Effects of soil incorporated tagasaste herbage on the growth of maize

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Abstract

Maize (*Zea mays* L.) dry matter (DM) and grain yield after soil incorporation of tagasaste (*Chameaecytisus palmensis* L.) herbage, and the effects of this incorporation on soil chemical and physical properties were assessed in a field trial in 1997/98. Maize was sown four (November) and eight (December) weeks after the incorporation of four rates (0, 5, 10 and 15 t DM/ha) of finely chopped tagasaste into the seedbed. Incorporation of 15 t DM/ha tagasaste increased maize DM yield from 19,740 to 25,430 kg/ha and grain yield by 33%. The November sown crop produced significantly higher grain yield than the December sown crop but DM yield did not differ with sowing date. Leaf area duration (LAD) increased with 15 t DM/ha incorporation but sowing date had no significant effect. Maize sown in November intercepted 17% more photosynthetically active radiation (PAR) but had a lower radiation use efficiency (RUE), than the December sown crop. Tagasaste incorporation increased RUE from 2.59 to 3.22 g DM/MJ of intercepted PAR at 0 and 15 t DM/ha levels respectively. Tagasaste incorporation reduced soil bulk density and increased total soil N, NO_3^- and C but had no influence on soil C:N ratio and pH. The results show that tagasaste incorporation can improve soil fertility and increase succeeding crop yield.

Additional key words: Chameaecytisus palmensis, Zea mays, *dry matter yield, photosynthetically active radiation, radiation use efficiency, soil fertility*

Introduction

Using legume plant residues to improve soil productivity in agricultural systems in countries which use low inputs of nitrogen (N) fertilisers is once more attracting interest. In New Zealand, the bulk of soil N comes from organic N via biological N fixation. Walker (1995) reported that white clover (*Trifolium repens* L.) pasture in New Zealand fixed 210 kg N/ha per year and that this N fixation was equivalent to 4.5 million tonnes of urea annually. This reduces the fertiliser cost of growing subsequent crops (Taylor, 1980). Both McKenzie and Hill (1984) and Dalland *et al.* (1993) have shown through experiments that soil fertility can be improved significantly through the incorporation of legumes in crop rotations. In Kenya, the yield of maize intercropped with *Leucaena leucocephala* (Lam.) deWit and cowpea (*Vigna unguiculata* (L.) Walp.) was increased, and the need for fertiliser N reduced (Mureithi *et al.*, 1995). Marshall *et al.* (1996) and Yamoah (1997) reported that organic matter incorporation reduces soil bulk density, although organic matter breakdown may be determined by soil factors such as moisture and temperature which may vary with sowing date.

A study in Canterbury, New Zealand, to assess maize yield responses to time of sowing by Johnstone and Wilson (1991) showed that October sown crops yielded 19% more grain than November sown crops. Early sowing in Canterbury is important as, at least with early maturing cultivars, early sowing can help to ensure the crop matures before the onset of early frost (Wilson *et al.*, 1991). In New Zealand, the effects of organic matter incorporation on subsequent maize production have not been extensively investigated. The aims of this study were to assess the effects of tagasaste dry matter (DM) incorporation, and maize sowing date, on the DM and grain yield of maize.

Materials and Methods

The experiment was conducted on a Templeton silt loam soil at Lincoln University (New Zealand Soil Bureau, 1968). The treatments were four rates of tagasaste incorporation (0, 5, 10, 15 t DM/ha) and as a bioassay two rates of calcium ammonium nitrate (100 and 200 kg N/ha). Maize seed (cv. Janna) was sown at four weeks (7 November 1997) and eight weeks (5 December 1997) after tagasaste incorporation. The experiment was a 2 x 4 factorial randomised complete block design. There were three replicates and the plot size was 6.3 m x 5 m.

Tagasaste biomass was harvested and applied fresh after subsampling for DM, N and carbon (C) percentages. Nitrogen and C were determined using a Leco CNS-2000 analyser. Tagasaste clippings consisted of leaf : stem ratio of 3:1 chopped into small pieces (about 1.0 cm thick) with a chipper and incorporated with a rotary hoe to 15 cm depth. The N and C percentages of tagasaste were 3.3% and 46.9% respectively, giving a C:N ratio of 14:1. Soil nutrient analysis prior to incorporation showed total N, NO_3^-, NH_4^+, organic C, C:N and pH of 0.180%, 12.7 ppm, 2.0 ppm, 1.8%, 9.8:1 and 5.7 respectively. The soil chemical tests were repeated after grain harvest including soil bulk density which was determined using a MC-S-36 strata gauge at depths of 5, 10, 15 and 20 cm.

Maize seeds were treated with carboxin and thiram fungicide and sown at a rate of 17 seeds/m^2 into 30 cm rows using an Öyjord cone seeder. Plant establishment was 15 and 16 plants/m^2 for the November and December sown crops respectively. Weeds were controlled by hoeing and the crops were irrigated according to a water budget using a sprinkler.

Maize DM, leaf area index (LAI), and the amount of radiation transmitted through the canopy (T_i) were recorded starting 38 days after sowing (DAS) and continuing fortnightly until final harvest. Dry matter was estimated from 0.36 m^2 quadrats. Plants sampled were cut just above the soil surface and oven dried to a constant weight at 70°C. LAI and T_i were measured using a LICOR LAI 2000 Plant Canopy Analyser. Four readings were taken above and beneath the crop canopy from each plot. The LAI was used to calculate the leaf area duration (LAD) using the relationship:

$$LAD = \sum(L_{A\,1} + L_{A\,2})(T_2 - T_1)/2 \qquad (1)$$

where L_A = leaf area and T = time (Gardner *et al.*, 1985). The proportion of radiation intercepted (F_i) by the canopy was calculated according to Gallagher and Biscoe (1978):

$$F_i = 1.0 - T_i\,. \qquad (2)$$

The amount of intercepted photosynthetically active radiation S_a was calculated from Szeicz (1974):

$$S_a = F_i \times S_i \times 0.5 \qquad (3)$$

where S_i was the total incident solar radiation recorded at the nearby Broadfield Meteorological Station from the time of crop emergence to physiological maturity. Radiation use efficiency (RUE) was determined as the gradient of the relationship between DM and S_a.

Final DM and grain yields were estimated at 150 and 136 DAS for the November and December sown crops respectively from a single sample from within 1.0 m^2 from each plot. After the number of ears/m^2 were counted, four plants were randomly subsampled and the ears counted and then threshed by hand. The grain was oven dried to a constant weight at 70°C and weighed. Gompertz function curves (Pegelow *et al.*, 1977),

$$Y = C^* \exp(-\exp(-b(x-m))) \qquad (4)$$

were used to describe DM accumulation, where Y is DM yield, C is the final above-ground dry matter, b and m are constants. The weighted mean absolute growth rate (WMAGR: the mean growth rate over the period when the crop accumulated most of its DM), duration of exponential growth (DUR: duration of crop growth over which most growth occurred) and the maximum crop growth rate (C_m) were calculated for the crop using the values of C, b and *e* in the following equations:

$$WMAGR = Cb/4 \qquad (5)$$

$$DUR = C/WMAGR \qquad (6)$$

$$C_m = Cb/e \qquad (7)$$

where *e* is base of natural logarithm and equals approximately 2.718. Curves were fitted with the MLP program and the least squares technique was used (Ross *et al.*, 1979). All results were analysed by ANOVA, and Standard Error of the Mean (SEM) calculated.

Results

Climate

The cropping season for 1997-98 was considerably drier and warmer than the average long term means (Fig. 1). Total rainfall, maximum and minimum temperatures from 1 October 1997 to 30 April 1998 were respectively 170 mm, 21.8°C and 9.7°C compared with long term means of 384 mm, 19.8°C and 9.0°C over the same period. Over this period the mean monthly solar radiation received (616 MJ/m^2) was higher than the long term mean of 526 MJ/m^2.

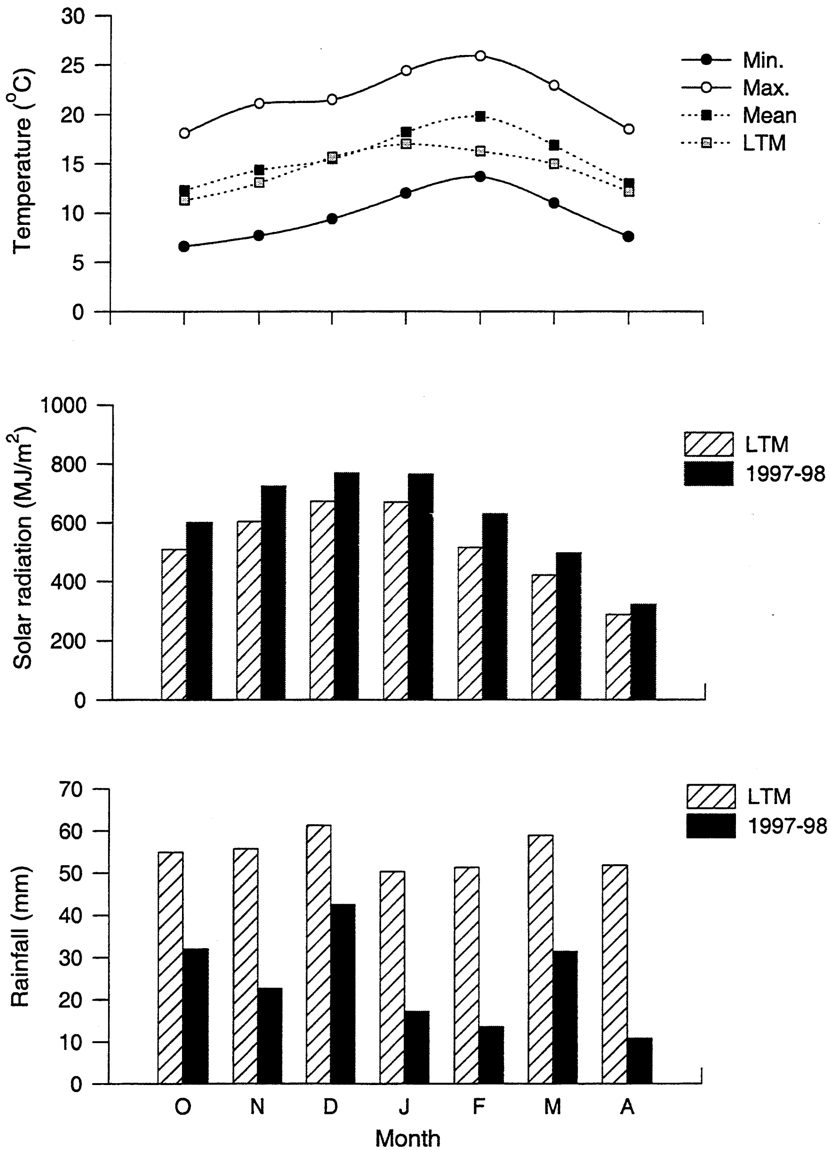

Figure 1. Weather pattern for the 1997-98 growing season and the long term mean (LTM) from 1975-91 for Lincoln University, Canterbury (data from Broadfield Meteorological Station).

Soil nutrients

Total soil nitrogen (TN), organic carbon (OC), C:N ratio, pH and bulk density did not differ with sowing date (Table 1) but NO_3^- was higher for the December sowing. Both TN and OC increased with 10 and 15 t DM/ha incorporation. Generally, soil NO_3^- increased at all rates of tagasaste incorporation compared with the control; the 10 t DM/ha recording the highest levels of 30.3 ppm and the control had the lowest at 16.3 ppm. Tagasaste incorporation had no effect on the C:N ratio and soil pH but it reduced bulk density from 1.42 g/cm^3 in control plots to 1.35 g/cm^3 in 10 and 15 t DM/ha plots.

Growth and dry matter production

Maize dry matter yield was significantly increased following tagasaste incorporation (Table 2) with yields ranging from 19,740 to 25,430 kg/ha for 0 and 15 t DM/ha incorporation respectively. Dry matter production was not affected by sowing date and there was no interaction between sowing date and tagasaste incorporation. The addition of 100 and 200 kg N/ha gave DM yield of 22,850 and 27,560 kg/ha respectively and these were similar to yields from the 10 and 15 t DM/ha incorporation respectively. The increase in DM yield was significant at 100 and 200 kg N/ha and the two rates differed significantly. The 15 t DM/ha incorporation increased both the weighted mean average growth rate (WMAGR) and maximum crop growth rate (C_m) by 26% but had no significant effect on the duration of exponential growth (DUR) (Table 3). Maximum LAI for all treatments occurred at 94 DAS. LAI and LAD increased with 15 t DM/ha incorporation ($P < 0.05$). The December sowing had a higher LAI than the November sowing but this had no significant effect on LAD.

Grain yield and harvest index

Tagasaste incorporation of 15 t DM/ha increased grain yield from 7,610 to 10,090 kg/ha (Table 2). The lowest and highest grain yields were recorded in the 5 and 15 t DM/ha incorporation plots respectively. The addition of 100 and 200 kg N/ha gave a grain yield of 8,760 and 11,840 kg/ha respectively and these were similar to yields from the 10 and 15 t DM/ha of tagasaste plots respectively. However the increase in grain yield was only significant for the 200 kg N/ha rate. The November sown crop produced 41% more grain (9,780 kg/ha) than the December sown crop (6,920 kg/ha). Harvest indices were generally low for all the treatments (Table 2) compared to 0.51 reported by Millner *et al.* (1996). Tagasaste incorporation did not affect HI but, the November sown crop had a higher HI than the December sown crop.

Table 1. The effect of tagasaste incorporation and date of sowing maize on the soil chemical and physical properties six months after incorporation.

	Total N (%)	Organic C (%)	C:N	NO_3^- (ppm)	pH	Bulk density (g/cm^3)
Sowing date						
Nov	0.196	2.2	11.1	20.7	6.0	1.40
Dec	0.202	2.2	11.1	30.6	5.9	1.37
Significance	ns	ns	ns	**	ns	ns
SEM	0.003	0.02	0.1	1.8	0.04	0.01
Tagasaste (t DM/ha)						
0	0.182	2.0	11.0	16.3	6.0	1.42
5	0.195	2.2	11.2	25.8	5.9	1.41
10	0.203	2.3	11.1	30.3	5.9	1.35
15	0.214	2.4	11.1	30.0	5.9	1.35
Significance	**	**	ns	**	ns	*
SEM	0.004	0.03	0.2	2.5	0.05	0.02
Interactions	ns	ns	ns	ns	ns	ns
CV (%)	5	4	4	24	2	3

ns, non-significant; *, $P < 0.05$; **, $P < 0.01$

Table 2. The effect of sowing date and tagasaste incorporation on the dry matter (DM), grain yield, harvest index (HI), intercepted photosynthetically active radiation (S_a) and radiation use efficiency (RUE) of maize.

	DM (kg/ha)	Grain yield (kg/ha)	HI	S_a (MJ/m^2)	RUE (g DM/MJ)
Sowing date					
Nov	23,540	9,780	0.41	974	2.64
Dec	22,070	6,920	0.32	811	3.15
Significance	ns	**	**	**	*
SEM	553	530	0.02	8.7	0.09
Tagasaste (t DM/ha)					
0	19,740	7,610	0.38	879	2.59
5	22,580	7,360	0.33	887	2.89
10	23,480	8,350	0.35	898	2.86
15	25,430	10,090	0.39	906	3.22
Significance	**	*	ns	ns	*
SEM	781	750	0.03	12.3	0.12
Interactions	ns	ns	ns	ns	ns
CV(%)	8	22	19	3	6

ns, non-significant; *, P < 0.05; **, P < 0.01

Table 3. The effect of sowing date and tagasaste incorporation on the average growth rate (WMAGR), duration of exponential growth (DUR), maximum growth rate (C_m), leaf area duration (LAD) and maximum leaf area index (LAI) of maize.

	WMAGR (kg/ha/d)	DUR (days)	C_m (kg/ha/d)	LAD (days)	Maximum LAI
Sowing date					
Nov	270.1	95.7	397.5	313	3.8
Dec	279.3	86.5	411.0	324	4.5
Significance	ns	ns	ns	ns	**
SEM	16.1	7.1	23.7	4.7	0.08
Tagasaste (t DM/ha)					
0	240.3	90.8	353.6	302	4.0
5	260.8	94.8	383.8	316	4.1
10	294.3	87.7	433.0	321	4.2
15	303.5	91.1	446.5	335	4.4
Significance	*	ns	*	*	*
SEM	22.8	10.0	33.5	6.6	0.11
Interactions	ns	ns	ns	ns	
CV(%)	20	27	20	5	6

ns, non-significant; *, P < 0.05; **, P < 0.01

Intercepted PAR and radiation use efficiency

Sowing date had a significant effect on total intercepted PAR but tagasaste incorporation had no effect (Table 2). The November and December sown crops respectively intercepted a maximum of 95 and 98% of the total incident radiation. Maximum interception or canopy closure occurred at LAI of 3.7 and 4.3 for the November and December sown crops respectively. Accumulated DM yield and cumulative intercepted PAR

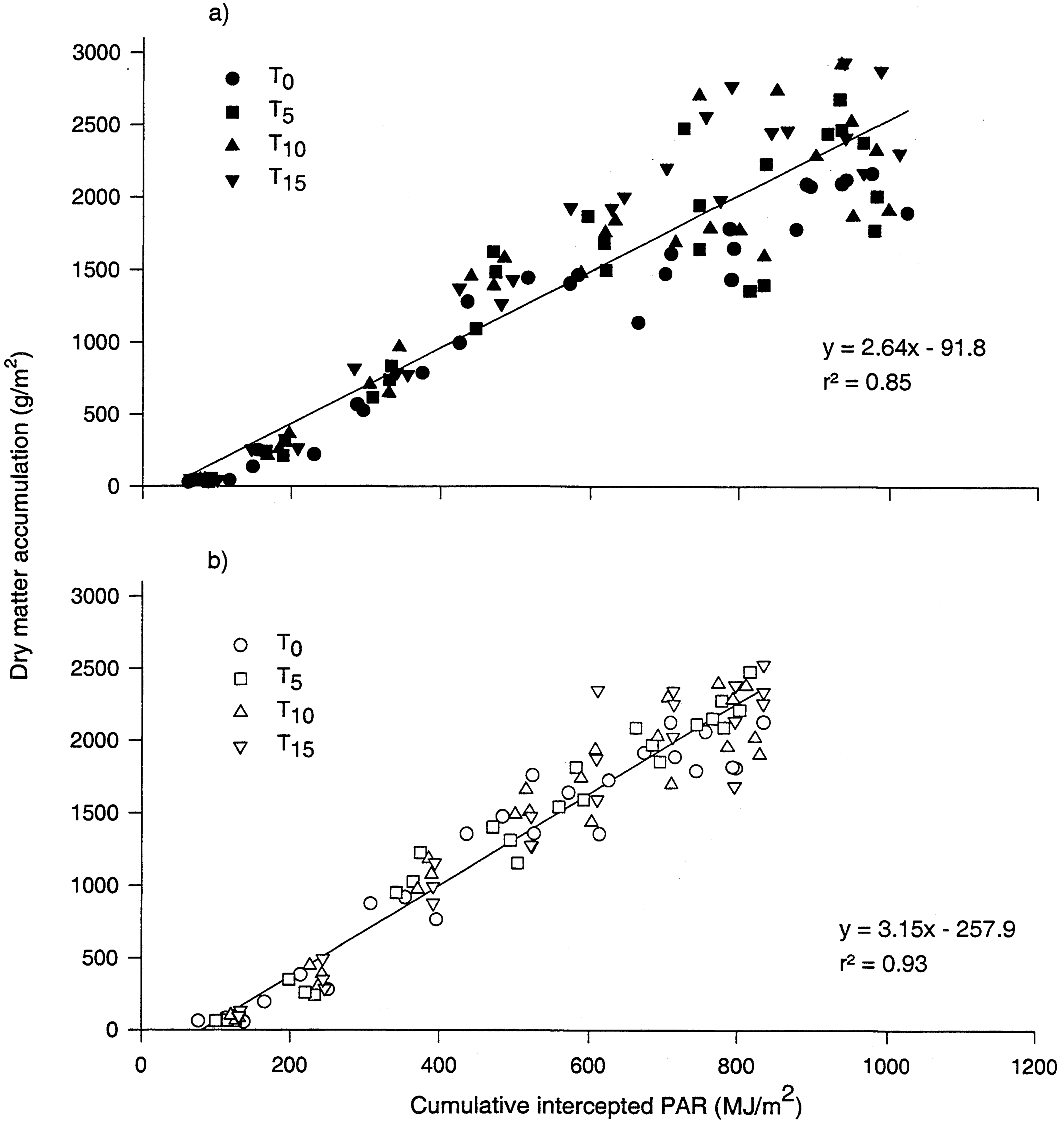

Figure 2. Relationship between dry matter accumulation and cumulative intercepted PAR of maize sown in November (a) and December (b) with 0, 5, 10 and 15 t DM/ha tagasaste incorporation.

for both sowing dates were strongly correlated (Fig. 2). The two sowings produced 2.64 and 3.15 g DM/MJ of intercepted PAR in the November and December sown crops respectively; however the former intercepted 17% more PAR than the latter. The 15 t DM/ha incorporation increased RUE of maize by 24% compared with the control (Table 2).

Discussion

Increased soil organic C with tagasaste incorporation did not raise the soil C:N ratio as N levels correspondingly increased. The tagasaste herbage had 3.3% N and low C:N ratio (14:1) and therefore incorporation of at least 10 t DM/ha increased the soil N. Rosen *et al.* (1993) reported that organic materials with excess N beyond C:N ratio of 30:1 can provide immediate fertiliser value to crops. The reduction of soil bulk density by tagasaste confirms reports by Marshall *et al.* (1996) and Yamoah (1997) that soils containing high organic matter have a lower bulk density than those with a low organic matter content. Salau *et al.* (1992) attributed this reduction to increased soil biological activity, resulting in higher soil porosity.

Dry matter yields obtained in this study were higher than the yield reported by Millner *et al.* (1996) for Janna maize of 15,800 kg/ha. The high plant density and high population at establishment may partly account for this as Millner *et al.* (1996) reported higher DM yields at higher densities. Differences in DM due to tagasaste incorporation resulted mainly from differences in WMAGR and C_m. As shown in Tables 1 and 3, incorporation of 10 and 15 t DM/ha increased soil N, and hence increased LAI and LAD. The higher LAD should enable the crops to intercept more PAR but it did not because LAI's were above critical in all treatments. This could be due to the close plant spacing. However, the 24% increase in RUE, higher WMAGR and C_m due to 15 t DM/ha incorporation, resulted in higher DM accumulation than the control. This confirms a report by Lieffering (1995) that additional N increased LAD, WMAGR and C_m which resulted in higher DM yields in temperate cereals. Addition of 100 and 200 kg N/ha gave similar grain and DM yield as 10 and 15 t DM/ha tagasaste respectively. This suggests that incorporation of 10 and 15 t DM/ha tagasaste could supply maize equivalent amount of N to that obtained from 100 and 200 kg N/ha respectively.

Harvest indices did not differ with tagasaste incorporation and were low for all rates of incorporation relative to the 0.51 reported by Millner *et al.* (1996). The failure of additional N to cause differences in HI has been reported by Lieffering (1995) in temperate cereals. The low HI was partly due to the high plant density. Millner *et al.* (1996) observed a decline in HI of maize with increased plant density. The November sown crop as consequence of a higher HI, had a higher grain yield than the December sowing. The late sowings tended to have a lower HI because the crops had higher population at establishment and flowered 8 days earlier than the first sowings. Pyke and Hedley (1985) reported that in peas this may result in more assimilate being partitioned into vegetative growth with a resultant drop in HI. The late sowings produced more shoot at the expense of grain because the vegetative growth phase coincided with long photoperiods and high temperatures. The higher RUE of the December sown crop was not reflected in DM yield as the November sown crop grew for longer and intercepted more PAR which compensated for its lower RUE.

Conclusions

Tagasaste incorporation increased both the DM and grain yield of maize. The recommended level of incorporation is 10 t DM/ha and that gave a similar yield to 100 kg N/ha. Sowing maize in early November gave maximum yields. Tagasaste incorporation increased soil N and reduced bulk density but had no effect on pH or the C:N ratio.

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