Effect of soil incorporated tagasaste residues on maize dry matter and grain yield

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Abstract

The value of incorporating tagasaste (*Chameaecytisus palmensis* L.) as an organic fertiliser was compared with the use of calcium ammonium nitrate at 200 kg N/ha. Irrigation (full or nil) was applied over the fertiliser treatments in a factorial split-plot randomised complete block design. Tagasaste incorporation increased total soil nitrogen (N) and organic C content. It reduced soil bulk density but had no effect on the soil C:N ratio or pH. Soil pH declined with the application of 200 kg N/ha. Dry matter (DM) yield of maize (Zea mays L) was increased 5,200 kg/ha with irrigation. Irrigation did not increase grain yield, but it did increase mean grain weight by 21%. There was a significant interaction between tagasaste incorporation and irrigation for DM production. In irrigated plots the 27,000 kg/ha of DM yield from the 200 kg N/ha plots was about 14% higher than the yield from plots where tagasaste had been incorporated; these latter plots produced 3,200 kg more DM/ha than the control plots. However in the unirrigated plots, DM yields did not differ between incorporation and N-fertilizer treatments. Both treatments gave higher DM yield than the control. Tagasaste incorporation can increase total soil N and can increase maize yield provided soil moisture is not limiting.

Additional key words: Chameaecytisus palmensis *L,* Zea mays *L, irrigation, fertiliser, nitrogen, yield.*

Introduction

Organic materials added to soil can increase soil nitrogen (N) and increase availability of micronutrient which can increase the yield of succeeding crops. Yamoah *et al.* (1998) showed that incorporation of at least 10 t DM/ha of tagasaste pruning increased maize DM yield by increasing soil N levels. Marshall *et al.* (1996) and Yamoah (1997) reported that organic matter incorporation reduced soil bulk density. Organic matter breakdown may be determined by soil factors such as temperature and moisture. Warm, wet climatic conditions enhance the decomposition rate (Pandey and Singh, 1982) while cold temperatures and drought slow down the rate.

Under drought conditions, the application of inorganic N fertiliser may not be economic for farmers as crops may not be able to utilise the applied N. It is therefore important to ensure that soil moisture is not limiting. This can be achieved by either, altering sowing date to coincide with periods of adequate rainfall, or by irrigation. Yamoah *et al.* (1998) showed that in Canterbury late sowing of maize resulted in a lower grain yield than early sowing but sowing date had no effect on DM yield. Maize grain yield often responds positively to irrigation (Jamieson and Francis; 1991, Jamieson *et al.*, 1995). Mean grain weight is the grain yield component of maize which is most affected by drought (Jamieson and Francis, 1991; Jamieson *et al.*, 1992). Research to assess the effect of tagasaste incorporation on the growth of maize under drought and irrigated conditions will help clarify the potential of leguminous woody organic materials to maintain fertility in a sustainable cropping system. The aims of this study were to assess the effect of inorganic fertiliser and tagasaste incorporation on the soil, and on the grain and DM yield of maize under two different soil moisture regimes.

Materials and Methods

Site and Experimental Design

The experiment was conducted on a Templeton silt loam soil at Lincoln University (New Zealand Soil Bureau, 1968). The site was cultivated by ploughing and dutch harrowing. The experiment was a split-plot randomised complete block design. Main plot treatments were two irrigation levels (nil and full) and sub-plots were 200 kg N/ha of calcium ammonium nitrate,and 0 or 10 t DM/ha tagasaste incorporation. No basal fertiliser was applied. There were three replicates and the sub-plot size was 8.4 m x 5.0 m.

Husbandry

Tagasaste biomass was harvested and applied fresh after sub-sampling for DM, N and carbon (C) percentages. The N and C contents were determined using a Leco CNS-2000 analyser. Tagasaste clippings had a leaf : stem ratio of 3:1. They were chopped into small pieces (about 1.0 cm thick) with a chipper and were soil incorporated with a rotary hoe to about 15 cm depth. The N and C percentages of the tagasaste were 3.3% and 46.9% respectively, giving a C:N ratio of 14.

Maize seed (cv. Janna) was sown on 2 November 1998 (28 days after tagasaste incorporation). The fertiliser treatment was broadcast 14 days after seedling emergence and all plots were irrigated with 18 mm of water. Maize seed was treated with carboxin and thiram fungicide at 200 g/l and sown at 12 seeds/m^2 using an Öyjord cone seeder. The plant population at establishment was 10 plants/m^2. Weeds were controlled by atrazine at 1.5 kg/ha applied at 400 kPa pressure. The fully irrigated crop was given about 20 mm of water by sprinkler each time the volumetric soil moisture content reached 17%. Irrigation was done four times before tasselling and four times after tasselling. At the last irrigation only 10 mm of water was applied. The unirrigated and irrigated crop respectively received a total of 190 and 340 mm of water.

Measurements

Maize DM was measured starting 38 days after sowing (DAS) and was continued fortnightly until final harvest. In each plot, at random, half of the area was used for sequential destructive harvests throughout the season and the remainder was left for final hand harvests. Dry matter was estimated from 0.72 m^2 quadrats. Plants sampled were cut just above the soil surface and oven dried to a constant weight at 70 °C. Final DM and grain yields were estimated from a single 1.0 m^2 sample at 136 and 150 DAS (i.e., 18 March and 1 April 1999) for the unirrigated and irrigated crops respectively. All the tagasaste treatments (both unirrigated and irrigated crops) were harvested at 150 DAS. After the number of ears/m^2 was counted, seven plants were randomly sub-sampled and the ears counted and then hand threshed. The grain was oven dried to a constant weight at 70 °C, weighed and counted.

Soil analysis

Soil samples were taken from each plot prior to tagasaste incorporation (Table 1) and at two and six months after the tagasaste incorporation using a soil corer. Four cores were randomly taken from 0-25 cm soil depth and analysed for total N, organic C, and pH. Total N and pH were determined by a semi-micro Kjedahl method and a pH meter respectively. Soil bulk density was determined using a MC-S-36 strata gauge. One reading was taken from each plot at depths of 5, 10, 15, 20 and 25 cm and the mean value was computed. Volumetric soil moisture content (θ) was determined from 30 cm depth using Time domain reflectometry (TDR). Three measurements of θ were taken, at random from each plot during grain filling. All results were analysed by ANOVA and mean separation was based on LSD tests at $P < 0.05$ level.

Table 1. Soil chemical analysis for the research sites at 0-25 cm depth.

		Nutrient			
pH	C:N	Total N (%)	Organic C (%)	NO^3- (ppm)	NH_4+ (ppm)
5.7	11.3	0.18	2.1	23.8	3.0

Results

Climate

Climatic data were recorded at the Broadfield Meteorological Station, Lincoln, about 2.0 km from the experimental site. The 1998-99 cropping season (October 1998 to April 1999) had a total rainfall of 270 mm which was only 70% of the long term mean (1975-91). Maximum and minimum temperatures over the same period followed the long-term pattern with mean temperatures of 19.6 and 10.3 °C respectively. The total incident solar radiation of 3,990 MJ/m^2 was higher than the long-term value of 3,680 MJ/m^2.

Soil

Soil tests conducted six months after tagasaste incorporation showed higher total N levels in the 200 kg N/ha plots than in both the control and the 10 t DM/ha of tagasaste incorporated plots (Table 2). There was a positive, linear relationship between total soil N and C ($r^2 = 0.88$, $P < 0.01$). The soil C percentage did not vary with tagasaste incorporation. The C:N ratio decreased in the 200 kg N/ha plots with a mean of 11.5 but it was not affected by 10 t DM/ha of tagasaste. Soil pH was unaffected with incorporation of 10 t DM/ha but it was reduced in the 200 kg N/ha plots from 5.8 to 5.4.

At grain filling, the volumetric soil water content in the unirrigated plots was approximately 66% of that in irrigated plots. However, it did not vary with the incorporation of 10 t DM/ha or 200 kg N/ha. Soil bulk density decreased from 1.41 g/cm^3 in the control plots to 1.37 g/cm^3 in the 10 t DM/ha plots.

Dry matter yield

Incorporation of 10 t DM/ha of tagasaste increased DM yield by 21% to 22,300 kg/ha compared with the control plots (18,400 kg/ha) (Table 3). Plots which received 10 t DM/ha of tagasaste or 200 kg N/ha produced

Table 2. The effect of irrigation and incorporation of tagasaste or fertiliser on the soil chemical and physical properties six months after tagasaste incorporation.

Treatment	N[1] (%)	N (%)	C (%)	C:N	pH	Volumetric[2] soil moisture content (%)	Bulk density (g/cm3)
Irrigation							
Nil	0.20	0.194	2.33	12.0	5.5	13.8	1.37
Full	0.18	0.171	2.04	11.9	5.8	21.0	1.43
Significance	ns	ns	ns	ns	ns	*	ns
s.e.m.	0.016	0.013	0.168	0.09	0.15	0.84	0.015
Incorporation							
0 t DM/ha	0.18	0.175	2.16	12.3	5.8	17.4	1.41
10 t DM/ha	0.19	0.180	2.19	12.2	5.7	18.1	1.37
200 kg N/ha	0.20	0.193	2.21	11.5	5.4	16.7	1.42
Significance	**	*	ns	**	**	ns	*
s.e.m.	0.002	0.004	0.032	0.12	0.06	0.58	0.012
Interaction	ns	ns	ns	ns	ns	ns	ns
CV (%)	2.3	5.6	3.6	2.5	2.4	8.2	2.1

[1] Analysed 2 months after tagasaste incorporation; [2] Analysed at grain filling; ns, non-significant; *, P < 0.05; **, P < 0.01

Table 3. The effects of irrigation and incorporation of tagasaste or fertiliser on maize dry matter and grain yield, harvest index (HI) and grain yield components.

Treatment	DM (kg/ha)	Grain yield (kg/ha)	HI	Cobs/m^2	Grains/cob	Mean grain weight (mg)
Irrigation						
Nil	18,600	8,300	0.44	10.2	340	240
Full	23,800	11,100	0.47	11.0	350	290
Significance	*	ns	ns	ns	ns	*
s.e.m.	713.9	547.8	0.021	0.70	6.6	4.7
Incorporation						
0 t DM/ha	18,400	8,500	0.46	10.0	330	260
10 t DM/ha	22,300	10,500	0.47	10.8	350	270
200 kg N/ha	22,900	10,100	0.44	11.0	340	270
Significance	**	*	ns	ns	ns	ns
s.e.m.	482.0	391.0	0.013	0.42	17.5	6.1
Interaction	*	ns	ns	ns	ns	ns
CV (%)	5.6	9.9	7.8	9.7	12.6	5.6

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

a DM mean of 22,600 kg/ha. Irrigated maize plants produced 5,200 kg more DM/ha than the unirrigated maize plants. There was a significant interaction between incorporation of tagasaste or 200 kg N/ha and irrigation for DM production. In the irrigated plots, the 200 kg N/ha and the control respectively gave the highest and the lowest DM yields (Table 4). Dry matter yield from the 200 kg N/ha treatment was 27,000 kg/ha. This was higher than the yield from plots with 10 t DM/ha which was 23,800 kg/ha. However, in the unirrigated plots, DM yields were similar in the 10 t DM/ha and 200 kg N/ha plots. Both treatments gave higher DM yield than the control.

Grain yield and harvest index

Tasselling started at 66 and 73 DAS for the unirrigated and the irrigated crops respectively. Plots which received 10 t DM/ha of tagasaste gave a grain yield of 10,500 kg/ha (Table 3), which was similar to the 10,100 kg/ha from 200 kg N/ha plots. Both yields were higher than the control grain yield (8,500 kg/ha). The highest grain yield was approximately 24% higher than the control yield. Grain yield was related positively, and linearly with DM production ($r^2 = 0.84$, $P < 0.01$; Fig. 1). Grain yield did not differ with irrigation and the overall mean was 9,700 kg/ha ($P = 0.067$). Harvest index (HI) did not differ among incorporation levels or between irrigation treatments. The mean HI was 0.46.

Grain yield components

Yield components were very stable. Only mean grain weight varied with treatment (Table 3). The number of cobs/m^2 was not affected by any treatment and the grand mean was 10.6 cobs/m^2. Grains/cob were also not affected by treatment and the mean was 345 grains/cob. Grain weight was not affected by tagasaste incorporation but irrigated plants produced grains (290 mg) that weighed 21% more than grains from unirrigated plants (240 mg). There was a positive, linear relationship ($r^2 =$ 0.61, $P < 0.01$) between mean grain weight and grain yield (Fig. 2).

Table 4. The irrigation x incorporation of tagasaste or fertiliser interaction on dry matter (DM) yield of maize.

Treatments	DM (kg/ha) Irrigated	Unirrigated
0 t DM/ha	20,600	16,300
10 t DM/ha	23,800	20,900
200 kg N/ha	27,000	18,700
s.e.m.	681.6	

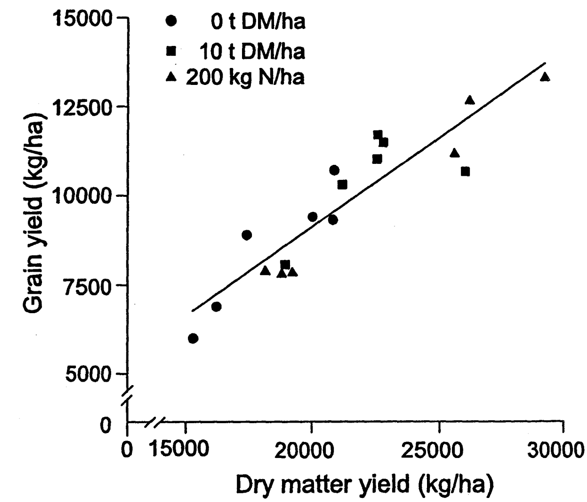

Figure 1. Relationship between dry matter and grain yield of maize following the incorporation of 0 and 10 t DM/ha of tagasaste and the application of 200 kg N/ha. $Y = -830 + 0.5x$ ($r^2 = 0.84$).

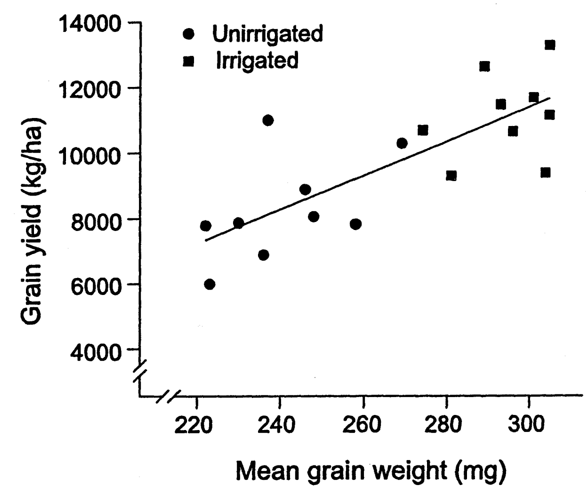

Figure 2. Relationship between mean grain weight and grain yield of irrigated and unirrigated maize. $Y = -4{,}190 + 52x$ ($r^2 = 0.61$).

Discussion

Chemical analyses on the tagasaste residues showed a mean N content of 3.3%. This implies that application of 10 t DM/ha will add approximately 330 kg N/ha to the soil when the material is fully decomposed. A fraction of this N though, is likely to be lost through volatilisation, leaching and denitrification. The incorporation of low C:N ratio tagasaste pruning did not increase the soil C:N ratio. This suggest there was little or no immobilisation of soil N because maize grown in the tagasaste incorporated plots showed no N deficiency symptoms. Rosen *et al.* (1993) reported that organic materials with excess N beyond a C:N ratio of 30 could provide immediate fertiliser value to crops. The reduction of soil bulk density by the tagasaste residues 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 some of this reduction to increased soil biological activity, resulting in higher soil porosity. Significant interaction between incorporation and irrigation for maize DM production showed that the response to additional N or tagasaste depended on the soil nutrient status. This could also be due to improved soil physical condition as organic matter lowers penetration resistance of the soil and increases infiltration rate and pore volume fraction (Dalland *et al.*, 1993). This can increase the soil water holding capacity (Jacobowitz and Steenhuis, 1984). In contrast, θ did not change with tagasaste incorporation at 10 t DM/ha. As noted by Jacobowitz and Steenhuis (1984), θ is more likely to increase at higher rates of organic matter incorporation at similar levels of water application.

Since all the maize crops were irrigated soon after fertiliser application, it is probable that the crops did not experience moisture stress during their early growth. Even without further irrigation, maize plants from the tagasaste incorporated plots maintained their photosynthetic tissues for 14 days after the control and the 200 kg N/ha plants had undergone leaf senescence. This increased the amount of PAR intercepted by those crops (data not presented) and lead to increased grain yield, probably by promoting the translocation and remobilisation of more assimilate into the sinks.

The DM yield of the irrigated maize increased as a result of increased PAR interception. Similar results have been reported by Jamieson *et al.* (1994) with barley. Unirrigated maize tasselled about a week before irrigated maize and is therefore likely to have accumulated less DM than the irrigated maize. The significant interaction between irrigation and incorporation showed that both N and soil moisture can influence maize growth and DM production. Liang *et al.* (1992) also found a significant interaction between N and irrigation. Application of 200 kg N/ha to unirrigated maize reduced the amount of PAR intercepted due to early leaf senescence. This resulted in low DM production (18,700 kg/ha) compared with the 27,000 kg/ha DM yield of irrigated maize where 200 kg N/ha was applied. This shows that moisture stress affects N uptake which may result in poor maize growth and low DM yield.

The failure of irrigation to increase grain yield was, at least in part, due to the experimental design used for the analysis. Using a split plot design with only two levels of irrigation as the main plots gave only one degree of freedom for testing main plot effects. Irrigation however, increased the mean grain weight as a result of a prolonged grain filling period. This confirms the report of Jamieson *et al.* (1992) who found a significant reduction in the mean grain weight of maize under drought conditions.

The failure of additional N to affect HI contradicts the work of Muchow (1994) but confirms an observation by Lieffering (1995) in several temperate cereals. The mean HI of 0.46 observed in this study, is similar to the HI of 0.45 reported by Andrade (1995) and 0.46 by Millner *et al.* (1996) at a plant population of 10 plants/m^2. The implication is that HI of maize is stable.

Conclusions

Total soil N increased with the incorporation of either tagasaste or 200 kg N/ha and while the application of 200 kg N/ha increased soil acidity, the tagasaste reduced the soil bulk density. Both DM and grain yields were increased by the incorporation of either 10 t DM/ha of tagasaste or 200 kg N/ha. Irrigation increased the DM yield of maize in Canterbury.

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