Intercropping maize-silage in New Zealand[1]

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Abstract

Simultaneous intercropping of maize silage with a secondary crop may increase the productivity of farm rotations in New Zealand. The aim of this research was to help identify the most suitable species and intercrop sowing times for intercropping with maize. Field experiments were conducted in 2006-07 and 2007-08. In 2006-7, the intercrops (Italian ryegrass, cv. Moata; kale, cv. Grunner; forage brassica, cv. Hunter and balansa clover, cv. Bolta) were sown in the maize crop at various intervals (at maize sowing, eight weeks after maize sowing, and soon after the maize-silage harvest). Intercrops sown at the same time as the maize significantly reduced maize and total silage (maize + intercrop) dry matter (DM) yields compared with maize alone. Delaying intercrop sowing had no effect on maize or total DM yields. In all cases, the intercrops established well but either died or failed to produce productive stands over the winter. In the second season several refinements were made to the intercropping. Forage brassica (cv. 'Hunter') sown at the same time as maize still reduced maize and total silage DM yields regardless of sowing rate, but perennial ryegrass (cv. 'Aries') and other sowing dates did not. Only forage brassica sown at the same time as the maize gave a viable intercrop stand that grew during the subsequent winter. The highest yields were achieved when maize alone was grown, over summer and followed by Italian ryegrass in the winter (36.7 t DM ha^{-1} $year^{-1}$).

Additional keywords: silage DM yield, intercrop yield, Italian ryegrass, kale, forage brassica, balansa clover, *Zea mays*, *Brassica campestris* x *Brassica napus, Brassica oleracea*. ssp. *acephala*, *Lolium multiflorum, Trifolium balansae*

Introduction

Intercropping involves growing two or more crops in close proximity simultaneously in the same paddock, such that they interact (Papendick *et al*., 1976; Sullivan, 2003). Intercropping is an established practice in many developing countries, and is gaining interest in developed countries as growers seek to adopt more environmentally sustainable farming methods whilst improving profitability.

Variations in intercropping are based on the timing of sowing and harvesting, and the degree of mixing/separation of the crops. Maize (*Zea mays* L.) is grown in rows, and therefore maize intercropping systems fall in the category of row-intercropping (Papendick *et al.*, 1976). Relay-

[1]Revised 2010

intercropping occurs when two or more crops grow simultaneously but only during part of the life cycle of each crop (Papendick *et al*., 1976). For example, a second crop might be sown after the first crop but before the first crop is ready to harvest. This example is of particular relevance to New Zealand maize-silage growers aiming to reduce the time lost between the maize harvest and sowing and establishment of a subsequent winter crop.

New Zealand maize-silage growers are interested in intercropping for several reasons: to increase total annual biomass production and economic returns, minimise nutrient (e.g. N) leaching, improve soil structure and productivity, improve resilience to vehicle movements, manipulate maize crop silage quality, and to provide further options for winter grazing or silage (Carey *et al*., 2006). While potential benefits can be gained from intercropping, growers are also aware of some of the likely disadvantages, such as increased input costs and management time, competition between the intercrop and the maize for water and nutrients, and changes in cultivation and other management practices (Carey *et al*., 2006).

The aim of this research was to provide answers to two fundamental questions before New Zealand maize-silage growers trial intercropping:

(1) what are the most suitable plant species for intercropping with maize? and

(2) when should intercrops be sown?

Materials and Methods

Site and experimental details

Experiments were undertaken during 2006-07 and 2007-08 at Plant & Food Research, Hastings (39 ° 36′ 30.74 "S, 176 ° 54′ 46.26 "E). The soil was a Mangateretere silty-clay loam. Key soil test results are summarised in Table 1.

Table 1: Soil test results for the two seasons. The depth of soil sampled was 0-15 cm for all test variables except mineral-N where the sampling depth was 0-30 cm.

Soil test	2006-07	2007-08
pH	5.8	6.3
Olsen P (µg ml^{-1})	37	23.0
Exchangeable cations (me 100 g^{-1})		
Ca	11.7	12.3
Mg	2.3	1.7
K	0.8	1.0
Na	0.2	0.1
CEC (me 100 g^{-1})	21.5	19.0
Mineral N (kg N ha^{-1})	38.0	18.0

The 2006-07 experiment was a randomised complete-block design with 4 replicates and 13 treatments (4 intercrop species, three sowing dates, and a no-intercrop control). Plots were 4.56 m wide (six 76 cm maize rows) x 10 m long. Maize (Pioneer hybrid 36H36) was sown on 21 October 2006 at

90,000 seeds ha^{-1}. Intercrops were sown by broadcasting and light raking at various intervals: at maize sowing (SD_1), 52 days after maize sowing (SD_2) and 147 days after maize sowing (SD_3, which was 11 days after the maize silage harvest). Intercrop species and sowing rates used were forage brassica (*Brassica campestris* L. x *Brassica napus* L. cv. Hunter; 5 kg ha^{-1}), kale (*Brassica oleracea* L. ssp. *acephala* DC. cv. Grunner; 5 kg ha^{-1}), Italian ryegrass (*Lolium multiflorum* Lam. cv. Moata; 25 kg ha^{-1}) and balansa clover (*Trifolium balansae* Boiss. cv. Bolta; 25 kg ha^{-1}); abbreviated henceforth as FB, K, IR and BC respectively.

All plots received 18 kg N ha^{-1} and 20 kg P ha^{-1} as di-ammonium phosphate at maize sowing and 145 kg N ha^{-1} as a urea side dressing (48 days after maize sowing). Approximately 20 mm of irrigation was applied in November and 50 mm in January to assist the establishment of the SD_1 and SD_2 intercrops respectively (Figure 1). SD_3 intercrops received no irrigation.

In 2007-08 the experiment was also a randomised complete-block design with 4 replicates. Individual plots were again 4.56 m wide by 10 m long. Maize (Pioneer hybrid 34D71) was sown on 21 October 2007 at 100,000 seeds ha^{-1}. The intercrops were FB (cv. Hunter), IR (cv. Moata) and perennial ryegrass (PR; *Lolium perenne* L. cv. Aries). FB and PR were sown at 50 and 100% of the recommended sowing rate if these crops were sown by themselves (i.e. 2.5 and 5.0 kg ha^{-1}, and 12.5 and 25 kg ha^{-1} respectively), and at two intervals (at maize sowing, and 26 days after maize sowing; SD_1 and SD_2 respectively). Control (maize only) plots were also established giving a total of nine treatments. Italian ryegrass was sown on 9 April 2008 (177 days after maize sowing; 22 days after the silage harvest), at 25 kg ha^{-1} in an area adjacent to the main experiment. Yield measurements from this area over winter were used to estimate the dry matter (DM) production that could be expected under a common system in New Zealand of cultivating and then sowing an annual ryegrass crop soon after maize silage harvest. The necessary cultivation for this could not be achieved on the control plots without disturbing the other treatments.

All plots received 92 kg N ha^{-1}, as urea, broadcast and incorporated prior to sowing; 36 kg N ha^{-1} and 40 kg P ha^{-1} as di-ammonium phosphate banded down the spout at sowing; and 138 kg N ha^{-1} as urea broadcast on 26 November 2007. A total of 175 mm of irrigation water was applied during the season (Figure 1).

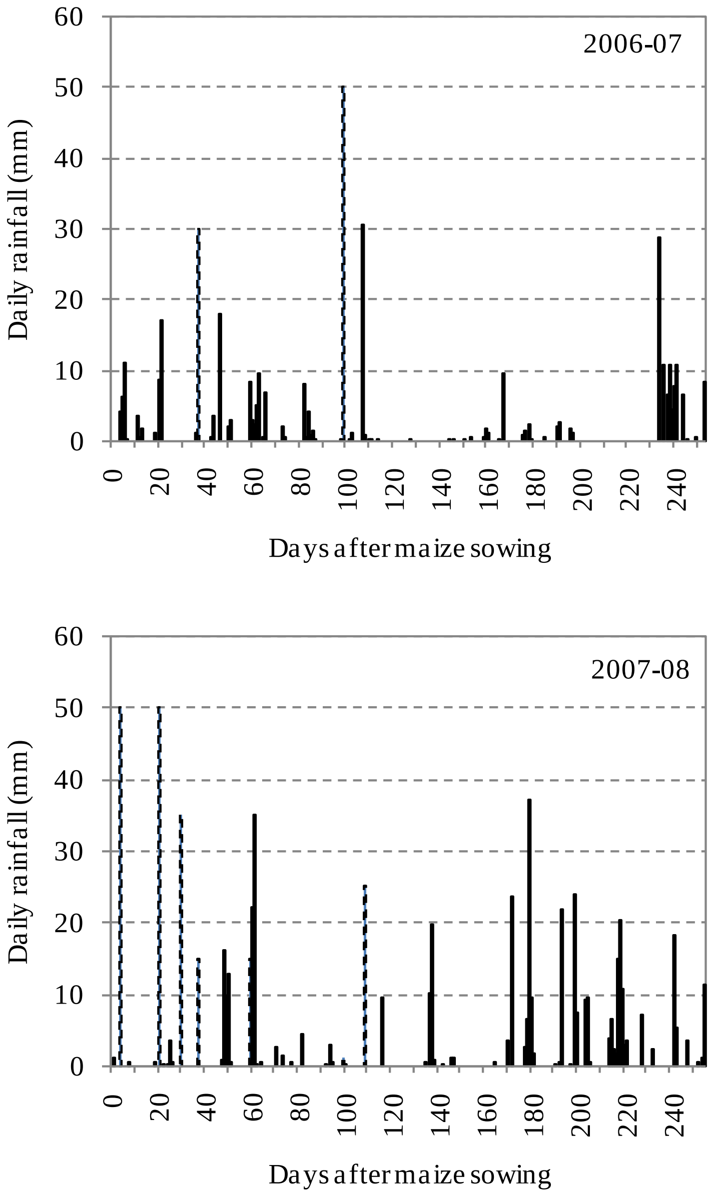

Figure 1: Daily rainfall (solid bars) and irrigation (dashed bars) from days after maize sowing (21 October) until the end of June. SD_2 intercrops in 2006-07 were sown 52 days after maize sowing and SD_3 intercrops 147 days after maize sowing. Respective sowing times for 2007-08 were 26 and 177 days after maize sowing. Seasonal rainfall and irrigation totals were 370 mm and 626 mm in 2006-07 and 2007-08, respectively.

Measurements

In 2006-07 measurements included: soil temperature (6 December 2006; control and SD_1 plots); maize shoot biomass, leaf counts and vigour scores (greenness and size relative to the control) (11 December 2006; all plots except SD_3); radiation interception (12 December 2006; control and SD_1 plots); visual weed assessments (11 December 2006; all plots); and intercrop plant population density (various dates; all plots except the control). The main silage harvest was taken on 6 March 2007 (136 days after maize sowing). From each plot all plant material 10 cm above ground level was harvested from a 4.5 m^2 quadrat (which included two 3 m lengths of maize row).

Plant material was separated into maize and intercrop components which were weighed and sub-sampled and then oven-dried at 70 °C for 7 days. The remaining plant material on each plot was then removed using a forage harvester. However, this process damaged much of the intercrop plant material that would have otherwise promoted rapid re-growth in SD_1 and SD_2 plots.

In 2007-08 there was greater emphasis on monitoring intercrop death during the maize growing season. Intercrop plant counts (plants m^{-2}) were taken approximately three weeks after intercrop sowing in both the early and late sown intercrops; and at approximately 15 and 11 weeks after intercrop sowing in the SD_1 and SD_2 intercrops respectively.

At each sampling date plant counts were taken in 3 randomly selected, permanently located, 0.375 m^2 quadrats $plot^{-1}$. The main silage harvest was taken on 18 March 2008 (155 days after maize sowing).

Maize and intercrop material was hand harvested from a quadrat, as in the previous year, except the quadrat size was 3.75 m^2. Remaining plant material was removed by hand in the SD_1-FB plots (the only plots to have significant amounts of intercrop still growing in them). Winter season biomass accumulation in these SD_1-FB plots was assessed on 2 September 2008 by harvesting a 3.75 m^2 quadrat at ground level (to simulate livestock grazing). The SD_3-IR plot, sown adjacent to the experimental area, had four 1 m^2 samples collected from random locations on the same date.

A commercial maize grain harvester was used to harvest grain from all plots on 16 June 2008, ensuring that SD_1-FB and SD_3-IR were not shaded by the standing maize crop over the winter.

Weed control

In 2006-07 weed control was a major concern and was performed on several dates using a combination of herbicides and hand weeding. In 2007-08 weed control with herbicides was more effective.

Data analysis

Data was analysed by Genstat V9 using ANOVA. There were no significant interactions among main treatments (i.e. sowing time or intercrop/species). Therefore only the main effects are reported. Contrast analysis was used where appropriate.

Results

2006-07

Maize silage yield in control plots at 23.9 t DM ha^{-1} was typical for a New Zealand maize-silage crop but well below the usual potential of more than 30 t ha^{-1} at this site (see results from 2007-8 below, and Pearson *et al*. (2004)). All SD_1 intercrops reduced maize silage yield, with SD_1-K and SD_1-FB having a greater effect than SD_1-BC and SD_1-IR (Table 2). None of the SD_2 intercrop treatments affected maize yield, and of the SD_3 intercrop treatments only the BC and FB treatments reduced maize silage yield.

Maize-silage yields in SD_3-BC and SD_3-FB were significantly less than the control even though the SD_3 intercrops were not sown until after the maize harvest. The use of maize biomass estimates (10 plants plot^{-1}, 11 December 2006) as a covariate when analysing the maize-silage yields indicated that maize yields in SD_3 intercrop treatments were not significantly different from the control. This supports the notion that the reduction in maize yield in these plots was probably due to less than ideal weed-control during the maize growth.

At the time of maize silage harvest, the SD_1 intercrop yields ranged from 1.6 t DM ha^{-1} (IR and FB) to 4.1 t DM ha^{-1} (K) (Table 2). In all cases SD_1 intercrop yields were well short of the corresponding reduction in maize yield in these treatments. The SD_2 and SD_3 intercrops yielded no harvestable DM because they were below the 10 cm cutting height. Maize was the main contributor to total annual DM yield, therefore all SD_1 intercrops had significantly less total annual yield than the control.

Table 2: Maize and intercrop yields (t DM ha^{-1}) for 2006-07. Control = maize only (no intercrop); BC = balansa clover; IR = Italian ryegrass; FB = forage brassica; K = kale. SD_1 = intercrop sown at maize planting; SD_2 = 8 weeks after maize sowing; and SD_3 = 11 days after silage-harvest. Combined silage yield = maize yield + intercrop yield. Intercrop winter yield = yield accumulated by the intercrops over winter. Total annual yield = combined silage yield + intercrop winter yield.

Intercrop	Sowing date	Maize-silage yield	Intercrop silage yield	Combined silage yield	Intercrop winter yield	Total annual yield
Control	-	23.9	0.0	23.9	0.0	23.9
BC	SD_1	14.6	2.1	16.7	0.7	17.4
BC	SD_2	20.9	0.0	20.9	0.1	20.9
BC	SD_3	19.7	0.0	19.7	0.4	20.1
IR	SD_1	15.7	1.6	17.3	0.6	17.9
IR	SD_2	23.6	0.0	23.6	1.3	24.9
IR	SD_3	20.7	0.0	20.7	1.8	22.5
FB	SD_1	10.9	1.6	12.5	0.3	12.8
FB	SD_2	22.3	0.0	22.3	0.5	22.8
FB	SD_3	15.7	0.0	15.7	2.4	18.1
K	SD_1	10.7	4.1	14.8	1.4	16.1
K	SD_2	21.9	0.0	21.9	0.8	22.6
K	SD_3	20.9	0.0	20.9	1.8	22.7
	LSD (5%)	3.9	0.8	4.0	0.6	4.1
	P	<0.001	<0.001	<0.001	<0.001	<0.001

The SD_1 intercrops established well and were vigorous and fast-growing. By 7 December 2006 (47 days after sowing) SD_1-IR had 218 (± 60) plantsm^{-2}, SD_1-BC 601 (± 169) plants m^{-2}, SD_1-K 63 (± 37) plants m^{-2}, and SD_1-FB 67 (± 48) plants m^{-2}. Although repeat plant counts were not made in the SD_1 intercrops, it appears that plant population density declined throughout the season in them all except in SD_1-K. Nevertheless, complete ground cover was attained in most areas approximately 1 month after sowing. At that time, the fraction of radiation intercepted (*f*) was in the order of SD_1-BC (0.65), -IR (0.60), -K (0.57), -FB (0.56); all significantly higher than the control (0.40) (P<0.001; LSD = 0.03).

Soil shading by the SD_1 intercrops influenced soil temperature and maize performance. On 6 December 2006 in the SD_1 treatments the average soil temperature at 5 cm depth was 13.6 ºC compared to 14.0 ºC in control plots (P=0.085; df = 7). Contrast analysis indicated that soil temperature in the SD_1-IR plots (13.7 ºC) was not different from the control (P=0.714; df = 19) whereas SD_1-BC (13.2 ºC; P=0.063), -FB (13.2 ºC; P=0.055) and -K (13.0 ºC; P=0.064) were lower.

These temperature differences were correlated with maize leaf counts taken on the same day, such that maize plants on SD_1 intercrop plots had, on average, 6 fully-expanded leaves compared to 7 on the control plots. Further soil temperature, as measured on 6 December 2006, accounted for 55% of the variance in the final maize yield (P<0.001).

In SD_2 intercrops, establishment was similar to the SD_1 intercrops. Thirty six days after SD_2 intercrop sowing SD_2-IR had 226 (± 75) plants m^{-2}, SD_1-BC 421 (± 166) plants m^{-2}, SD_1-K 89 (± 41) plants m^{-2}, and SD_1-FB 167 (± 37) plants m^{-2}.

In SD_2 intercrops plant death rates increased during the season (Figure 2). The SD_2 intercrops did not flower, and winter production of these intercrops was from the few viable plants that persisted over the summer months and possibly from new plants germinating in autumn from the seed that did not germinate soon after sowing.

In SD_3 intercrops, germination was slow due to very dry soil conditions. Significant rain did not fall until about 20 days after SD_3 intercrop sowing (Figure 1). On 3 May 2007 (47 days after SD_3 intercrop sowing) SD_3-IR had 189 (± 92) plants m^{-2}, SD_3-BC had 112 (± 108) plants m^{-2} SD_3-FB had 72 (± 28) plants m^{-2} and SD_3-K had 41 (± 14) plants m^{-2}, indicating poorer establishment than in the SD_1 and SD_2 intercrops.

The SD_1-IR and SD_1-BC intercrops died mid-way through the season after they had flowered, whereas SD_1-K, and to a lesser extent, SD_1-FB maintained a viable stand throughout the season. Both BC and IR are annual (self-regenerating) crops by nature and there was evidence of self-seeding in autumn given that SD_1-BC and -IR managed to produce some fresh harvestable biomass during the winter. However, re-establishment of these crops after silage-harvest was not helped because the experimental design prevented soil re-cultivation on those plots after silage harvest. It is also possible that any seed set, over summer, may have had poor vigour due to poor irradiance of the intercrops during seed filling.

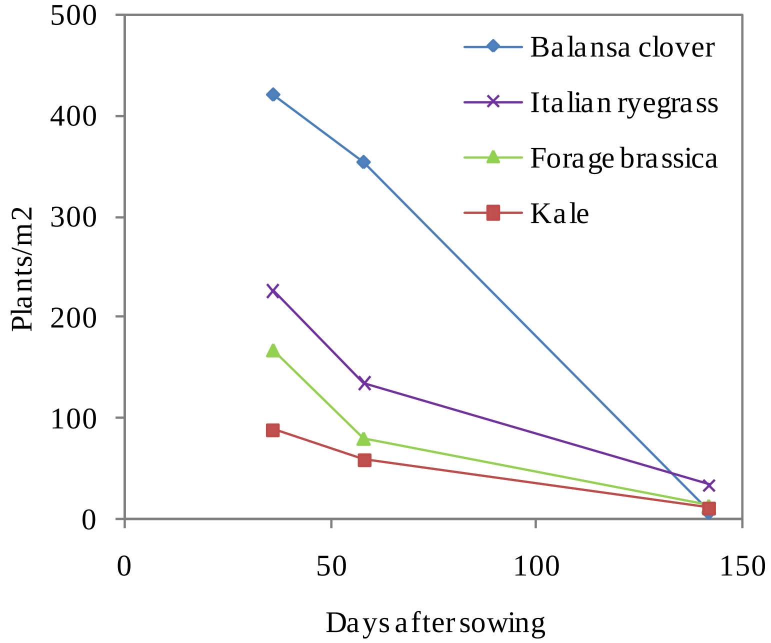

Figure 2: The decline in intercrop plant population density over time from sowing date 2 (SD_2) (day zero is the day SD_2 intercrops were sown; 12 December 2006). At 142 days after sowing (3 May 2007) clover had 6 plants m^{-2}, kale 10 plants m^{-2}, ryegrass 33 plants m^{-2} and forage brassica 12 plants m^{-2}.

2007-08

Maize silage yield was substantially higher than in 2006-7 (Tables 2 and 3). It was unaffected by the PR intercrops, irrespective of time of sowing and the SD_2 FB intercrops (Table 3). However, compared to the controls, maize-silage yield was reduced to 80% in SD_1-FB_{50} and 57% in SD_1-FB_{100}. Maize-silage yields in SD_2-FB plots (both sowing rates) were significantly higher than in SD_1-FB plots.

Maize-silage DM % was not affected by any treatment. There were no significant differences in N % of the maize-silage material between the control, SD_1-FB_{100} and SD_1-PR_{100} (mean = 1.03 % N), indicating that N did not limit the maize component at silage-harvest.

Only SD_1-FB intercrops had any viable plants remaining at silage-harvest. Although SD_1-PR had full ground cover at silage harvest, it was senesced material and the amount of biomass was not measured because it was below harvestable height. A thatch was present at silage harvest in SD_2-PR but it was not as dense as in SD_1-PR. SD_1-FB_{50} had one plot with viable plant material in the harvest area, as did all four plots of SD_1-FB_{100}. Considering only these five plots the maize-silage yield had a negative linear relationship with intercrop silage yield ($R^2 = 0.90$; $y = -14.869x + 22.107$), suggesting strong competition between the FB-intercrops and maize.

Total silage yield showed the same patterns of treatment differences as the maize silage yield, because only the SD_1-FB intercrops gave a silage yield, and these were too small to offset the maize yield reductions (Table 3). This same pattern was evident in the total annual yield. Total annual yield was highest in the control treatment due to the additional DM yield of the winter (annual) ryegrass. Total annual yield was not enhanced by winter production in SD_1-FB_{50} (P=0.229) but it was in SD_1-FB_{100} (P=0.006).

Table 3: Maize and intercrop yields (t DM ha^{-1}). Combined silage yield = maize yield + intercrop yield. Intercrop winter yield = yield accumulated by the intercrops over winter. Total annual yield = combined silage yield + intercrop winter yield. The "intercrop winter yield" for the control is that measured for Italian ryegrass sown soon after the maize harvest (see methods).

Treatment	Maize-silage yield	Intercrop silage yield	Total silage yield	Intercrop winter yield	Total annual yield
Control	31.5	-	31.5	5.2	36.7
SD_1-FB_{50}	25.1	0.1	25.2	1.0	26.2
SD_1-FB_{100}	18.1	0.3	18.4	2.2	20.6
SD_2-FB_{100}	32.9	-	32.9	-	32.9
SD_2-FB_{50}	32.8	-	32.8	-	32.8
SD_1-PR_{100}	29.5	-	29.5	-	29.5
SD_1-PR_{50}	29.7	-	29.7	-	29.7
SD_2-PR_{100}	34.2	-	34.2	-	34.2
SD_2-PR_{50}	29.3	-	29.3	-	29.3
P	<0.001	0.171	<0.001	<0.001	<0.001
LSD	5.0	0.4	4.9	1.24	4.8

The SD_1 and SD_2 intercrops established well (Figure 3) and grew quickly usually achieving greater than or equal to 50% ground cover around three weeks after sowing. The SD_2 intercrops had slightly lower plant populations than SD_1 intercrops. Contrast analysis indicated that at approximately three weeks after sowing intercrop plant population was significantly higher in the 100% than in the 50% sowing rates in both SD_1 and SD_2 and also that the intercrop plant populations in SD_1 and SD_2 at this time were similar for each sowing rate by species combination.

By 11 weeks after intercrop sowing SD_2-PR was in the dying off (Figure 3). Measurements were not taken in SD_1-PR at the same time because the sward was too thick to count individual plants, but observations indicated that the health and vigour of the SD_1-PR intercrops was also in decline.

Leaf counts at approximately six weeks after maize sowing indicated no differences among treatments, so soil temperature was assumed to be the same in all treatments and was not measured. Both SD_1 and SD_2 intercrops experienced severe shading as the maize canopy closed (six to eight weeks after maize sowing). Shading had less of an impact on SD_1-FB crops because the expansive nature of the FB canopy meant that it converged on the intercrop-free strip and competed with the maize, reducing the size and vigour of the maize canopy.

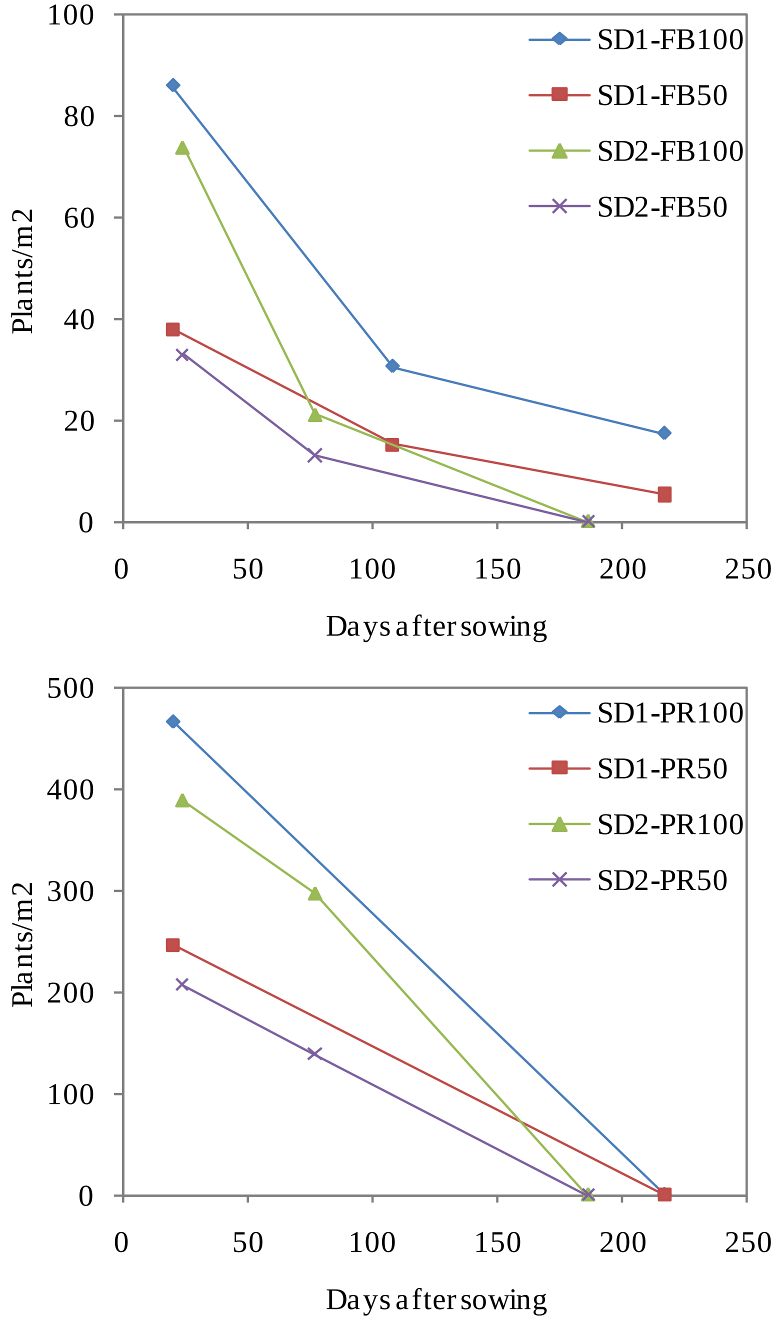

Figure 3: The decline in plant population density of forage brassica (FB; left) and perennial ryegrass (PR; right) intercrops over time in 2007-08. Sowing dates (SD_1 and SD_2) were at maize sowing and 26 days after maize sowing respectively, and the two sowing rates (treatment suffixes 50 and 100) were respectively 50 and 100% of recommended commercial sowing rates for pure stands. Final sampling was at silage-harvest.

Discussion

In 2006-7 all SD_1 intercrops reduced maize yield. Maize was the major component of silage yield and SD_1 intercrop growth was minimal over the winter months, and so total annual DM yield was also reduced by the intercrops. SD_2 intercrops did not affect maize yields nor did they increase total annual DM yield. This was primarily due to poor intercrop survival under the maize canopy and poor winter production. Reduced competition for light and water, achieved through wider maize row spacing and/or lower maize population density may have reduced the death of SD_1 and SD_2 intercrops during summer (Semere and Froud-Williams, 2001; Ghanbari *et al.*, 2010). The SD_2 intercrops did not flower, and so their winter production was from the few viable plants that persisted over the summer months and possibly from delayed (autumn) germination of some seeds from the original sowing. The SD_3 intercrops (sown after maize-silage was harvested) also failed to increase total annual yield, but this was probably due to the dry conditions and the broadcast sowing (with no cultivation) used to sow the crops. Drilling and irrigation might have greatly enhanced productivity.

The negative effect of SD_1 intercrops on maize yield in 2006-7 was probably due to cooler soil temperatures and competition for water, N and light. Our results show a clear relationship between shading by the intercrops, soil temperature and maize performance. Ghanbari *et al*. (2010) also found that intercrops reduced soil temperature in maize intercropping systems, and Stone *et al*. (1999) showed an influence of soil temperature on maize leaf appearance rates in Hawke's Bay. Use of the maize model, AmaizeN (Li *et al*., 2006), indicated that the measured maize yield in the control plots (23.9 t DM ha^{-1}) was slightly lower than the simulated yield if water and N were not limiting (25.2 t DM ha^{-1}). The required amount of fertiliser N for this simulated yield was 154 kg N ha^{-1}. At maize sowing the mean amount of soil mineral N was 38 kg N ha^{-1} in the top 30 cm soil and less than 4 kg N ha^{-1} between 30 and 120 cm depth (data not shown). Fertiliser N applications totalled 163 kg N ha^{-1} during the season, and so there was very little N that was surplus to maize requirements.

In 2007-08, significant improvements were made on the previous season's systems. Total annual yields and maize yields were much higher, although the intercrop yields were still poor. The only intercrop treatment to yield significantly was the FB at SD_1, and even then there was a much greater loss in maize yield. Winter yield from IR was significantly higher than any of the intercrop treatments, suggesting that the existing system of following the maize-silage harvest by planting IR was the most productive under these conditions.

The 2007-08 experiment highlighted problems that will need to be overcome with intercrop persistence. Perennial ryegrass had poor persistence under the maize canopy, probably the result of an inability to cope with low light and possibly low soil moisture levels. Ryegrass species are not as deep rooting as forage brassicas (Kristensen and Thorup-Kristensen, 2004) which may make forage brassicas more drought tolerant. This would contribute to their better persistence and productivity in intercropping systems. However, a high sowing rates of forage brassica was more persistent than a lower sowing rate, so other factors may also be involved.

Intercrops may bring benefits not directly related to total DM production. The dense thatch observed here in the PR intercrops may enhance ability of the soil to withstand vehicle movements during silage harvest, particularly under wet conditions. If allowed to persist, such thatches may reduce the risk and severity of erosion if maize or winter crops such as Italian ryegrass or oats are direct drilled into them.

Conclusions

This work has shown only limited viability and persistence of intercrops grown in maize crops established using standard maize sowing rates (90,000-100,000 plants ha^{-1}) and row spacing (76 cm). This was probably mainly due to the low light and soil moisture levels under the maize canopy. Brassica species seem to be more persistent and competitive when intercropped with maize than ryegrass and clover. Based on the systems used in this research, the most productive system is the standard practice of growing maize silage over summer followed by Italian ryegrass in winter. If soil cover to enhance resilience to traffic and/or reduce erosion is the primary goal then either annual or perennial ryegrass sown in 45 cm swaths between maize rows should be beneficial, although it is unlikely there will be significant winter regrowth.

For maize intercropping to be viable and sustainable in New Zealand more detailed work needs to be done to determine ways of enhancing intercrop persistence. Variables to be investigated should include wider maize row spacing and lower maize seeding rates.

Acknowledgements

This work was funded by the MAF Sustainable Farming Fund and the Foundation for Arable Research. Assistance during the trial was provided by Nathan Arnold and Isabelle Sorenson (Plant & Food Research) and Andrea Pearson (Foundation for Arable Research).

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