Effect of total defoliation on maize growth and yield

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Abstract

Maize seedlings can be damaged through a variety of means including traffic, stock grazing, insect damage, hail, and wind damage. The aim of this experiment was to determine the effect of timing of total maize plant defoliation by ground level cutting on crop growth and yield. Two trials were conducted in the 2007-08 season (Hawke's Bay and Canterbury). At each site, defoliation at maize growth stages V2, V4, V6 and V8 were compared with an uncut control. Each treatment was replicated four times, and plant growth, leaf area and final crop yield measured. There was no grain yield loss when plants were cut up to growth stage V4 but defoliation delayed maturity resulting in higher grain moisture content. Defoliation at V6 severely reduced grain yield by 60% in Hawke's Bay and 20% in Canterbury. The crop did not recover when plants were defoliated at growth stage V8. Defoliation of maize up to growth stage V4 will have minimal effect on grain yield but may delay maturity, and defoliation by cutting does not take into account other impacts associated with defoliation in field situations such as compaction, freezing, shear stress, bruising and other secondary impacts.

Additional keywords: *Zea mays*, time of defoliation

Introduction

Maize seedlings can be damaged by a variety of means including vehicular traffic, stock grazing, cutworm, hail, and wind damage. The impact of losing leaves or the entire plant from ground level shortly after emergence will affect crop regrowth and final yield. Growers will often replant their fields if damage occurs. However, the timing of the damage and its severity will both influence the decision to replant. Understanding the effect of defoliation at different growth stages will assist growers in re-plant decisions if their crop is damaged.

Partial defoliation (loss of leaves) has been studied internationally (e.g. Lauer *et al*., 2004) but nothing has been published on total defoliation of maize under New Zealand conditions. This initial feasibility study aims to determine the effect of timing of total defoliation, in early season, on the subsequent yield of the maize crop.

Materials and methods

Two trials were conducted in the 2007-08 season, one in Hawke's Bay and the other in Canterbury. While the treatments were similar at the two sites, more detailed measurements were conducted in the Hawke's Bay trial. For this reason, the approach used at the two sites will be described separately.

Hawkes's Bay site details

The trial was conducted at Plant & Food Research, Hastings, in a crop sown on 15 October 2007 (hybrid 34D71, population 100 kg ha^{-1}). The soil type at the site was a Mangateretere silt loam. Fertiliser applied before and at sowing was urea at 200 kg ha^{-1} (92 kg N ha^{-1}) and DAP at 200 kg ha^{-1} (36 kg N ha^{-1} and 40 kg P ha^{-1}). This was followed by a broadcast application of urea at 300 kg ha^{-1} (138 kg N ha^{-1}) on 26 November 2007. The trial was fully irrigated, with irrigation scheduled from weekly neutron probe soil moisture monitoring.

Leaf area assessments were made on 20 March 2008. The length and width of three leaves were measured from five plants in each plot. The leaves measured were those immediately below the ear (cob), the ear leaf, and immediately above the ear. Leaf area was calculated by multiplying the product of length and width by a factor of 0.73 (Wilson *et al*., 1995). The area of the largest leaf is strongly linked to the total plant leaf area thus affecting radiation interception and therefore crop yield (Muchow *et al*., 1990).

Final crop yields were determined on 12 May 2008 by removing 2.5m of the three central rows of each plot. Total plant biomass and dry matter content (DM %) were measured along with grain yield and grain moisture content. Grain yield is reported at 14% moisture content.

Canterbury site details

The trial was conducted at the Foundation for Arable Research, Chertsey site in a crop sown on 4 November 2007 (hybrid 39G12 at 120 kg ha^{-1}). The soil type was a Chertsey silt loam. Fertiliser N applied before and at sowing was 108 kg N ha^{-1} which, along with the existing soil mineral N pool, was enough to meet crop requirements. The trial was fully irrigated and irrigation scheduled by three-weekly soil moisture monitoring by neutron probe to 0.6 m.

In the Canterbury trial, four treatments were imposed in a Latin square design with four replicates. Plots were 5 rows wide (row width = 0.762 m) and 6 metres long. The treatments were applied at different growth stages by cutting the maize off at ground level using secateurs. All plants in each plot were cut. The four treatments were, control (uncut), V3 (plants cut at growth stage V3), V5 (plants cut at growth stage V5) and V6 (plants cut at growth stage V6). The Hawke's Bay trial was similar except the trial was a randomised complete block design and the cutting treatments were imposed at growth stages V2, V4, V6 and V8.

For each cut, plant population, plant growth stage, total biomass and leaf area were determined. Leaf area was measured on entire sample rather than per plant so standard errors were not calculated for this measure. Final crop yield was determined on 11 April 2008 by removing all plants from a 2.5 metre length of the two central rows of each plot. Total plant biomass and dry matter content (DM %) were measured. Grain yield was determined by removing and drying grain from three cobs per plot.

Results

Hawke's Bay

Plant assessments at cutting

Good regrowth after cutting was observed within three to five days in treatments V2 and V4 (Table 1) although defoliation did check crop development (Table 2). Regrowth of plants cut at V6 was mostly as new tillers rather than regeneration of the main stem of the plant. No plants recovered from cutting at V8. Leaf area assessments made on 20 March 2008 found the area of the largest leaf (A_{max}) was significantly less ($P<0.001$, $LSD_{0.05} = 57$) in the plants cut at V6 (654 cm^2) than those in the control, V2 and V4 treatments (average of 761 cm^2).

Table 1: Crop assessments conducted at each defoliation event in Hawke's Bay (standard errors in brackets).

Treatment and date	Biomass removed (kg DM ha^{-1})	Leaf area (cm^2 $plant^{-1}$)	Growth stage at cutting	Regrowth after cutting
V2 - 5 Nov	20 (1.1)	28	1.9 (0.1)	Good
V4 - 16 Nov	80 (2.2)	169	3.8 (0.1)	Good
V6 - 26 Nov	584 (41)	394	6.0 (0.1)	Poor
V8 - 10 Dec	2416 (117)	4319	8.3 (0.1)	Nil

Table 2: Regrowth assessments made on 26 November in Hawke's Bay.

Treatment	Leaf area (cm^2 $plant^{-1}$)	Growth stage
Control	394	6.0 (0.1)
V2 - 5 Nov	213	4.6 (0.2)
V4 - 16 Nov	82	4.1 (0.1)

Crop yield assessments - 12 May 2008

Due to the well fertilised and irrigated growing conditions, crop yields were very high. There was no significant effect on plant population (average 103,000 plants ha^{-1}) although tillering was more evident in the V6 plots. Tiller counts were not assessed.

The control (uncut) plots produced more total biomass than all other treatments yet the grain yield was the same as the V2 and V4 treatments (Table 3). Harvest index (HI, the percentage of total biomass that is grain) in the control treatment tended to be lower than the V2 and V4 treatments but the difference was not statistically significant. The control treatment had the lowest grain moisture content. The V2 and V4 treatments produced similar total biomass and grain. Grain moisture content was less in the V2 treatment than the V4 treatment.

The V6 treatment produced the least amount of total biomass (18.2 t DM ha^{-1}) and grain (8.2 t ha^{-1}). Both plant and grain moisture content was highest for these plants, suggesting a difference in crop maturity. Visually, the plants in the V6-cut treatment were greener and less advanced than the other treatments. Interestingly, HI in this treatment (% of total biomass that is grain) was much lower than all other treatments. This was probably due to many of the plants in this treatment being tillers.

Table 3: Effect of defoliation on maize yield, moisture content and harvest index in Hawke's Bay.

Treatment	Total biomass t DM ha^{-1}	Plant DM %	Grain yield t ha^{-1}	Grain moisture %	Harvest Index (HI) %
Control	33.1a	63.7a	20.4a	19.6a	53.6a
V2	27.7b	57.3a	20.4a	20.9b	60.3a
V4	25.5b	56.6a	18.9a	22.3c	64.8a
V6	18.2c	47.6b	8.2b	27.2d	40.4b
Significance	<0.001	<0.01	<0.001	<0.001	<0.01
LSD $_{0.05}$	3.9	7.5	3.3	1.1	12.4

Canterbury

Plant assessments at cutting

The amount of biomass removed at each cut is shown in Table 4. Due to site, sowing time and hybrid differences, it is not meaningful to compare these results with Hawke's Bay. Regrowth assessments were not made.

Table 4: Crop assessments conducted at each defoliation event in Hawke's Bay (standard errors in brackets).

Treatment and date	Biomass removed (kg DM ha^{-1})	Leaf area (cm^2 plant^{-1})
V3 – 4 Dec	35 (1)	48
V5 – 13 Dec	133 (8)	234
V6 – 21 Dec	396 (11)	337

Crop yield assessments - 11 April 2008

Unlike the Hawke's Bay experiment, plant population was significantly reduced in the V6 treatment, lowering total biomass (Table 4). Biomass of individual plants was reduced in all plots that were defoliated, following a similar trend to Hawke's Bay. Plant dry matter content, an indication of crop maturity, was greatest in the control and declined with cutting. The same result was found with grain moisture in Hawke's Bay.

Like total yield, grain yield in the V6 plots was significantly less than in the uncut treatment (Table 5). Due to the declining population, the grain yield per plant was greater in V6 treatment than in the uncut or V3 treatment. This is quite different to the Hawke's Bay site where grain per plant in the V6 treatment was less than half that found in the other treatments.

Table 5: Effect of defoliation on plant population, yield and moisture content in Canterbury.

Treatment	Population 000 ha^{-1}	Total biomass t DM ha^{-1}	Plant DM %	Grain yield t ha^{-1}	Harvest Index %
Control	116a	15.4a	55.5a	9.3a	50a
V3	118a	14.7a	49.7b	8.4ab	49a
V5	117a	14.8a	45.2c	9.5a	53b
V6	97b	11.8b	39.3d	7.4b	54b
Significance	<0.05	<0.05	<0.001	P=0.054	<0.05
LSD $_{0.05}$	14	2.0	4.1	1.3	3

Discussion

Up to growth stage V4 total defoliation to ground level did not result in loss of maize grain yield at either trial site. The leaf area removed at these stages is minimal in relation to total plant and the size of the largest leaves around the cob was unaffected by V2 and V4 defoliation, thus it is not surprising that yield loss is minimal. However we found that defoliation up to V4 may affect total biomass, which was reduced in Hawke's Bay but not Canterbury. The reason for the different response between grain and total yield is not known.

Defoliation at V6 will had a significant impact on yield, particularly grain yield. Harvest index was severely reduced with cutting at V6 in Hawke's Bay but not in Canterbury where plant population was severely affected instead. The difference in response between sites is considerable and may be related to different hybrids, sowing times and climatic conditions. Lauer *et al*. (2004) also found the response to defoliation varied among growing environments and seasons.

While grain yield may not be affected with defoliation up to growth stage V4, consistent between sites and with other observations (e.g. Hicks *et al*., 1977) is the delay in crop maturity as a result of defoliation. This has implications for harvest scheduling and crop quality, particularly in field situations where only parts of the paddock may be affected.

The conclusion from this study is that defoliation of crops up to growth stage V4 will have a minimal effect on maize yield although crop maturity may be delayed. This simulated defoliation by cutting does not take into account other impacts associated with defoliation in the field, such as compaction, freezing, shear stress, bruising and other secondary impacts. Growers should assess crop regrowth before deciding to replant damaged crops.

References

Hicks, D.R., Neson, W.W and Ford, J.H. 1977. Defoliation effects on corn hybrids adapted to the northern corn belt. *Agronomy Journal* 69: 387-390.

Lauer, J.G., Roth, G.W., and Bertram, M.G. 2004. Impact of defoliation on corn forage yield. *Agronomy Journal* 96: 1459-1463.

Muchow, R.C., Sinclair, T.R., and Bennett, J.M. 1990. Temperature and solar radiation effects on potential maize yield across locations. *Agronomy Journal* 82: 38-343.

Wilson, D.R., Muchow, R.C. and Murgatroyd, C.J. 1995. Model analysis of temperature and solar radiation limitations to maize potential productivity in a cool climate. *Field Crops Research* 43: 1-18.