques appear to be associated with increasing amounts of ammonium.

Table 3. Average soil properties (0-10 cm soil depth) measured prior to implementation and 3 months post treatment application for harvest control, fallow and green manure plots.

		Available N (mg/kg)		Organic
		Nitrate	Ammonium	Carbon (%)
Initial (May 1998)		9.2	14.7	0.45
Fallow	3 months post	21.3	6.7	0.51
Field pea (harvest)	3 months post	7.3	7.3	0.51
Field pea	3 months post	7.3	9.0	0.52
Canola	3 months post	3.3	6.7	0.53
Lathyrus	3 months post	4.0	18.3	0.58
Mustard	3 months post	4.7	7.3	0.62
Oat:vetch	3 months post	3.0	10.0	0.61
Oats	3 months post	1.7	4.0	0.56
Vetch	3 months post	4.0	15.7	0.60

The harvested field pea control treatment yielded 1.23 t/ha at this site.

Treatment responses appear to be variable, plant available nitrogen dependent on both crop and implementation techniques (Table 4). In general, for legume crops nitrogen release appears to be more rapid when green manured. This indicates that incorporation of residues into the soil increases the rate of decomposition and subsequent mineralisation of organic matter.

Table 4. Plant available nitrogen (ammonium and nitrate) and organic carbon (%) of soil assessed 3 months post green manuring in December 1998 for field peas, lathyrus and oats.

Crop	Technique	Available N (kg/ha)	Organic Carbon (%)
Field pea	Green manure	24	0.57
	Green mulch	14	0.49
	Brown manure	11	0.50
Lathyrus	Green manure	26	0.62
	Green mulch	22	0.58
	Brown manure	19	0.54
Oats	Green manure	8	0.66
	Green mulch	3	0.55
	Brown manure	6	0.48

1999 RESULTS

Seeding details in 1999

Following soil characterisation in 1999, wheat cultivar 'Carnamah' was sown and nitrogen treatments imposed in order to determine response for grain yield and quality parameters from treatments imposed in 1998.

- Sowing date: June 6th, 1999
- Crop, variety and seed rate: Wheat cv. 'Carnamah' @ 80kg/ha

- Base Fertiliser: 110 kg/ha Super Phos at seeding
- Fertiliser treatment: Urea topdressed June 17th at 0 (0N), 40 (40N) and 80 (80N) kg/N/ha.

Soil Properties in 1999

An evaluation of soil chemical fertility was carried out in May 1999, eight months after implementing renovation techniques to assess the effect of residue management and crop type (Table 5). Results indicate the initial build up of both nitrate and ammonium measured three months after residues, have disappeared. This indicates continued N mineralisation over summer and movement of N, either deeper into the soil profile or as a result of leaching. This is not surprising given the high amount of summer rainfall received at this site (approximately 197mm received January-April).

Soil analysis indicates organic carbon has increased on average over the site from approximately 0.45% measured prior to treatments in 1998 to 0.56% at seeding in 1999. A wide variation in organic carbon was observed under treatments, with no significant differences in 1999 (Table 5). Sampling of surface soil may be a limitation to the correct interpretation of results, as the treatments may have had a significant impact on the soil characteristics relative to the 'surface'.

No significant differences (P=0.05, data not presented) in soil chemical fertility were measured between treatments, when assessed prior to seeding in 1999.

Table 5. Average soil properties (0-10 cm soil depth) measured prior to implementation, and 8 months post treatment application for harvest control, fallow and green manure plots. Data is the average of all treatments.

	Nitrate (mg/kg)	Ammonium (mg/kg)	Phosphorous (mg/kg)	Potassium (mg/kg)	Sulphur (mg/kg)	Organic Carbon (%)	Iron (mg/kg)	EC (dS/m)	pH ($CaCl_2$)
May 1998	9.2	14.7	35	432	4.5	0.45	676	0.06	5.4
8 months post incorporation (May 1999)									
Fallow	7.0	1.3	34	351	4.7	0.47	775	0.039	5.4
Field Peas (harvest)	6.7	1.0	45	299	3.3	0.53	714	0.042	5.4
Canola	5.7	1.3	40	307	4.2	0.59	700	0.037	5.3
Field Peas	8.3	1.7	40	318	4.1	0.60	676	0.037	5.3
Lathyrus	7.0	2.0				0.51			
Mustard	4.0	2.0				0.54			
Oat/Vetch	6.3	1.7	40	328	4.4	0.52	713	0.034	5.3
Oats	7.0	2.0				0.59			
Vetch	8.0	3.0				0.61			

Physical soil parameters were difficult to estimate for treatments particularly for water infiltration and steady state flow rates. These measurements were done using disc permeameters, measurements replicated three times in each plot and treatments replicated 3 times in an effort to reduce the errors associated with variable results.

Results indicate the initial capacity for the soil to wet up (sorptivity) is significantly lower for fallow treatments compared to most renovation techniques and steady state flow rate through the profile is higher (Table 6). This may indicate the potential for treatments to enhance rapid entry of rainfall, and increase moisture retention by decreasing the rate of flow through the soil effectively. Data suggests the sorptivity rate has increased from initial rates measured in 1998, whilst the steady state flow rate remains unchanged for residue treatments.

Soil bulk density (dry) indicated no difference between imposed treatments and a soil porosity value of between 42 and 49% by volume was achieved (Table 6). No significant differences (P=0.05) in gravimetric water content (measured to 30cm depth) were observed prior to seeding in 1999 resulting from implementation of treatments in 1998.

Table 6. Physical soil parameters of soil at seeding in 1999 under field pea treatments imposed in 1998 at Mullewa on a loam soil.

Measurement	Fallow	Brown manure	Green manure	Green mulch	*LSD (P=0.05)*
Bulk density (Mg/m^3)	1.52	1.33	1.43	1.41	*0.26 NS*
Sorptivity (mm/hr)°	13.6 (Slow)	16.7 (Slow)	18.0 (Slow)	17.4 (Slow)	*3.4 **
Flow rate (mm/hr)	47.0	27.3	32.4	30.1	*8.8 ***
Total porosity (Mg/m^3)	42.3	49.4	45.7	46.5	*9.9 NS*
Volumetric water (%)	7.0	11.3	10.4	12.1	*6.3 NS*
Available water (mm/m)	69.6	113.2	103.6	121.3	

° Interpretation of water intake for infiltration rates was taken from Soil Analysis: an Interpretation Manual (Eds. K.I. Peverill, L.A. Sparrow and D.J. Reuter, CSIRO 1999, p.97)

Crop type also influenced water infiltration when green manured, with differences measured in initial sorptivity rate (data not presented). Fallow plots recorded the lowest sorptivity at approximately 13 mm/hr whilst green manure field peas recorded 18 mm/hr; oat/vetch, oats and vetch had slightly higher values ranging from 21.5-23.9 mm/hr, and canola recorded a high value of 30 mm/hr. No significant differences were observed in steady state flow rate. Soil porosity was significantly higher (P=0.05) on green manure treatments than when under fallow.

Trial Results in 1999

Crop establishment was as expected and averaged 145 plants/m^2 across the trial site. Tiller number was significantly influenced (P=0.05) by the application of nitrogen across treatments, increasing from 1.0 tillers/plant to 1.6 tillers/plant with 40 kg N ha. Early crop growth measured at stem elongation (DM stem) indicates fallow treatments had significantly greater plant biomass than other treatments and oat treatments had the least, as expected (Table 7). Field pea and lathyrus treatments had greater early biomass than non-legume residue treatments. However, at anthesis (DM anth), the best legume treatments indicated similar levels of crop biomass to fallow. Significantly greater biomass was achieved with additional nitrogen for all treatments at all growth stages (Table 7).

Table 7. Crop growth of wheat cv. 'Carnamah' in 1999, following green manure treatments imposed at Mullewa in 1998 on a loam soil. Data is the average of all treatments.

Treatment (Crop)	0N DM stem	40N DM stem	80N DM stem	0N DM anth	40N DM anth	80N DM anth
Canola	1.10	2.19		3.72	5.19	
Field peas (Harvest)	1.57*	2.12*	2.48	3.60*	4.80*	5.55
Field peas	1.53	2.58		4.44	5.33	
Fallow (Chemical)	1.85*	2.36*	2.44	4.35*	5.39*	5.28
Lathyrus	1.52	2.56		4.35	5.39	
Mustard	1.19	2.19		3.43	4.95	
Oats	0.87	1.66		2.11	4.79	
Oat/vetch mix	1.14	2.01		3.43	4.75	
Vetch	1.33	2.17		3.67	5.16	
LSD (P=0.05)	*0.26 (0.28*)*			*0.47 (0.50*)*		

Incorporation methods did not have a significant impact on early crop growth of wheat and were similar to both the harvest treatment and fallow treatments with nil nitrogen (data not presented). Application of nitrogen increased plant biomass at stem elongation, with fallow and harvest treatments increasing by 28-36%. Renovation treatments appear to have had a higher response rate to nitrogen application, increasing from between 61-81% in early biomass.

In 1999, grain yield on treatments with nil applied nitrogen was between 25 and 31% higher for the fallow, field pea and lathyrus green manures (Table 9) compared to the harvest control. Although smaller in magnitude, this response was also evident for the field pea and lathyrus green manure treatments when additional nitrogen was applied. For all other treatments, grain yield differences at nil applied nitrogen were reasonably consistent with responses at 40 kg N ha.

Table 8. Grain yield and protein of wheat cv. 'Carnamah' in 1999, following green manure crops treatments imposed at Mullewa in 1998 on a loam soil. Data is the average of all treatments.

	Yield (t/ha)		Protein (%)	
Treatment	0N	40N	0N	40N
Canola	1.74	2.06	9.6	10.7
Field peas (Harvest)	1.62	2.04	9.9	10.9
Field peas	2.13	2.23	10.4	11.8
Fallow (Chemical)	2.02	2.08	10.4	11.7
Lathyrus	2.11	2.25	10.3	11.6
Mustard	1.78	2.09	9.6	10.7
Oats	1.31	1.89	9.7	10.2
Oat/vetch mix	1.74	2.03	10.1	11.1
Vetch	1.85	2.10	10.1	11.6
LSD (P=0.05)	*0.15*		*0.4*	
	(0.13 within crop)		*(0.44 within crop)*	

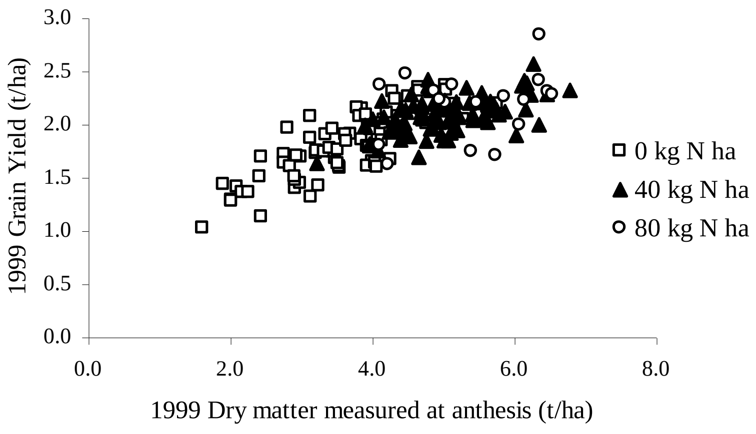
No significant differences in 1999 grain yield or protein were observed under the different incorporation techniques such as green manuring, brown manuring or mulching (data not presented). This may be in part due to the high rainfall experienced in early 1999, possibly contributing to a loss of available nitrogen through leaching and influencing trial results.

In general, grain protein was highest under renovation legume and fallow treatments (Table 9). Increasing grain protein was also observed with nitrogen application, though no interaction with crop species was apparent (Table 9). The extra fertiliser nitrogen increased grain protein by similar amounts in all treatments. This suggests that all treatments were still responsive to nitrogen, even where green manure crops had been incorporated.

A subset of treatments had additional nitrogen applied at 80 kg N ha. In these treatments, grain yield and head number on harvest and fallow treatments remained unchanged (data not presented). A significant reduction in grain weight was however observed (P=0.05), with a corresponding increase in grain protein to between 13.0 and 13.3% for fallow and harvest treatments respectively. Contrary to expectation, grain screenings also continued to decline with increasing nitrogen rates (data not presented).

Other yield components such as effective heads (number/m^2), increased significantly (P=0.05), whilst average grain weight and hectolitre weight (weight by volume) declined with the application of nitrogen at 40 kg N ha (data not presented). Harvest index did not change for any treatments and averaged 53% for the trial. Black point at this site was high (average percentage black point affected grain was 22%) but decreased almost 10% with increasing nitrogen (data not presented). Small grain screenings were below 1.5% and tended to be reduced when supplied with extra nitrogen (data not presented). Harvested field pea and fallow treatments were observed to have the highest grain screenings and significant reductions (P=0.05, data not presented) were observed with additional nitrogen.

A strong relationship was evident between plant biomass measured at anthesis and grain yield. This relationship was significantly influenced by nitrogen rate, with increasing nitrogen rates explaining less of the variation in grain yield observed (Figure 1). No relationship was evident between grain



trogen at seeding (data not

nthesis and grain yield (t/ha) of

ata is the average of all

R^2=0.65

R^2=0.26

There appears to be little evidence of a relationship between potential nitrogen calculated from crop residues in 1998 (above ground dry matter only) and either grain yield (Figure 2) or crop biomass in 1999. Neither is any relationship evident between grain yield and either volumetric water to 30cm depth or plant available nitrogen at seeding (data not presented).

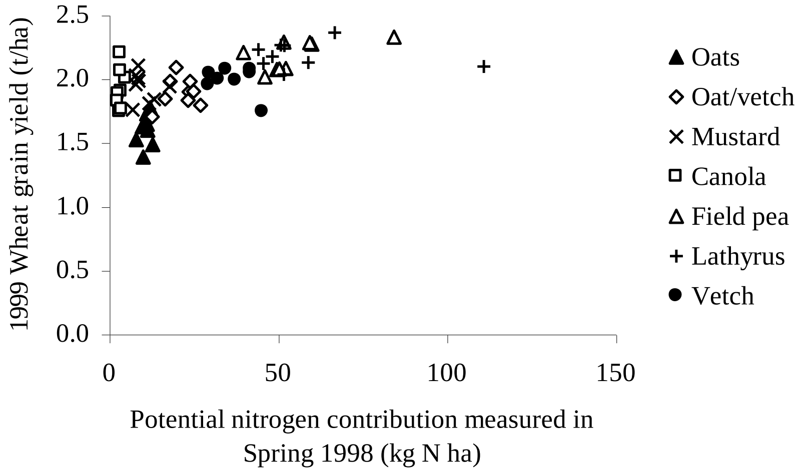


Figure 2. Relationship between potential nitrogen (kg N ha) contributed from above ground dry matter in 1998, and grain yield (t/ha) of wheat cv. 'Carnamah' in 1999 for different crop residue treatments. Data is the average of all treatments.

2000 RESULTS

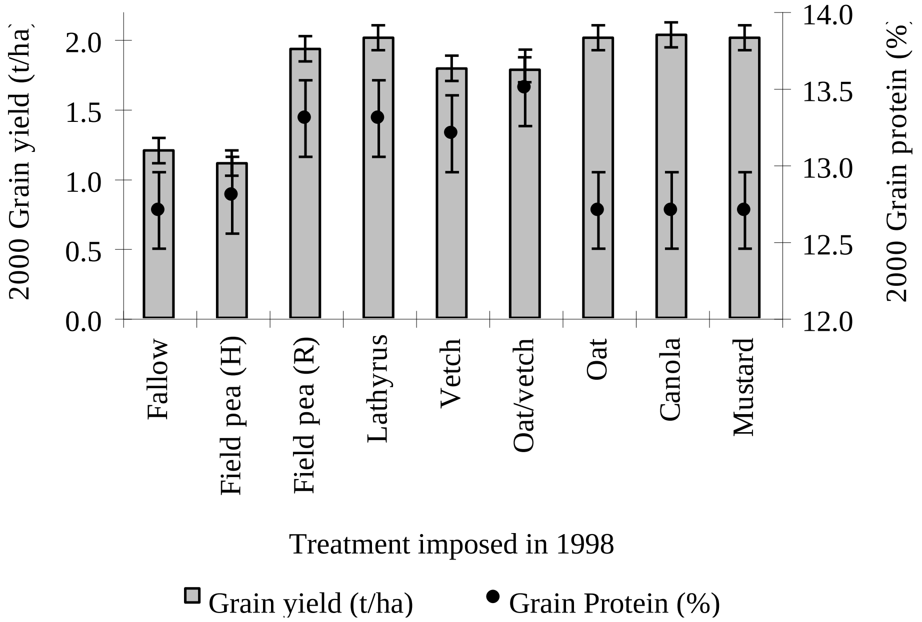
Seeding Details in 2000

In 2000, Ajana wheat was sown in order to determine any further benefits in grain yield and quality parameters from treatments imposed in 1998.

- Sowing date: June 16th, 2000
- Crop, variety and seed rate: Wheat cv. 'Ajana' @ 80 kg/ha
- Base Fertiliser: 130 kg ha Agstar at seeding

Trial Results in 2000

In 2000, the harvested field pea and fallow treatments had significantly lower grain yields than other treatments (Figure 3), indicating the benefits of renovation techniques may be maintained for longer than a single season. Lathyrus sp. and field peas were the best renovation choices. No significant differences in grain yield or protein were observed under the different incorporation techniques such as green manuring, brown manuring or mulching in 2000. Neither was there any effect of the nitrogen (40 kg N ha) treatments imposed in 1999, on crop growth and yield in 2000. Subsequently, data is presented as an average value.



F... following renovation t... l treatments.

Grain protein for the site was above the 11.5% typically required for Australian Hard (Figure 3). Lower grain proteins were observed in mustard, oat, canola, fallow and harvested field pea treatments, than other treatments. Due to the relatively low growing season rainfall experienced at this site in 2000, subsequent reductions in grain quality were largely associated with small grain screenings greater than 5%.

Additional nitrogen applications on harvested field pea and fallow treatments (80 kg N ha), indicate significantly higher grain yields and protein content were achieved compared to nil treatments. Yield increased a further 0.5 t/ha to approximately 1.7 t/ha, whilst protein increased by 0.3 %.

2001 RESULTS

Seeding Details

In 2001, field peas were sown in order to determine any ongoing benefits in grain yield and quality parameters from treatments imposed in 1998.

- Sowing date: 7th June 2001
- Crop, variety and seed rate: Field pea cv. 'Parafield' @ 110kg/ha
- Base Fertiliser: 79 kg/ha DAP at seeding
- Herbicides: 2 L Bladex May 21st
  2 L Dc Tron + 0.3 L Targa + 0.3 L Wetter July 24th
  300mL Fastac 3rd September (misted)

Trial Results

Grain yield in 2001 was not significantly influenced by treatments imposed in 1998 or 1999, ranging from 3.6 to 4.7 t/ha (Figure 4).

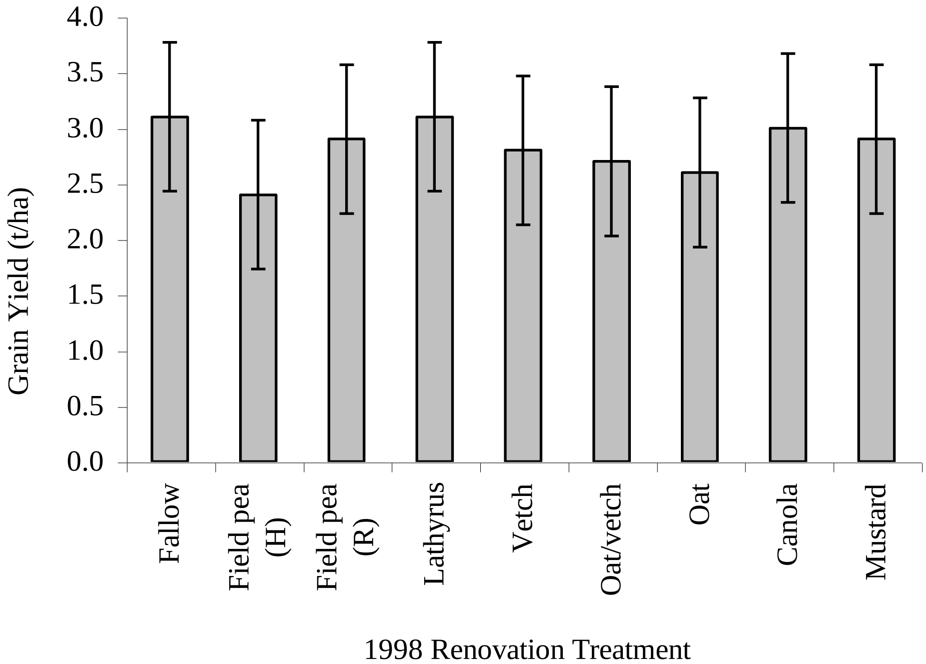


Figure 4. Grain yield (t/ha) of field pea cv. 'Parafield' in 2001 following renovation treatments imposed on a loam soil at Mullewa in 1998. Data is the average of all treatments.

2002 RESULTS

Seeding Details in 2002

In 2002, wheat cv. ‘Carnamah’ was sown in order to determine medium term benefits in grain yield and quality parameters from treatments imposed in 1998.

- Sowing date: 21st May, 2002
- Seed rate: 83 kg/ha
- Crop, variety and seed rate: Wheat cv. ‘Carnamah’
- Base Fertiliser: 85 kg/ha Maxamstar at seeding, 50 kg/ha urea topdressed 18th June
- Sprayed: 350mL Diuron + 450mL HCPA + 100mL Lontrel
- Other: 1.5 t/ha lime topdressed over whole trial area

Trial Results in 2002

Grain yield and protein in 2002 was not influenced by treatments or crop type imposed in 1998, and was limited by low growing season rainfall at this site. Grain yields ranged from 0.44 to 0.52 t/ha, whilst grain protein averaged 16.8% for the site (data not presented). Seasonal conditions are reflected in low hectolitre weight (well under current receival specifications at less than 71 kg per hectolitre), high screenings (between 9 and 13%) and high grain protein (>16%) at this site (data not presented).

Economics 1998-2002

This trial site (established in 1998 at Mullewa) indicates harvested field pea treatments continued to achieve significantly lower grain yields than green manured treatments for approximately three years, indicating the benefits of renovation techniques may be maintained for longer than a single season. The total income for each of the years during which this trial has been conducted are detailed in Table 10, including total income per hectare over five years for selected treatments.

Table 9. Total income of a five year rotation (GM: wheat: wheat: peas: wheat) following green manure treatments imposed at Mullewa in 1998 on a loam soil. Data is the average of all treatments.

Green manure Crop	1998 Pea Yield (t/ha)	1999 Wheat Yield (t/ha)	2000 Wheat Yield (t/ha)	2001 Pea Yield (t/ha)	2002 Wheat Yield (t/ha)	* Income 1998-2001 ($/ha)	* Income 1998-2002 ($/ha)
Canola	0	1.9	2.0	3.0		$1483	
Field peas (Harvest)	1.23	1.8	1.1	2.4	0.47	$1426	$1541
Field peas	0	2.2	1.9	2.9	0.49	$1522	$1644
Fallow (Chemical)	0	2.1	1.2	3.1	0.44	$1369	$1477
Lathyrus	0	2.2	2.0	3.1		$1599	
Mustard	0	1.9	2.0	2.9		$1461	
Oats	0	1.6	2.0	2.6	0.46	$1353	$1466
Oat/vetch mix	0	1.9	1.8	2.7		$1359	
Vetch	0	2.0	1.8	2.8		$1401	

** This calculation is presented per hectare and represents the return on actual crop yields based on AWB pool prices (Golden Rewards) for relevant years, including protein payments and inclusion of any dockages applicable for grain screenings and black point. Costs have been deducted for treatments applied in 1998 but have not been deducted since (assumed to be the same).*

Conclusions or recommendations

Potential nitrogen contributions are assumed to be 40% of the total nitrogen contribution, assessed from the dry weight and nitrogen content (N% tissue) of the green manure crops measured at anthesis. Legume crops provided the most potential nitrogen of all treatments, due to high tissue nitrogen and moderate to high biomass production. Oats had the highest biomass but were low in tissue nitrogen and potential nitrogen benefits were therefore negligible. Any benefits from this type of crop, would be largely associated with the contribution of organic carbon to the soil. Emergence of both canola and mustard was poor, whilst the lathyrus and vetch competed poorly with weeds due to slow initial growth.

The percentage of undecomposed material remaining on the soil surface at seeding in 1999, varied from approximately 35% for oats down to 10% for lathyrus. The general pattern was that the crops with higher tissue nitrogen content broke down quicker. This indicates the microbial degradation of legume crops is likely to be faster than for brassica or cereal crops.

Differences in water infiltration observed may indicate the potential for treatments to increase the initial sorptivity of soil (ability for more rapid entry of rainfall) and decrease the flow rate through the soil (effectively increasing moisture retention). This may allow earlier sowing after summer rains, increased moisture availability during the growing season and potentially longer availability under dry finishing conditions. These results are variable and subject to trial/operator error. Further evaluation of these attributes is required prior to evaluation of renovation techniques.

The high cost of seeding and maintenance of the green manure crop, can significantly influence the gains or losses experienced over this three year period. It may be most economic, to green manure legume crops in seasons with low potential returns (poor yield potential or price). The cost of harvesting a lupin crop for example may prove less beneficial than using it as a green manure to improve wheat yield and quality, where prices are depressed or where disease/season has reduced yield potential. Strategic use of green manure crops as a tool in integrated weed management or potential productivity gains through addressing specific problems may result in little or no short term economic gain where employed in better performing paddocks and must be viewed as a long term strategy to overcome yield constraints. However, strategic use of these techniques for poor performing paddocks, or paddock that would have otherwise been ‘rested’, are likely to result in economic responses, particularly where using low cost crops or pasture has been employed as there is no requirement to recover the cost of foregone yield – only those associated with growing a crop and the implementation of techniques.

Total income for each of the five years during which this trial has been conducted, are detailed in Table 10, including total income per hectare over this period for some treatments. This data supports the hypothesis that a green manuring:wheat:wheat rotation, may be as profitable as a legume:wheat:wheat rotation using either a field pea or *Lathyrus* crop. Given this assessment does not include any additional benefits that may be gained from green or brown manuring in terms of additional weed control and potential improvement of soil characteristics such as the addition of organic material, improved soil structure and longer term productivity gains, these techniques are likely to prove both economical and sustainable by providing additional benefits that may be observed in lower herbicide costs through better weed management, improved soil health and a more flexible farming system.