LEAF STRIPPING AND DETASSELLING INCREASE EAR GROWTH RATE AND MAIZE GRAIN YIELD

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Abstract

Field experiments were conducted in three seasons (1998/99, 1999/00 and 2000/01) to determine the effects of removing the male flower (detasselling) or oldest leaves (leaf stripping) on grain yield of maize. Detasselling increased yield by 11.2-12.2% in the first two seasons and by 32.3% in the third. The effect of leaf stripping on grain yield depended on timing; leaf stripping at anthesis (50% silking) increased yield by 16.6% in the first season and by 28% in the second, whereas leaf stripping at three to four weeks before or after anthesis had no significant effect on yield. In the third season, ear growth rate was measured over a seven week period, two weeks after leaf stripping and/or detasselling, from 12 to 18 WAE. Coefficients of linear regression of ear dry weight over the seven week period were 18.29 ± 1.564, 20.10 ±.1.264, 20.43 ± 1.329 and 25.02 ± 1.528 for the intact, leaf stripped, leaf stripped and detasselled and detasselled treatments, respectively. Detasselling increased radiation interception (RI) by sub-tassel leaves and by the cob leaf by 10-28% and 5-27%, respectively. Moreover, detasseling may have reduced apical dominance, allowing greater rates of kernel filling. The results indicate that detasseling and leaf stripping may offer small holders feasible methods for maximizing maize grain yield.

Key words: Leaf stripping, detasselling, radiation interception, grain yield

1.0 Introduction

The domestication of the maize plant (*Zea mays* ssp. *mays*) from its wild ancestor *tiosinte (Zea mays* ssp. *parviglumis*) was accompanied by an increase in apical dominance which concentrates resources in the main stem and apex of the plant with a corresponding suppression of axillary branches (Doebley *et al*., 1997). In maize one or more of the topmost axillary branches develops into the female part of the plant (Lejeune and Bernier, 1996), which on pollination produces the economic yield of maize, the maize grain. Apical dominance in maize during the reproductive stages is expressed through the tassel. The tassel is the centre for the production of indole-acetic acid (IAA), which mediates the partitioning of photo-assimilates in favour of the main stem and apex at the expense of the developing axillary buds (ears) (Medford and Klee, 1989; Damptey, 1982). Selection for small tassels that impose little apical dominance on the developing ear has been proposed to increase maize grain yield (Paterniani, 1981). Garnier *et al*. (1993) demonstrated a strong negative (⍰0.88) correlation between tassel weight and maize grain yield. Detasselling, the removal of the tassel after its emergence, is an option available to smallholder farmers, to improve maize yield by reducing the apical dominance effect and by increasing the penetration of radiant energy into the canopy (Subedi, 1996; Mostert and Marais, 1982).

Leaf stripping, i.e., the removal of lower leaves from the maize plant at anthesis or post-anthesis, increases radiant energy penetration to the under-storey crop in intercropping (Subedi, 1996) and can provide fodder to feed animals (Dzowela, 1985). Photosynthesis occurs in the leaf and the leaf is the source of photo-assimilates from which partitioning occurs to the sinks that are proximal to this source and which show the highest sink demand. In maize, upper leaves export principally to the shoot apex, middle leaves to both the shoot apex and the roots and lower leaves to the roots. With time, the leaves undergo senescence, and in grasses this begins at the lower older leaves and progresses up the plant. When senescence progresses net assimilation rate progressively declines as a result of the metabolic break down of proteins, enzymes and chlorophyll and export of nitrogen to the developing ear (Wada *et al*., 1993). Senescing leaves are a source organ for both nitrogen and carbon but, because the degradation of chloroplast proteins and export of their degradation products to sink organs results in loss of photosynthetic capacity; the leaves serve as a source of nitrogen only at the expense of source capacity to produce carbon assimilates (Jiang *et al*., 1999). Yield of maize in semi-arid environments like Zimbabwe is limited by water stress episodes that are most damaging by reducing assimilate production at flowering/pollination and post flowering grain filling stages. Maize is a sink-limited crop in most growing conditions but a source limited crop if resource availability is strongly reduced during anthesis and seed filling (Borras et al., 2004). We hypothesize that partial defoliation of maize at flowering will reduce water loss by transpiration in the post- anthesis period and increase maize grain yield in water limited environments like Zimbabwe. Shimada *et al.* (1992) reported that decreasing leaf area by defoliation increased cell turgidity and apparent photosynthesis in water restricted plants. Crookston and Hicks (1988) found that positive yield response to maize defoliation was associated with low-end of the season available water but had no defoliation had no effect on maize grain yield in normal seasons. Shimada et al. (1992) found that grain yield of soybean was reduced by defoliation only under well watered conditions but was not affected defoliation in water restricted plants. Zhu *et al*. (2004) reported an 7%, 10.7% and 22% increase in grain yield, harvest index and water use efficiency, respectively, in an early sown late maturity wheat defoliation at late tillering, when compared to an intact control.

Detasselling and leaf stripping have potential to increase the yield of a minor crop, intercropped with a tall cereal crop, by increasing photosynthetically active radiation (PAR) intercepted by the minor crop (Subedi, 1996). If leaf stripping and detasselling increased yield in maize, then it would be an added benefit that would accrue to smallholder farmers that leaf-strip and detassel to increase the yield of a minor crop, such as pumpkin or beans. Subedi (1996) determined the effects of a of detasselling and leaf stripping on maize yield and demonstrated benefits to maize grain yield with detasselling but not with leaf stripping, in a maize-finger millet (*Eluesine coracana* Gaertn.) intercropping system. There was no testing of the effect of timing and intensity (number of leaves stripped) of leaf stripping in the study by Subedi (1996). We hypothesize that intensity and timing of leaf stripping are important factors in determining the effects of leaf stripping on maize grain yield because of the relationship between leaf area and canopy transpiration (Shimada, 1992) and the fact that grain filling in maize occurs mostly from assimilates produced post anthesis (Borras *et al*., 2004).

The aim of this study was to determine the effect of detasselling and timing and intensity of leaf stripping on the radiant environment and yield of monocrop maize. The results would provide insight into the effects of leaf stripping and detasselling on tropical maize varieties used by smallholder farmers in Zimbabwe and allow optimization of these processes for application in mixed cropping systems. Hypotheses tested during the study were (a) leaf stripping and detasselling increase maize grain yield (b) timing of leaf stripping is important in determining the effect of leaf stripping on maize grain yield and (c) leaf stripping and detasselling increase the rate of dry matter accumulation during cob development.

2.0 Materials and Methods

Experiments on the effect of detasselling and leaf stripping were conducted at the University of Zimbabwe farm in the 1998/1999, 1999/2000 and 2000/2001 seasons. The University of Zimbabwe farm is 14 km to the north-west of Harare, at an altitude of 1500 m above sea level, on fersiallitic red clay soils with more than 40% clay and an annual rainfall average of 800-1000 mm. In both seasons, the land was disc ploughed and disc harrowed to a fine tilth and planting furrows were opened at 90 cm spacing in November, unless stated otherwise. Two maize seeds were dropped into the planting furrows at 30 cm spacing to achieve a maize density of 37,000 plants ha^{-1} after thinning. Basal fertilizer (compound D, 8% N, 14% K_2O, 7% P_2O_5) was banded into the open planting furrows at 300 kg ha^{-1}, before seeding in all seasons. Ammonium nitrate (34.5% N) was side-dressed on the maize plants at 300 kg ha^{-1}, half of which was applied at 4 WAE (weeks after emergence) and the other half at 8 WAE.

Experiment 1 (1998/1999 season)

A 3 × 3 factorial experiment with three replications was set up using a randomized complete block design. The first factor was the intensity of leaf stripping with three levels viz. stripping 4 bottom leaves, stripping four alternate bottom leaves and stripping six bottom leaves. The second factor, timing of leaf stripping had three levels viz. stripping at 9 WAE, 12 WAE and at 15 WAE. Superimposed on this factorial design was detasselling treatment achieved by detasselling half of each plot. A short season three way maize hybrid, Pan 67 obtained from Pannar Seeds® and recommended for the smallholder sector in Zimbabwe, was planted. The crop was hoe-weeded twice, at 4 and 8 WAE.

Leaf stripping was accomplished by cutting the required leaves at 9, 12 and 15 WAE. The leaves were cut at the junction between the leaf sheath and the stem, oven-dried to a constant weight at 80 °C, and weighed. A sample of ground leaves from each treatment was analysed for nitrogen content using the Kjeldahl method.

PAR penetration into the canopy was determined by placing Li-Cor 191-SA line quantum sensors (Li-Cor, Lincoln, Nebraska, USA) at four levels in the canopy: ground level, cob level, just below the tassel and above the tassel. The PAR measurements were taken, next to the maize stems, at 15 WAE. Measurements were made at three positions at 2, 4 and 6 m along the middle row of each treatment plot. The average PAR reading from the three positions was analysed. Detasselling was done when 50% of all plants had produced silks (50% silking), at 12 WAE. Tassels were grabbed and pulled upwards leaving all the upper maize leaves intact.

Gross plots were 4.5 m wide and 7.5 m long comprising five rows of maize. The net plot was 2.7 m wide and 6.0 m long consisting of three rows. Maize cobs from the net plot were hand-harvested and shelled and moisture content of the grain was measured using a moisture meter. Maize grain yield was standardized to 12.5% moisture before analysis.

Experiment 2 (1999/2000 season)

The second experiment was a 3 × 2 factorial set up as a randomized complete block design with three replications. It measured the effects on maize yield of three levels of leaf stripping (none, stripping four leaves at eight WAE and stripping four leaves at 12 WAE) with two levels of detasselling (detasseled *vs* untreated). A short season maize three-way hybrid, SC 513, from Seed-Co® (Zimbabwe), was planted at an inter-row spacing of 0.8 m and a within-row spacing of 0.3 m to establish a final density of 41,600 plants ha^{-1}.

Experiment 3 (2000/2001 season)

We hypothesized that if leaf stripping and detasselling increased maize grain yield through increased assimilate allocation to the developing ear, then the effects of these treatments should be captured in increased rates of ear growth. The third experiment was set up to measure yield and growth rate of the ear in leaf stripped, detasselled and leaf stripped and detasselled maize in comparison to an untreated control. All plant manipulations were made at 50% silking (10 WAE). Four lowest leaves, which at 10 WAE were not yet fully senesced, were removed during leaf stripping. A medium season three-way hybrid, SC 637, from Seed-Co® (Zimbabwe) was planted at an inter-row spacing of 0.9m and within row spacing of 0.3m to establish a final density of 37 000 plants ha^{-1}. Gross plot size was 6.3m wide and 7.5m long comprising seven rows of maize. The net plot (4.5 m × 7.5 m) consisted of five middle rows on either side of which were two border rows. At weekly intervals from 12 till 18 WAE, four plants were selected randomly from the outer two rows of each plot. They were cut and separated into leaves and leaf sheaths, stems, husks and cobs and oven dried at 80° C till a constant dry weight, and weighed. Maize grain yield and 100 grain weight was determined from maize harvested from the net plot after adjusting to 12.5% moisture content.

2.1 Photosynthesis Measurements

Photosynthesis was measured on a sample of seven plants of cultivar SC 701, a single cross hybrid from Seed-Co® (Zimbabwe) when the plants were at 50% silking (anthesis) in March 2003. Photosynthesis was measured on isolated fully lit maize plants in order to attain an estimate of maximum photosynthetic capacity in full light. Measurements were made with a portable photosynthesis system (Model LI-6200, Li-Cor, Lincoln, Nebraska, USA). Measurements were made, starting from the lowest leaf that was still alive and moving up the plant to the highest leaf just below the tassel. The pooled measurements of PAR and CO_2 exchange rate from each leaf position from the seven plants were fitted with a negative exponential equation ($P_n = P_{n,max}(1 - e^{-\alpha H/P_{n,max}}$) using the SAS NLIN procedure SAS 1999)P_n is the net photosynthesis of the leaf in micromoles of CO_2 m^{-2} s^{-1}, H is the radiation incident on the leaf in Joules (J) m^{-2} s^{-1}, α is the light use efficiency of the leaf (the initial slope of the P_n curve as H approaches zero) in micromoles of CO_2 J^{-1} of incident H, and $P_{n,max}$ is the maximum P_n at PAR saturation. The estimated values of $P_{n,max}$ for the leaf positions up the plant were compared using the generated standard errors.

2.2 Analysis of Data

All maize yield data were standardized to 12.5% moisture content before analysis. Data were subjected to analysis of variance using the SAS statistical package (SAS,1999) The standard error of the difference was calculated and used for mean separation when treatment effects were significant at $P<0.05$. Standard error of the difference bars are used on all figures, unless otherwise stated.

3.0 Results

3.1 Maize Grain Yield

In experiment 1, the effects of detasseling and leaf stripping were additive, as shown by non significance of the interaction between both factors ($P > 0.05$). There was a positive main effect of detasselling on grain yield (+11.2%; $P < 0.05$) while time of leaf stripping showed an optimum response; the highest yield was obtained with leaf stripping at 12 WAE (anthesis) with lower yields both with leaf stripping at 9 and 15 WAE. The lowest yield was obtained in the control treatment, i.e. without any detasseling or leaf stripping. The combination of detasseling and leaf stripping at 12 WAE produced the highest yield with 16.6% increase in maize grain yield compared to the untreated control (Figure 1a).

A similar response as in experiment 1 of yield to time of leaf stripping was observed in experiment 2 (Fig. 1b). The highest yield was obtained with leaf stripping at 12 WAE, and lower yields with leaf striping at 8 WAE or no leaf stripping. Detasseling, as in experiments 1, had a positive effect on yield (+12.2%, $P < 0.05$). However, in experiment 2, there was a significant interaction between the effects of leaf stripping and detasseling ($P = 0.009$). As shown in fig. 1b, the interaction is due to a stronger yield response to leaf stripping in the tasselled, compared to the detasselled treatment. With leaf stripping at the optimal time (12 WAE), tasselled and detasselled objects had similar yields in experiment 2, but with leaf stripping at a suboptimal time (8 WAE) or no leaf stripping, the tasselled objects had substantially higher yields. Averaged across the detasselling treatments, grain yield was 28% higher when maize was leaf stripped at 12 WAE than in the unstripped control (Fig. 1b).

The results of experiment 3 confirmed those of experiments 1 and 2 in demonstrating large and significant yield effects of detasselling (+32.3%) and of leaf stripping (+18%). As in experiment 2, the tasselled and detasselled treatments had similar yields when leaf stripped at the optimal time of 50% silking. Detasseling alone had a greater yield benefit (+32.3%) than the combination of detasselling and stripping (+16.2%), even though leaf stripping by itself increased yield (+18%) (Figure 2a). Treatment effects were significant at $P<0.001$. Treatment effects on maize grain test weight (100 grain weight) followed a similar trend with detasselling, leaf stripping and a combination of leaf stripping and detasselling increasing 100 grain weight by 10.5%, 6% and 4%, respectively, when compared to untreated (Figure 2b).

3.2 Ear Growth and Dry Matter Distribution after Leaf Stripping and Detasselling

Ear dry weight, with the husk removed, increased almost linearly with time until physiological maturity at 18 WAE (Figure 3a). Ear dry weight was significantly ($P < 0.05$) affected by the detasselling and leaf stripping treatments at all sampling dates. Ear dry weight was consistently highest in the detasselling treatment and lowest in the intact control. Ear dry weight did not significantly differ among the three detasselling and leaf stripping treatments; however detasselling resulted in significantly higher ear dry weight than the intact control throughout the grain filling period (Figure 3a). Coefficients of linear regression of ear dry weight over the seven week period from 12 WAE to 18 WAE were 18.29 ± 1.564, 20.10 ±.1.264, 20.43 ± 1.329 and 25.02 ± 1.528 for the intact, leaf stripped, leaf stripped and detasselled and detasselled treatments, respectively. Ear growth rate was highest in the detasselled treatment and lowest in the intact control. The leaf stripped and the combination of leaf stripping and detasselling ear growth rate did not significantly differ but were lower than in the detasselled and higher than in the intact control.

Husk dry weight increased up to 14 WAE and was generally maintained from that point on up to physiological maturity. The exception was in the detasselled treatment in which a distinct loss of husk dry weight occurred after 14 WAE (Figure 3b). Husk dry weight was consistently highest in the detasselled treatment, intermediate in the leaf stripped and leaf stripped and detasselled treatments and lowest in the intact control, and generally behaved similarly to cob dry weights (Figure 3b).

Leaf dry weight increased up to 14 WAE for the three detasselled and leaf stripped treatments and then decreased up to 16 WAE and was maintained up to physiological maturity (Figure 3c). The detasselled treatment consistently had the highest leaf dry mass, with the intact control lowest from 12-14 WAE and the leaf stripped and combination of leaf stripping and detasselling lowest from 15-18 WAE. Leaf dry mass increased up to 15 WAE in the intact control and was maintained up to physiological maturity (Figure 3c).

Stem dry weight increased from 12 WAE up to 14 WAE for the three detasselled and leaf stripped treatments and then the accumulated dry matter was lost over the following four week period, and at physiological maturity 18 WAE, stem dry weight was similar to the 12 WAE level (Figure 6b). In the intact control, stem dry weight marginally increased from 12 to 15 WAE, and was maintained up to 18 WAE (Fig 3d). Again, stem dry weight was consistently highest in the detasselled and lowest in the intact control, throughout the grain filling period (Figure 3d).

3.3 Leaf Nitrogen Content and Dry Mass of Stripped Leaves

The nitrogen content of stripped leaves, measured in Experiment 1, were significantly lower ($P < 0.001$) with removal at a later time (Fig. 4a). Leaf dry mass was significantly ($P < 0.001$) higher when the leaves were stripped at 12 than at 9 and at 15 WAE in Experiment 1 (Figure 4b). In Experiment 2, dry mass of stripped leaves significantly ($P = 0.001$) increased from 355 to 591 kg ha^{-1} between 8 and 12 WAE. The dry mass of stripped leaves significantly ($P < 0.001$) increased from 499, 643 to 756 kg ha^{-1}, with increased intensity of leaf stripping, from 4 bottom, to 4 alternate, and 6 bottom leaves stripped, respectively, in Experiment 1.

3.4 Canopy Radiant Environment

Incident PAR (IPAR) on the leaves immediately below the tassel was significantly ($P < 0.05$) increased by detasselling, from 68% to 97% of total incoming PAR in Experiment 1 (Figure 5a) and in Experiment 2 (Figure 5b).

Averaged across the leaf stripping treatments, detasselling significantly ($P < 0.05$) improved IPAR on cob leaves; by 27% in experiment 1, and by 15% in Experiment 2. In comparison to the unstripped and tasselled control, detasselling increased the proportion IPAR reaching the cob leaves by 46% in Experiment 1 (Figure 5a). The proportion of total IPAR reaching the ground was 61%, 32% and 10% in the detasselled, tasselled and control treatment, respectively, in Experiment 1 (Figure 5a). In Experiment 2, 25% and 9% of the total IPAR reached the ground in the detasselled and tasselled treatments, respectively (Figure 5b).

The IPAR reaching the cob-leaves increased ($P = 0.049$) with increased intensity of leaf stripping from 0 (control), 4 bottom, 4 alternate to 6 bottom leaves stripped in Experiment 1 (Figure 5c). This represented an increase in the proportion of incoming total PAR from 22%, 37%, 54% and 72% when 0, 4 bottom, 4 alternate and 6 bottom leaves were stripped, respectively. There was a significant increase ($P = 0.047$) in the amount of IPAR reaching the ground with increased intensity of leaf stripping from 110, 195, 277, to 361μmol m^{-2} s^{-1} when 0, 4 bottom, 4 alternate or 6 bottom leaves were stripped in Experiment 1 (Figure 5c). Timing of leaf stripping had no ($P > 0.05$) effect on PAR extinction within the maize canopy in Experiment 1 and 2. Averaged across the detasselling treatments, leaf stripping at 8 and 12 WAE resulted in 13% more total incoming PAR reaching the ground, than in the unstripped treatment (Figure 5d). Leaf stripping did not affect IPAR on cob leaves in Experiment 2 (Figure 5d).

3.5 Photosynthesis in Maize Leaves at Anthesis

The relationship between photosynthesis and incident PAR in maize leaves from the fourth lowest leaf alive at anthesis and up the plant are shown in Fig. 6. At this phenological growth stage of the maize, the lowest three leaves have lower $P_{n,max}$ than the upper leaves (Figure 10). $P_{n,max}$ was similar from the 4th lowest leaf to the 12th leaf just below the tassel (Figure 7).

4.0 Discussion

4.1 Detasselling and maize rain Yield

The significant increase in maize grain yield in responses to detasselling at tassel emergence observed consistently over the two experiments in this study are similar to what has been observed by Hunter *et al*., (1969); Mostert and Marais (1982); Subedi (1996); Edje (1983) and Amitai (1982). In addition, detasselling removes the shading effect by the tassel, thereby increasing the amount of incoming PAR reaching the leaves in the maize canopy and, therefore, increasing canopy photosynthesis and reducing the rate of leaf senescence (Mostert and Marais, 1982; Hunter *et al*., 1969). In this study, detasselling increased the incident PAR on the sub-tassel leaves by 10-29% and on the cob leaves by 15 and 27% compared to the tasselled treatments. Gardner *et al*. (1985) established that although all maize leaves contributed to grain yield, the actual contribution of each leaf was far much less than potential due to mutual shading. Andrade *et al*. (2002) and Barbieri *et al*. (2000) demonstrated that maize grain yield was positively correlated to the amount of radiation intercepted by the maize canopy during critical period bracketing flowering in maize. In this study, detasselling increased the proportion of total incoming PAR that penetrated into the canopy from anthesis onwards, well within the same critical period identified by Andrade *et al*., 2002 and Barbieri *et al*., 2000 for the grain yield response to increased radiation interception in maize. Therefore, an increased amount of PAR reaching the upper and middle leaf strata constitutes a likely contributing factor to the observed increase in maize yield upon detasseling.

Our results from Experiment 3 show that detasselling increased ear growth rate, 100 grain weight and maize grain yield by 42%, 10.2% and 32.2%, respectively, when compared to the intact control. The dry matter allocated to husks, leaves and stems after detasselling was always higher than in the intact control (Figure 5a, Figure 6), indicating the stimulation in growth of vegetative plant parts and axillary buds (cobs) as a result of the removal of apical dominance and increased IPAR on middle and upper maize leaves , on detasselling. It is also apparent from Fig 5a and 6 that dry matter accumulation in the husks, leaves and stems peaked at 14 WAE and then started to decrease from there on until physiological maturity in the detasselled treatment, but varied little with time in the intact control. It would seem from these results, that ear development and grain yield in the detasselled treatment benefited from the re-allocation of larger amounts of dry matter that had accumulated in the husks, leaves and stems on senescence, than in intact control. It is also noticeable that the decrease in dry matter of the husks, leaves and stems in the intact control was somehow delayed by a week, to 15 WAE, alluding to a shorter period of dry matter re-allocation to the developing ear in this treatment and occurred to a lesser extent, partly explaining the lower ear growth rates and grain test west observed in this treatment, than in the detasselled treatment.

The interaction between timing of leaf stripping and detasselling observed in Experiment 2 of this study indicates that these two interventions act on the same processes during the grain development and grain filling stages. Leaf stripping and a combination of leaf stripping and detasselling generally had intermediate results between those from detasselling and from the intact control in terms of dry matter distribution to the ear, husks and stem; 100 grain weight and grain yield. The results in Experiment 3 suggest that detasselling unstripped maize has an advantage over detasselling leaf stripped maize. The improvement in radiation penetration into the maize canopy on detasselling may increase assimilate production in by lower leaves allowing more assimilates to accumulate in the vegetative parts(leaves, stem and husks) and the ear in the detasselled only treatment, as observed in Experiment 3. When the lowest leaves are stripped, and detasselling carried out, leaves that would have benefited from increased radiation penetration and contribute a bit longer to net photosynthesis are removed, cancelling out the effect of detasselling of improving RI by the lowest leaves. This explains the similarity in dry matter distribution, 100 grain weight and grain yield between the leaf stripped and the leaf stripped and detasselled treatment in Experiment 3 (Figure 2 and Figure 3). The additional yield benefit derived from higher levels of illumination of lower leaves on detasselling cannot be obtained when the lower leaves are stripped, most likely explaining the similarity in dry matter accumulation between leaf stripped and leaf stripped and detaselled maize. These results generally tally with results from Expeiment 1 and 2, which show that at the optimum timing of leaf stripping (anthesis), maize grain yield was always similar between the leaf stripped and the leaf stripped and detasselled treatments (Figure 1).

4.2 Leaf Stripping and Maize Yield

Removal of leaves (leaf stripping) below the ear, before silking and 30 days after, resulted in no significant effect on maize grain yield (Subedi, 1996). In contrast to these results, this study showed that the removal of the lowest four to six leaves at 50% silking significantly increased maize grain yield by 16-28%. The timing of leaf stripping was established to be the crucial factor determining the grain yield response to stripping of the lower leaves in this study. Leaf stripping three or four weeks before and three weeks after 50% silking had no significant effect on maize grain yield, in part confirming the results obtained by Subedi (1996). The results on the effect of timing of leaf stripping on maize grain yield and photosynthesis measurements support the hypothesis that leaf stripping increased maize grain yield when the removed leaves were becoming senescent and consequently had low photosynthetic capacity but were contributing to water loss through transpiration. It is conceivable that removal of the lowest leaves reduced canopy transpiration and water stress in post- anthesis period as observed by Shimada et al. (1992) in soybeans. Maize grain yield was shown to be source limited when resource availability was reduced during grain filling (Borras *et al*., 2003). A major limiting factor to the realization of maximum grain yield potential in maize in semi- arid environments like Zimbabwe are episodes of water deficits during anthesis and grain-filling. Our results indicate that partial defoliation of the maize may alleviate moisture stress effects on grain yield by removing senescing leaves that make little contribution to assimilate supply for grain set and grain filling, yet contribute to water loss from the plant, resulting in the 16-28% observed increases in maize grain yield when compared to the intact control. Shimada et al. (1992) showed that in water restricted soybean plants, partial defoliation resulted in higher stomatal conductance and apparent photosynthesis in the remaining leaves. Zhu *et al*., (2004) recorded higher wheat grain

The effect of leaf stripping intensity on maize grain yield in Experiment 1 of this study suggests that the benefits of leaf stripping at anthesis are only realized when the lowest leaves are removed. When one upper leaf above the cob was stripped together with the lower leaves in the treatment in which four alternate leaves were stripped, maize grain yield became similar to that of the unstripped control. Removing leaves above the cob leaf that remain green and photosynthesizing throughout the grain development and grain filling stages in maize apparently cancelled out the benefits that accrued from removing the lower senescing leaves. It is foreseeable from these results that if more of the upper leaves had been removed, grain yield was likely to be reduced through a reduction of active photosynthetic area during the critical post-anthesis period for grain

In the context of mixed cropping systems, the demonstration that detasselling and leaf stripping can increase maize grain yield opens up the possibilities of fruitfully integrating these interventions to increase the productivity of these systems. As hypothesized by Subedi (1996), an increase in IPAR onto the minor crop under the dominant cereal crop brought about by leaf stripping and detasselling is expected to increase the growth and yield of the minor crop. The scenario of increased maize grain yields and increased minor crop yields with leaf stripping and detasselling is expected to result in substantial benefits in smallholder farming systems where maize-pumpkin and maize-bean intercropping system are widely practised. We are currently exploring several hypotheses with regards to leaf stripping and detasselling alleviating various types of stresses and maintaining or increasing maize grain yield under stress prone production environments. We hypothesize that leaf stripping and detasselling will reduce the impact of "competitive stress" when maize is intercropped with crops (beans, cowpeas, soybeans) and when maize is planted at high plant densities. Leaf stripping and detasselling will alleviate the negative effects of water deficits on maize grain yield when subjected to various levels of moisture stress (irrigation regimes) in water limited environments. Further studies to test these hypotheses are required.

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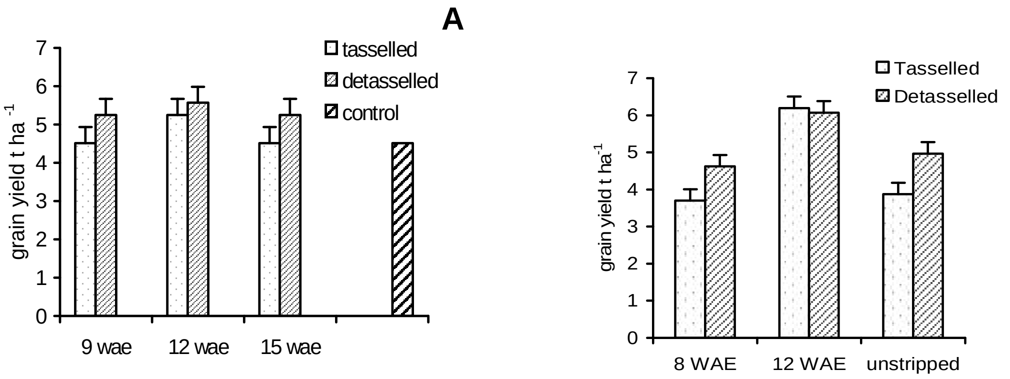


Figure 1: Effect of timing of leaf stripping on maize grain yield in tasselled and detasselled maize in Experiment 1 (A) and Experiment 2 (B)

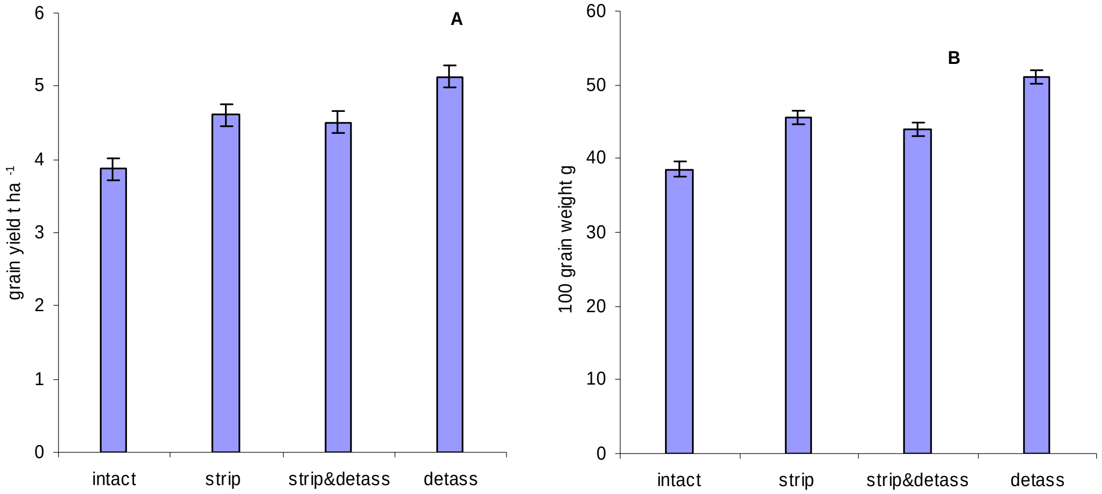


Figure 2: Effect of leaf stripping and detasselling on maize grain yield (A) and 100 grain weight (B) in Experiment 3

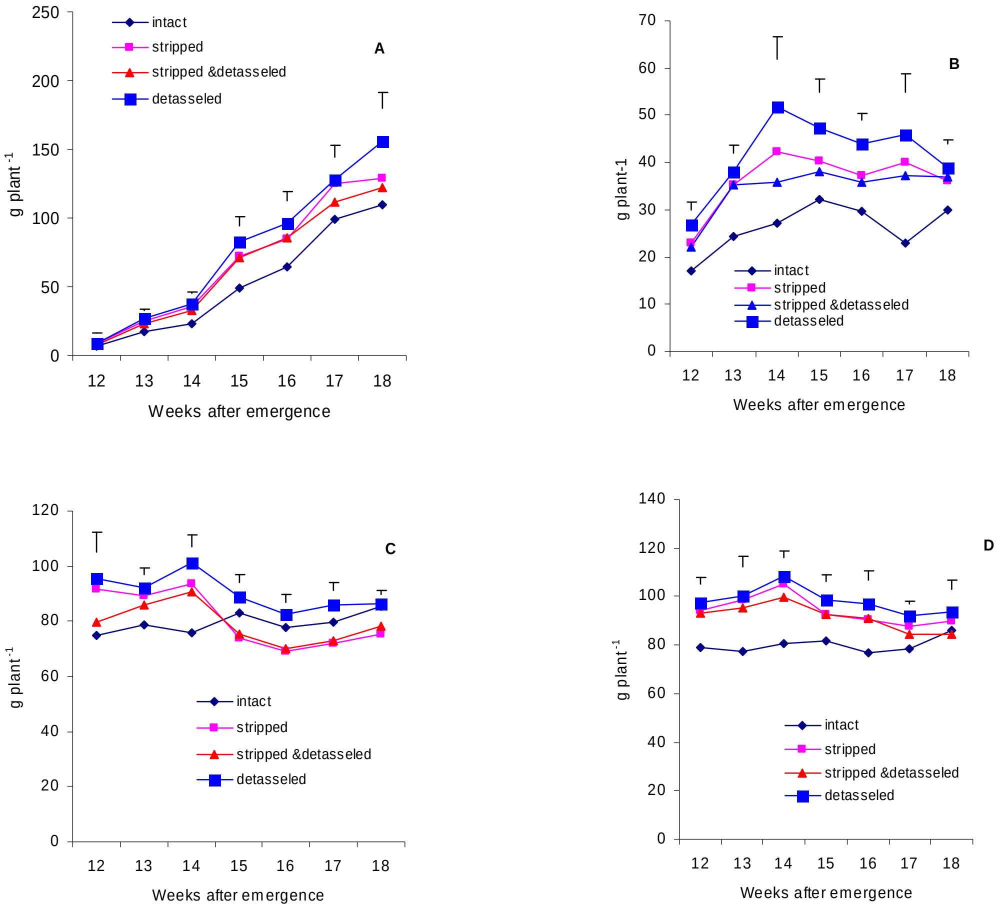
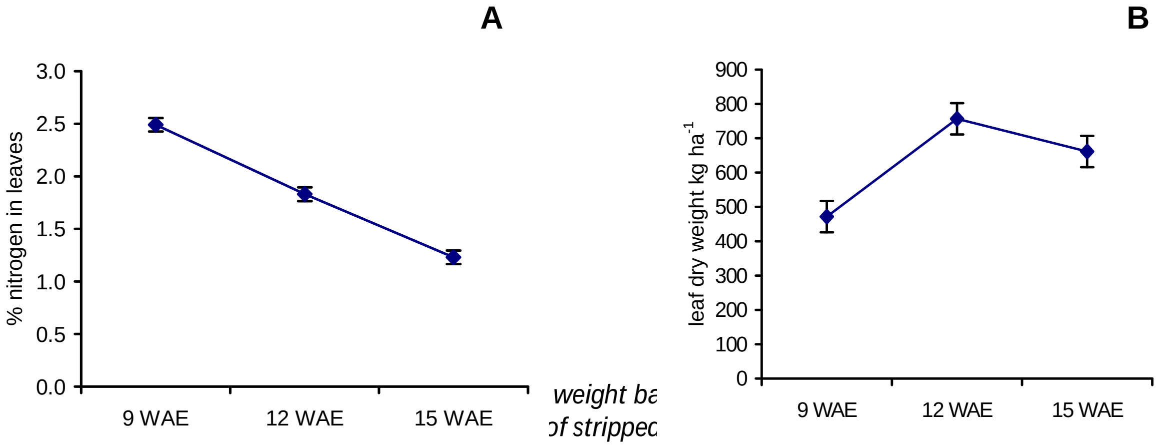


Figure 3: Changes in cob (A), husk (B), leaf (C) and stem (D) dry weight from two weeks after leaf stripping and detasselling treatments in Experiment 3. (Error bars are +SED)



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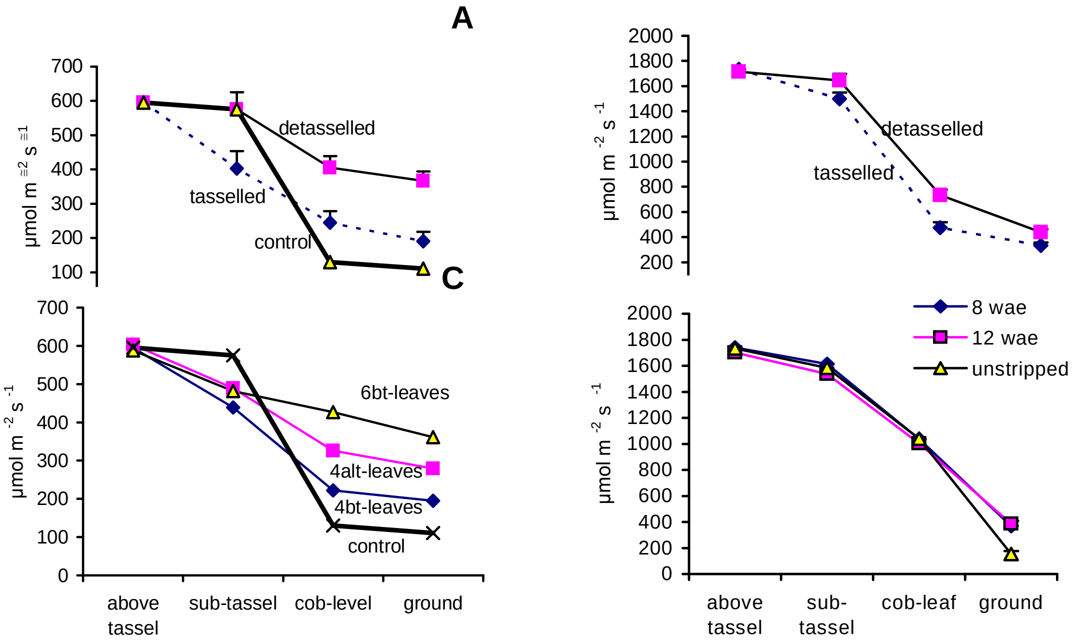
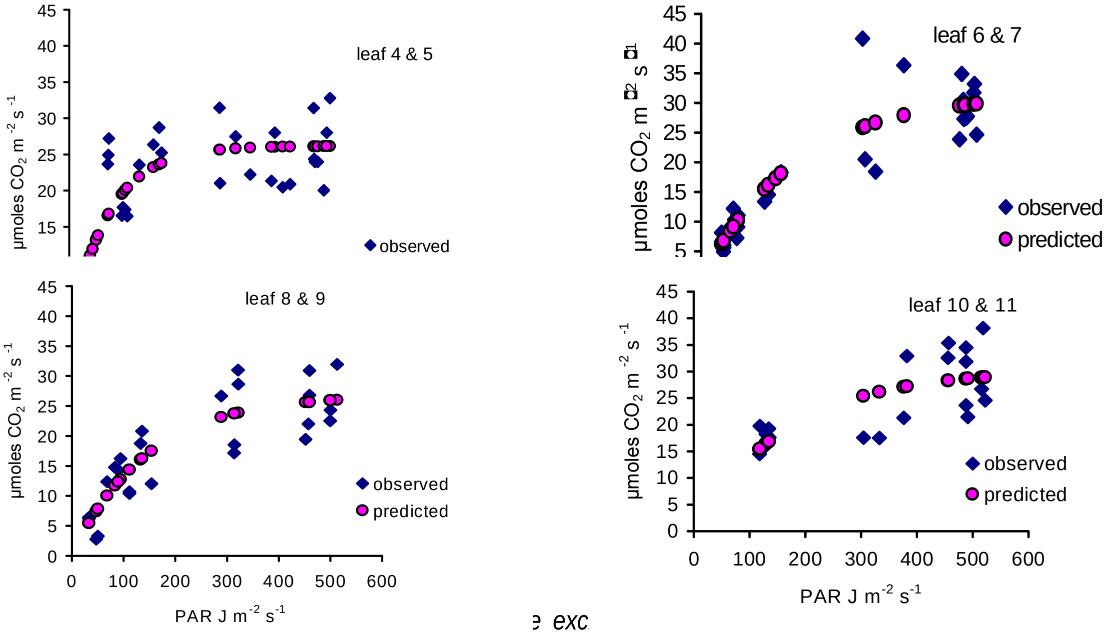


within the maize canopy at anthesis in Experiment 1 (A) and Experiment 2 (B). (C) Effect of leaf stripping intensity averaged across detasselling treatments on PAR extinction within maize canopy at anthesis in Experiment 1. (D) Effect of timing of leaf stripping on PAR extinction within maize canopy at anthesis in Experiment 2



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position from the bottom at anthesis. The data was fitted to the equation $P_n=P_{n,max}(1-e^{-\varepsilon H/P_{n,max}})$, where P_n is the CER, H is the PAR incident on the leaf. $P_{n,max}$ is the maximum photosynthesis at PAR saturation and ε is the light use efficiency of the leaf

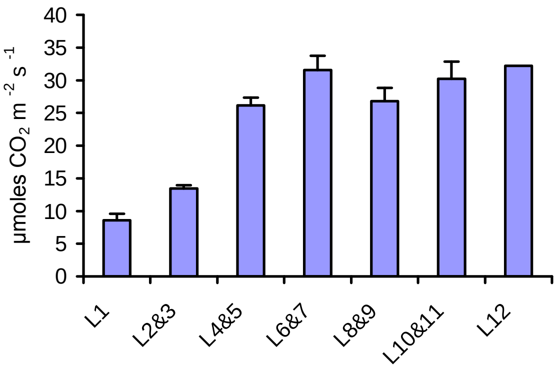

Figure 7: Estimated maximum rate of photosynthesis at PAR saturation in maize leaves from the lowest leaf alive (L1) to the top leaf just below the tassel (L12) at anthesis in cultivar SC 701, a single cross hybrid from Seed-Co® (Zimbabwe). Error bars represent the standard error of the mean