Winter tickbeans (*Vicia faba* L. var. minor) to enhance organic production

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Abstract

Under organic production systems winter cover crops play an important role in maintaining the fertility and structure of the soil. In this work we sought to quantify the advantages of tickbean (*Vicia faba* L. var minor) as a winter cover crop. Tickbeans were sown at three week (nominal) intervals from May-July 2003, at four monitor farms in the Eastland (Tairawhiti) region of the North Island of New Zealand. At termination (7^{th}-8^{th} October 2003), the tickbean biomass' averaged across all locations were 12.1, 6.6, 2.6, 0.7 t DM/ha^{-1} (for sowing dates 1,2,3 & 4 respectively). Apparent N-credit, an estimate of the sum of N-fixation and N-tie up, was estimated at 26 kg N (r^2=0.94) for every t DM/ha of shoot biomass. At three of the four sites, sweet corn was grown the following season. Nitrogen uptake by the sweet corn allocated to the earliest sown tickbean crops was increased significantly. Yield, however, was unaffected. At the other site the subsequent crop was maize. Here, yield was significantly higher (10 % level) after tickbean than after fallow treatments. Plant N uptake was not measured.

Additional key words: legumes, winter cover crops, sowing time, RPR, rock phosphate, nitrogen fixation

Introduction

Organic farming aims to be an integrated and sustainable agricultural system. It avoids the use of synthetically compounded fertiliser, pesticides and growth regulators. The system relies on crop rotations, crop residues, animal manures, legumes, winter cover crops, composts etc. to maintain soil fertility and to supply plant nutrients and control insects, weeds and other pests.

In a comparison between organic and conventional farming systems in New Zealand, Condron *et al.*, (2000) stated that organic farming under a well managed Bio-Gro organic system, with an adequate supply of nutrients, is probably sustainable over the long-term, but there are concerns about the supplies of nitrogen and of trace elements. In an effort to maintain and/or enhance soil quality and fertility, winter cover crops can play an important role by increasing the soil fertility and retaining minerals that might otherwise be leached out of the rooting zone; improving the soil structure and water holding capacity through the incorporation of crop residues; protecting the soil from erosion and structural degradation; breaking disease cycles and better control of weeds. Legumes are crucial as they can add nitrogen to the system. Lupins (*Lupinus angustifolius*) were widely used as a winter cover crop in New Zealand until the second World War (Vellasamy *et al.*, 1999). Janson and Knight (1980) showed that tickbeans (*Vicia faba* L. var. minor) have better potential as a cover crop as part of a green feed study comparing four legumes (clover, tickbean, pea and lupin). In addition, tickbeans or pigeon beans are more suitable for both standing green feed (Janson and Knight, 1980) and ensiling (see www.hort.purdue.edu/newcrop/afcm/fababean.html), giving them a potential advantage over the more traditional lupin crop.

The primary objective of the work reported here was to test the hypothesis that under organic production systems a winter cover crop of tickbeans will enhance availability of soil nitrogen (N) for a subsequent crop, leading to increased yield. The work had further objectives, which were to demonstrate to the farmers involved in the project: (1) the benefits of early sowing of winter tickbean cover crops and (2) the effects of summer crop sowing time on the performance of the summer crop.

Trials were established on four monitor farms in the Eastland (Tairawhiti) region, ranging from Manutuke in the south to Ruatoria in the north. Unfortunately, the remoteness of the locations and seasonal conditions lead to difficulties in establishing the summer crops.

Materials and Methods

The trials were conducted on four farm properties in Ruatoria, Tolaga Bay and Manatuke (two sites) in winter 2003 and summer 2003-2004, and farmers were involved (at varying degrees) in assisting with planting, cultivation, weed management and harvesting. Each site had an un-replicated 12-plot trial established. Plot size varied between sites and ranged from 120 m^2 to 192 m^2. Soil samples (0-15 cm), both before and after tickbeans were sown, were analysed by Analytical Research Laboratories (Table 1) using the New Zealand standard techniques for pH (1:25 w/v in water), bicarbonate-extractable (Olsen) P, exchangeable cations, bulk density and readily mineralisable N (0-30cm, using Keeney and Bremner's (1966) technique of anaerobic incubation at 40 ^{0}C).

Table 1. Soil Properties at the start of the project.

Site	pH	Olsen-soluble P ug/mL	Calcium MAF	Magnesium MAF	Potassium MAF	Sodium MAF	Min. Nitrogen kg/ha	Dry WT/Vol g/mL	CEC me/100 g
	5.3	10	11	61	9	8	114	0.81	22
2	6.1	16	18	75	16	7	146	0.96	23
3	6.7	14	29	52	22	8	67	1.10	25
4	6.0	22	21	68	24	10	156	1.14	23

Site	Calcium me/100 g	Magnesium me/100g	Potassium me/100g	Sodium me/100g	Ca %	Mg %	K %	Na %	Total
	11	3.3	0.6	0.2	47.5	14.7	2.6	0.8	66
2	15	3.4	0.8	0.1	63.5	14.4	3.5	0.6	82
3	20	2.0	1.0	0.1	81.9	8.3	3.9	0.5	95
4	15	2.7	1.1	0.2	65.6	11.8	4.7	0.7	83

Site 1 received a total of 3 t/ha of reactive phosphate rock (RPR) split into two equal applications equating to 400 kg/ha total P or 175 kg/ha citric soluble P. The first application was broadcast over the whole trial area just prior to the first tickbean sowing time. The second application was drilled directly beneath the seed when tickbean was sown. This application of RPR raised the Olsen-P value from 10mg/ml (1st May 03) to 12 mg/ml (8th Oct 03). The other three sites had similar Olsen-P values in May and October.

Nitrogen credit (N_c) estimates were calculated as follows:

$$N_c = \Delta N_t - \Delta N_f + cN$$

Where: ΔN_t = change in soil readily mineralisable N before and after tickbeans were grown (kg N/ha)

ΔN_f = change in soil readily mineralisable N over the same time period of fallow treatment (kg N/ha)

cN = total shoot N (kg N/ha)

Winter sowing time trials

Experiment 1: Tickbeans (cv. Maris Bead) were sown at 30-50 seeds/m^2 on four consecutive sowing dates (Table 2) at a 15 cm row spacing using an 11-row seed drill. Four plots were left fallow over winter. At site 2 there were only two consecutive sowing dates, due to unfavourable weather and soil conditions, and five plots were left fallow over winter. At *ca.* three weekly intervals, two 1 m^2 quadrat samples were taken from selected plots covering the range of sowing times planted. From these samples estimates of total biomass (t DM/ha) and plant density (plants/m^2) were obtained.

Final harvest was at 7th and 8th October 2003 when the tickbeans were incorporated into the soil with a rotary hoe (site 1) or mulched (site 2, 3 and 4).

Table 2. Winter cover crop (tickbean) experiment (2003) site details. ST = sowing time.

			Experiment 1				
Site	Crop	Sow rate (seeds/ha)	Winter-ST 1	Winter-ST 2	Winter-ST 3	Winter-ST 4	Harvest date
1	Tickbean	500,000	1-May	29-May	24-Jun	16-Jul	8-Oct
2	Tickbean	300,000	6-May	30-May	-	-	8-Oct
3	Tickbean	500,000	1-May	29-May	23-Jun	16-Jul	7-Oct
4	Tickbean	500,000	1-May	3-Jun	23-Jun	16-Jul	7-Oct

Summer crop experiments

Experiment 2: Sweet corn (cv. Chieftan) (sites 1, 3 and 4) and maize (Corson hybrid N4187) (site 2) was sown either by hand (site 1) or by vacuum seeder (sites 2, 3 and 4) at a fixed site-specific sowing date (Table 3). The summer crops were sown into four cultivated plots allocated to the various tickbean winter sowing times (Table 2), along with a plot that remained fallow over winter (sites 1, 2 and 3). All plots at site 4 were sown relatively late (7th Dec) due to establishment problems for the earlier sowing dates (see below).

Table 3. Summer crop (sweet corn and maize) experiments (2003/2004) site details. ST = sowing time.

			Experiment 2	Experiment 3			
Site	Crop	Sow rate (seeds/ha)	Summer-ST	Summer-ST 1	Summer-ST 2	Summer-ST 3	Summer-ST 4
1	Sweet corn	60,000	19-Nov	16-Oct	7-Nov	19-Nov	5-Dec
2	Maize	100,000	3-Nov	3-Nov	19-Nov	4-Dec	18-Dec
3	Sweet corn	60,000	24-Nov	28-Oct	24-Nov	7-Dec	-
4	Sweet corn	60,000	7-Dec	-	-	-	-

Weeds were managed by a combination of hand hoeing and inter-row cultivation (small hand rotary hoe) at site 1, inter-row cultivation (spider weeder), mounding and a follow-up hand weeding at site 3 and by cultivation (spider weeder) and mounding only at site 4.

Sweet corn yields were estimated by performing the following measures in two separate areas (averaged for analysis) within each plot: (1) population (number of plants in two x 5m row lengths); (2) yield (cobs removed and weighed from 30 randomly selected plants, a sub-sample (S/S) was collected, weighed and oven dried at 70 °C until a constant mass was attained. Yield (t DM/ha, t FM/ha) was determined by the relationship between sample weight, DM % and estimated population); (3) total biomass and whole crop N % (10 whole plants collected, weighed and a S/S collected (ca 400 g), weighed and oven dried at 70 °C until a constant mass was attained. Total biomass (t DM/ha) was determined by the relationship between sample weight, DM % and estimated population).

Maize was harvested for grain yield only by collecting the ears from two three-metre lengths of row in each plot. Grain was then removed using a Ransomes automated sheller. Total grain FM was recorded and a S/S collected (ca 900 ml), weighed and oven dried at 70 °C until a constant mass was attained. Grain yields are reported at 14 % moisture content.

Experiment 3: Sweet corn (cv. Chieftan) (site 1, 3) and maize (Corson hybrid N4187) (site 2) were sown by hand (site 1) or by vacuum seeder (sites 2 and 3) at four different sowing dates (Table 3). Site 4 was not included in this experiment due to problems with establishment in the first two sowing dates. At each sowing time, the summer crop was sown into a plot that had a full winter cover of tickbeans (tickbean winter ST1) along with a plot that remained fallow. These plots were paired at the beginning of the experiment based on native soil readily mineralisable nitrogen present at the start of the project. Harvest procedure was using the same method as described in experiment 1.

All data was statistically analysed by ANOVA and (non-linear) regression (Genstat 7.1) using either sites (tickbean winter sowing time experiment 1 and summer crop experiment 2; Figures 1, 2, 3 and 4) or summer sowing times at a site (experiment 3) as replicates (blocks).

Results and discussion

Tickbean sowing time trials

Despite the very wet conditions prevalent during the winter of 2003, tickbeans grew very well. Tickbeans at all sites showed similar growth patterns (relative to the growth stage) for each sowing date (Figure 1). At termination (7-8 October 2003), tickbean biomass' averaged across all locations were 12.1, 6.6, 2.6, 0.7 t DM ha^{-1} (sowing dates 1, 2, 3 & 4 respectively) (Figure 1). Total biomass plotted against days after sowing showed a similar curve (r^2=0.98) for all four sowing times (Figure 2).

$$Total\ Biomass = 0.11 * 1.03^{DaysAfterSowing}$$

Due to the "whole-systems" approach of the project, nitrogen-credit (fixation + tie-up, kg N/ha) rather than N-fixation only, was used as means of describing the benefits of tickbeans on the N status of the soil.

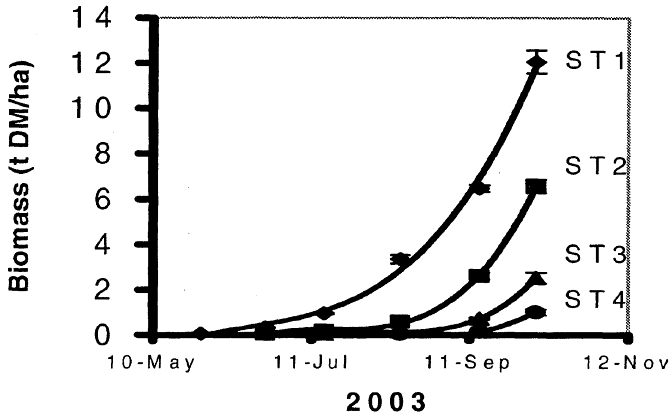

Figure 1. Tickbean biomass (t DM/ha ± SE) for each of the four sowing times (STs) averaged over the sites. ST1 and ST2 having four sites (n=4); ST3 and ST4 having only 3 sites (n=3). See Table 2 for experimental details. Error bars indicate standard errors of the treatment means (SE).

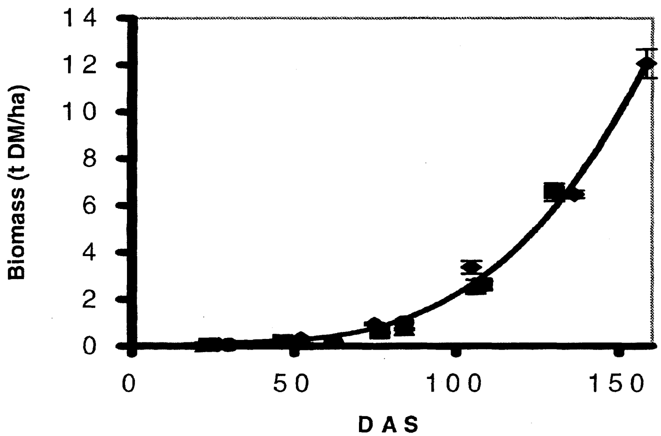

Figure 2. Tickbean biomass (t DM/ha ± SE) for each of the four sowing times (STs) averaged over the four sites, plotted against days after sowing (DAS). ST1 and ST2 having four sites (n=4); ST3 and ST4 having only 3 sites (n=3). See Table 2 for experimental details. Error bars indicate standard errors of the treatment means (SE).

Results (Figure 3) show a strong relationship between the amount of nitrogen credited and the biomass of the tickbean crop. Averaged over all sites, approximately 26 kg N was credited for every t (shoot) DM produced (r^2=0.94). The amount of N still tied up in the root systems of the crops was not measured but other work (Rochester *et al.,* 2001; Vellasamy; *et al.,* 1999), looking at percentage of whole plant nitrogen which is root nitrogen, the percentage of whole plant (roots + shoots) nitrogen in the roots, suggests that this can be quite variable, with figures ranging from 40 % to 17 %.

This figure is in agreement with those reported by Evans *et al.*, (1989), McCallum *et al.*, (2000) and Rochester *et al.*, (2001), whose figures ranged from 19-24 kg fixed N/t DM (including estimates of root N but not N-tie-up) using a range of legumes over a wide range of environments. Our data clearly indicate that when tickbeans were planted early, they produced much more dry matter and credited large amounts of N, which should boost soil nitrogen fertility and organic matter content. When they are planted late (after mid-late May), dry matter production and N credit is unlikely to be as substantial, due to a shorter crop duration in combination with a slow growth rate and slow N fixation at low temperatures.

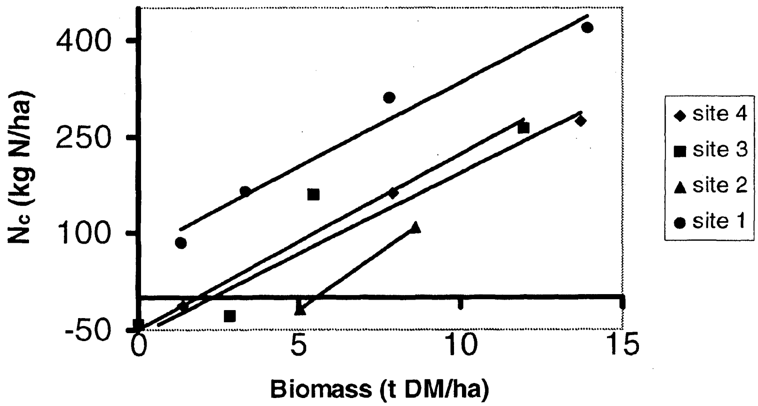

Figure 3. Nitrogen credit (N_c) in response to total tickbean biomass for each of the four sites (see text for details).

Summer crop experiments

Although our estimations of N-fixation described above indicated that significant amounts of N were contributed by the earlier tickbean sowing times, the subsequent sweet corn crops didn't show any significant differences in yield (average = 9.1 t/ha FM, CV 65 %)or total biomass accumulation (average = 7.2 t/ha DM, CV 40 %). This was thought to be attributed to a high level of variability in the sweet corn crops imparted by problems with crop establishment, and seasonal conditions (wet, cold then dry).

However, in a more uniform maize crop (site 2) there was a slight positive difference in grain yield (0.7 t/ha; P=0.075) in favour of winter tickbean over fallow. This effect was thought to be noteworthy because site 2 had up to 300 kg (average 240 ± 34 kg N/ha) of soil N available in fallow plots, This would have dramatically reduced any chance of detecting a response due to additional N, or N uptake brought about by the tickbeans.

Analysing the whole crop N % data for sweetcorn at each site using the summer crop sowing times as replicates (df=8) showed no significant differences (P >0.05) between early sown winter tickbeans and winter fallow. Reanalysing the data using the sites as replicates but with the tickbean sowing times (including fallow) as treatments (df=13), showed that tickbean sowing time 1 significantly (P=0.007) improved total crop N % (ie. N uptake) above all other treatments and by 0.312 % above the fallow treatment (Figure 4).

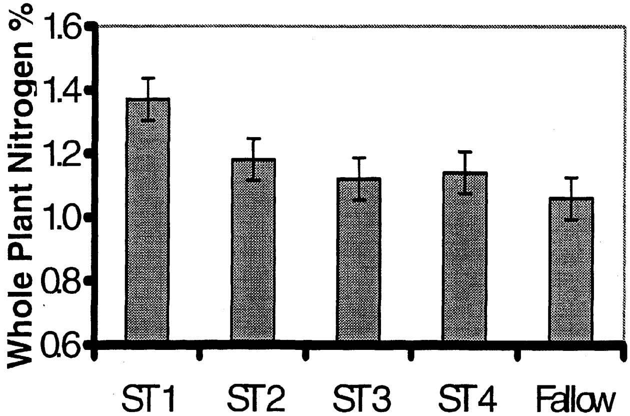

Figure 4. Whole plant nitrogen percentage (N%) of sweet corn for each of the four winter sowing time (ST) and fallow treatments. Error bars indicate LSD (5% level).

Conclusions

Tickbeans sown on 21st May produced 5.5 t DM/ha less than crops sown on 1st May. Around 26 kg N/ha (including fixation and tie-up) was credited for every tonne of tickbean shoot DM produced. Clearly, early sowing is a key requisite for maximising the benefits of winter tickbeans.

Whole crop N % was higher (P=0.007) in land that had winter tickbean sown on/around 1st May than in land that had later sowings or which remained fallow over winter. The advantages of winter tickbeans used as a green manure crop to boost subsequent summer crop performance may be limited to crops sown before mid-May.

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