Using plastic mulch to increase maize silage production in a cool climate with a short growing season

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Abstract

Maize is capable of producing large amounts of high quality silage when grown under optimum conditions. With good fertiliser and water management in New Zealand's South Island, maize can grow at 250-300 kg DM/ha/day in mid summer, but growth rates are usually much lower in spring and autumn when temperatures are cooler. In spring, it takes a long time for the leaf canopy to develop fully because cool minimum temperatures (~8?C) mean that production of leaf area is slow. At the other end of the relatively short season, there is a substantial risk of crops being killed by an early autumn frost before they reach silage maturity. In this research we evaluated the feasibility of using a photodegradable plastic mulch to increase soil temperature in spring, to accelerate canopy development, shorten growth duration and increase the yield of maize grown for silage at Lincoln, Canterbury, New Zealand (43.83?S, 171.72?E).

Early and mid-season maize hybrids, with comparative relative maturities (CRM) of 78 and 91% were sown on 24 October 2007 with the soil surface either covered with clear plastic or uncovered. The plastic mulch increased average soil temperature by 5?C at 5 cm depth until the plastic disintegrated at 30-35 days after sowing. This increased the rate of leaf appearance and reduced the time to full canopy development and maximum radiation interception. The time to silking was 10-12 days less in the treatment with plastic, and at 77 days after sowing (DAS) this treatment had produced 2.3 t DM/ha more than the uncovered treatment for both hybrids. At 99 DAS, the early hybrid with plastic had produced 4.0 t DM/ha more than the uncovered control while the mid-season hybrid had produced 0.9 t DM/ha more. However, at silage maturity there were no differences in harvested crop biomass, even though the plastic treatments were harvested 14 days earlier than the bare soil treatments. These results demonstrate the potential of using a plastic mulch to accelerate crop development and reduce the crop's duration, thereby reducing the risk of growing maize in this environment.

Key Words

Zea mays, canopy development, yield, silking

Introduction

Maize is a C4 crop of tropical origins. It has a high base temperature, of 8?C (Muchow et al., 1990), so crop development is slow when mean temperatures approach this value. Furthermore, maize photosynthesis and/or radiation use efficiency is also reduced when air temperatures fall below ~20?C (Wilson et al., 1995). In New Zealand maize is traditionally grown in the North Island (41-35?S) where the thermal environment is better suited to maize production than the South Island. However, recently maize silage production has increased in areas of the northern South Island (44-41?S) such as Canterbury. Cool and variable temperatures mean that maize crops are slow to produce an effective leaf canopy (generally the peak of LAI occurs after mid-summer), and are at substantial risk of being killed by an autumn frost (Wilson et al., 1994). The usual practice to reduce this risk and produce maximum yield is to use short maturity hybrids and early sowing dates, usually mid October (Wilson et al., 1994). In a warm season, a medium maturity hybrid will produce greater yields than a short maturity hybrid, but it will be at considerable risk of frost damage in a cool season. Another approach is to apply plastic mulch on the soil after sowing to increase soil temperature and enhance maturity (Stone et al., 1999). Experiments with maize grown under plastic mulch in Canada (Kwabiah, 2003), Ireland (Easson and Fearnehough, 2000) and North Island, New Zealand (Stone et al., 1999), have found yield increases of 1- 4 t ha^{-1} and maturity

occurring 6-15 days earlier. This research examines the effect of plastic mulch on the yield and development of an early and medium maturity maize hybrid in Canterbury.

Methods

Early (hybrid 39G12, CRM = 78) and medium maturity (hybrid 38H20, CRM = 91) maize hybrids (Pioneer Hi-Bred International Inc) were sown using a Samco (Limerick. Ireland) 4 row seeder and plastic layer on 24 October 2007 at Lincoln, New Zealand (43.83?S, 171.72?E), into a cultivated seed bed. Each hybrid was sown either covered with a photo-degradable perforated plastic mulch or left uncovered. The experimental design was a randomised complete block with four replicates (16 plots). Each plot was 10 m long and consisted of 8 rows. The row configuration consisted of pairs of rows that were 700 mm apart with 900 mm between each pair of rows. The crops were sown at a population of 116,000 plants ha^{-1}. The site was of moderate to high fertility, with a pH of 6.4 and an Olsen P of 19 ?g/ml. On 22 October 86 kg N ha^{-1}, 30 kg P ha^{-1} and 30 kg K ha^{-1} were broadcast across the site. Additional N was applied on 19 December 2007 at a rate of 161 kg N ha^{-1}. A total of 255 mm of irrigation was applied in addition to 270 mm of rainfall so that soil water was not limiting. Irrigation was applied using an overhead lateral irrigator.

Soil temperature at 50 mm depth was logged every 30 minutes using Hobo 4 channel external data loggers (Onset Computer Corporation, MA, USA), which were installed in each plot the day after sowing. In each plot five contiguous plants were marked soon after emergence. The number of fully expanded leaves (collar visible) was counted on these plants at intervals of 6-17 days between 12 November 2007 and 21 January 2008. Measurements of solar radiation interception were made at intervals of 6-16 days between 28 November 2007 and 17 January 2008 using a ceptometer (Decagon Devices Inc WA, USA). A further measurement was made 31 days later on 17 February 2008. The date of 50% silking for each crop was determined by counting the number of plants (out of 20 contiguous marked plants) that had visible silks at 2-3 day intervals between 11 and 28 January 2008.

Whole crop biomass was measured on three occasions for each crop. The first two measurements were made on 9 and 30 January 2008. These were timed to coincide with silking in the earliest (early hybrid with plastic) and latest (medium hybrid without plastic) maturing crops. For these two harvests, 10 contiguous plants were cut at ground level, their fresh weight was determined, and a five plant sub-sample was taken and dried for dry matter determination. Each crop was also sampled at silage maturity (2/3 milk line). Crops were harvested when the plastic and uncovered treatments were at a similar stage of maturity. To do this each plastic-covered treatment was harvested according to an assessment of the milk line. The corresponding uncovered treatment was harvested the same number of thermal units (?Cd, Tb = 0?C) after the plastic treatment with the same hybrid, as the difference in thermal units between silking dates in the plastic treatments of that hybrid. For each silage harvest, 20 plants were harvested from each crop. They were weighed fresh and then a three plant sub-sample was separated into leaves, stem, ear, and grain and dried for dry matter determination.

Results and Discussion

Air temperatures during the growing season were similar to the average. Solar radiation was slightly higher than average during spring but similar to the average thereafter. Between 0 and 30 days after sowing (DAS) mean 50 mm soil temperature was 15.8?C in the uncovered crops. The plastic mulch treatments increased this by an average of 5.5?C (Figure 1). This ranged from 3.3?C during the night to 9.9?C at midday. After 35 DAS the plastic had disintegrated and there was no further effect of the mulch treatment on soil temperature.

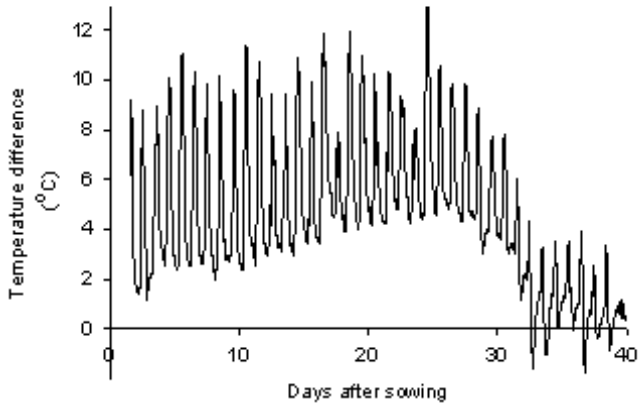

Figure 1. Difference in 50 mm soil temperature between plastic mulch and uncovered plots.

The increase in soil temperature advanced the date of silking for both hybrids. The uncovered early hybrid plots reached silking on 21 January (89 DAS) and the uncovered medium hybrid plots reached silking on 25 January (93 DAS). The same hybrids grown with plastic mulch reached silking on 11 January (79 DAS) and 12 January (80 DAS) respectively (Table 1). At silking the plastic mulch treatments had a ~ 2.5 t ha^{-1} greater DM ($P<0.05$) yield than the uncovered treatment (Table 1). For the 30 January measurement the difference between the plastic and uncovered treatments for medium hybrid was much smaller, being only 0.9 t ha^{-1}.

Table 1. Dates and days after sowing (DAS) of silking and silage harvest, whole crop DM on 9th and 30th January, and whole crop DM and DM% at final silage harvest for maize crops grown with or without plastic mulch.

Treatment	Silking				Silage harvest			
	Date	DAS	DM (t ha^{-1}) 9 Jan	DM (t ha^{-1}) 30 Jan	Harvest date	DAS	Total DM (t ha^{-1})	DM%
Early + plastic	11 Jan	79	9.0	15.3	18 Mar	146	26.9	33.8
Early uncovered	21 Jan	89	6.7	11.3	31 Mar	159	25.3	34.2
Medium + plastic	12 Jan	80	8.3	14.3	25 Mar	153	28.4	37.1
Medium uncovered	25 Jan	93	6.0	13.4	8 Apr	167	27.8	32.6
5% LSD plastic treatments	2 days		1.7	1.4	-		1.84	-

The plastic treatment also hastened maturity by 13-14 days (Table 1). The early hybrid crops were harvested at 34% moisture for both treatments whereas the medium hybrid treatments were harvested at 37 and 33% moisture for the plastic mulch and the uncovered treatments, respectively. There were no

statistically significant differences in harvested silage DM between the plastic treatments. For the early hybrid mean yield was 26.1 t ha^{-1}, and for the medium hybrid mean yield was 28.1 t ha^{-1}.

The increase in 50 mm soil temperature in the plastic mulch treatments markedly increased the rate of canopy development. Between 20 and 60 DAS the plastic mulch treatments had 2-3 more fully expanded leaves in both hybrids (Figure 2). At 80 DAS rapid stem elongation had occurred in the plastic mulch treatments which meant that they had 5 more fully expanded leaves than the associated uncovered treatments. This faster leaf appearance rate in the plastic mulch treatments resulted in greater solar radiation interception early in the season (Figure 3). For example, at 53 DAS the medium hybrid crops with plastic mulch intercepted 79% of incident radiation while the uncovered crops intercepted 44%. However, by 80 DAS both the plastic mulch and the uncovered crops had reached canopy closure and were intercepting ≥90% of incident solar radiation and there were no further differences.

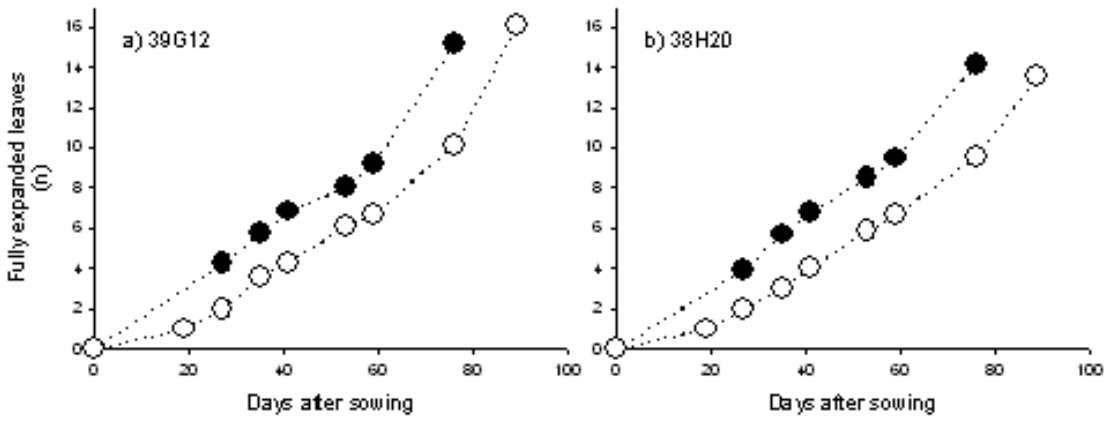

Figure 2. Number of fully expanded leaves against days after sowing for maize hybrids 39G12 – early (a) and 38H20 – medium (b) sown with (filled symbols) or without (open symbols) plastic mulch.

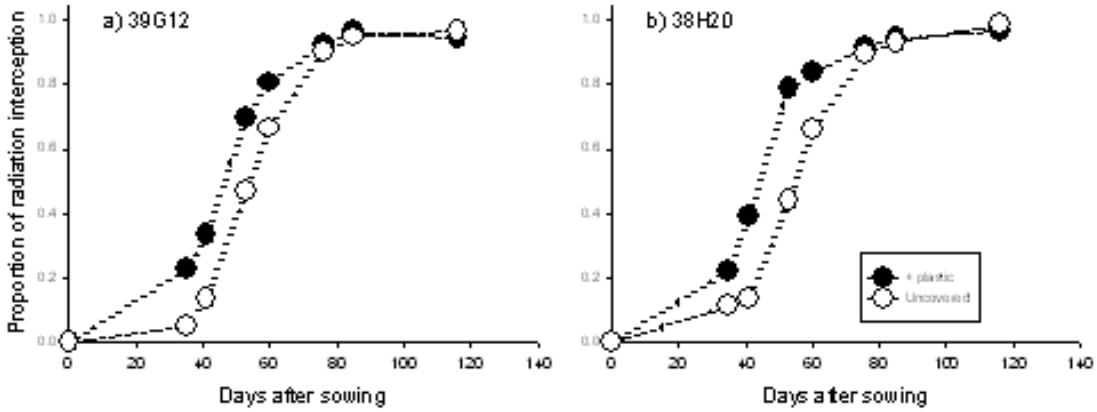

Figure 3. Proportion of incident solar radiation intercepted against days after sowing for 39G12 – early (a) and 38H20 – medium (b) maize hybrids sown with (filled symbols) or without (open symbols) plastic mulch.

Conclusions

The plastic mulch treatment showed potential as a system for silage maize production in this cool temperate climate. Final silage yield was not affected by the plastic mulch treatment, but using the plastic mulch allowed harvest to occur 14 days earlier.

This means that:

- the same hybrid could be sown with a much reduced risk of late season frost damage, or
- a later maturing hybrid (with an increased yield) could be grown in the same location with a similar risk of frost damage.

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