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The effect of herbicide tank mix on the weed species diversity in sugarcane (*Saccharum officinarum*)

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Key words: Sugarcane, weeds, pendimethalin, metribuzin, atrazine, chlorimuron ethyl.

Abstract

A field experiment was carried out at Triangle Estate, Zimbabwe to determine the efficacy of Pendimethalin, Chlorimuron ethyl and Metribuzin herbicide combinations on the weed species diversity in sugarcane. The experiment was laid out in a Complete Randomized Block Design (CRBD) with four replications. Treatments included; Chlorimuron ethyl (90g/ha), Metribuzin(2l/ha), Pendimethalin(2l/ha), Extreme Plus (0.8l/ha), Extreme Plus(1l/ha), Extreme Plus(0.8l/ha)+ Pendimethalin(2l/ha), Extreme Plus(1l/ha) + Pendimethalin(3l/ha), Pendimethalin(2l/ha) + Atrazine (2l/ha) and no weeding (control). The major weeds observed in this experiment are *Amaranthus viridis, Ipomoea sinensis, Boerhavia erecta, Rotboellia conchinchinensis, Commelina bengalensis* and *Cyperus spp* (purple and yellow). The herbicide tank mix of pendimethalin (2l/ha) + atrazine (2l/ha) significantly ($p<0.05$) controlled all weed species in this study except *Ipomoea sinensis*. The tank mix pendimethalin (2l/ha) + atrazine (2l/ha) resulted in 98.83% and 93% control for *Amaranthus viridis* and *Rotboellia conchinchinensis* respectively. *Ipomoea sinensis* was effectively reduced by metribuzin and Extreme plus (0.8l/ha) although its control was difficult. Extreme plus (0.8l/ha) effectively controlled all broadleaf weeds and *Cyperus spp*. Generally, spraying herbicides without mixing resulted in reduced control of weeds.

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Introduction

Sugarcane is a major industrial and cash crop in Zimbabwe (Mabveni, 2005). Sugarcane stalks are crushed to extract juice, which is then boiled and evaporated to produce thick syrup from which sugar granules form. These granules are used for domestic purposes, production of drinks, sweets, baking, bio-ethanol and many other commercial uses. Sugarcane also produces two by-products called molasses and bagasse. Molasses is thick syrup used as a livestock feed, fermented into bio-fuel and also used in road maintenance. Bagasse is a fiber constituent remaining after the juice is expressed. Bagasse is burned for steam generation to produce electricity which will be used in the industrial mill, irrigation and for domestic purposes. Sugarcane production in Zimbabwe contributes significantly to the Gross Domestic Product and also generates foreign currency for the country. Besides contributing to the economy, sugar industry employs directly about 25000 people and indirectly more than 125000 people (Zimbabwe Annual Action Programme, 2009).

Despite the economic importance of sugarcane, its production in Zimbabwe is still dogged by many challenges including water shortages due to frequent droughts, shortage of labour, low mechanization, pests and diseases and many other problems (ZSAES, 2012). Major losses in sugarcane production are accounted for by pests in the form of weeds (Mabveni, 2007). Weed pests in sugarcane production can account for between 20 to 70% losses in crop yield (Khan *et al.*, 2004). Weeds mainly affect sugarcane during the critical weed crop competition period which range between 27 and 50 days (Srivastava *et al.*, 2003). Weeds, besides competing for moisture and light also remove about four times nitrogen and phosphorus and two times potassium as compared to the crop during the first 50-days period of crop emergence (Nyanhete, 2005). Weeds interfere with sugarcane by shading emerging sugarcane shoots reducing tiller formation and survival. Some weeds also produce allelochemicals which can also inhibit sugarcane growth (Vasilakoglou *et al.*, 2005).

Herbicide use in sugar industry is a common way of reducing weed problems. Different types of herbicides are used in a single production cycle to reduce broadleaf weeds, annual grasses and sedges. The grower would require several subsequent applications in order to fully control all weeds since the weeds are variable and require specific herbicides. This increases operating costs in terms of labour and is time wasting. Alternatively, herbicides can be combined in a tank mix which is applied in a single once off to control a wider weed spectrum. A single once-off application also ensures that the grower controls different weed species simultaneously with a single application increasing efficiency (Green, 1991).The study therefore seeks to come up with the best tank mix to control most of the weed flora during the critical weed crop competition period.

Materials and methods

Field experiment was conducted at Triangle estate located in the south-eastern lowveld of Zimbabwe, eighty-one kilometers off the Masvingo-Beitbridge highway. Triangle is elevated 534m above sea level, 21 º 20'S latitude and 30 º 27' E longitude. The area lies in Agro-ecological region V receiving an average rainfall of 561 mm mainly in the summer months. The climate at Triangle is typified by very hot summers and short cold winters. Mean daily temperatures vary from 26 º C in summer to 16 º C in winter. Soil sampling was done prior to setting of the trial and the composite sample was taken to the laboratory for physical and chemical analysis.

The experiment was laid out in a randomized complete block design with four replications and slope was used as the blocking factor. The treatments are shown in Table 1.

Land preparation involved heavy duty disking, leveling, ripping, harrowing and ridging using a tractor. The ridges were constructed on pegged lines of a standard gradient 1:250 normally resulting furrows of gradient 1:200. An inter-row spacing of 1.5metres was maintained between furrows. After land preparation the basal fertilizer Single Super

Phosphate (18.5% P_2O_5) was applied at the rate of 400kg/ha in the furrow before setts were laid and then incorporated during sett covering. Nitrogen fertilizer was applied in three splits, the first split of 51.8kg/ha nitrogen was applied at first irrigation while the other 2 splits were applied at 4 and 8 weeks after planting. The treated setts were laid at the bottom of the furrow at 5cm depth in two continuous parallel lines. Setts were staggered so that the cut ends of one sett were opposite the center node of the sett next to it and the eyes facing downwards. The setts were then finally covered with 0.5m of soil. Herbicides were applied before the emergence of weeds and the sugarcane crop using a knapsack sprayer. A quadrant measuring 60cm x 60cm was used to assess the weed counts at 4 and 8 Weeks After Spraying (WAS) in the inter-row. A scale as according to European Weed Research Council (2010) was used to rate the weeds as shown in Table 2.

Table 1 . Treatment structure of the herbicide mix on weed species diversity in sugarcane.

Treatment	Treatment Composition
1	Chlorimuron ethyl-90g/ha
2	Metribuzin 2l/ha
3	Pendimethalin 3l/ha
4	Extreme plus (Chlorimuron+Metribuzin) 0.8l/ha
5	Extreme plus (Chlorimuron+Metribuzin) 1l/ha
6	Extreme plus 0.8l/ha+ Pendimethalin 2l/ha
7	Extreme plus1/ha + Pendimethalin 3l/ha
8	Pendimethalin 3l/ha + Atrazine 3l/ha
9	No weeding (control)

Table 2. European Weed Research council ratings.

Category Number	% Weed kill	Herbicidal effectiveness on Weed
1	100	Complete kill
2	97.5-99.9	Excellent
3	95.0-97.5	Good
4	90.0-95.0	Adequate
5	85.0-90.0	Just inadequate
6	75.0-85.0	Poor
7	65.0-75.0	Very poor
8	33.0-65.0	Useless
9	0-33.0	Almost no effect

Source: European Weed Research Council (2010)

Data generated was subjected to Analysis of Variance (ANOVA) using SAS software, Version 9.2 at 5% level of significance. The Least Significant Difference test was used to separate treatment means.

Results and discussion

Effect of herbicide tank mix on Amaranthus viridis percent control at 4WAS

Tank mix of Pendimethalin (2l/ha) + Atrazine (2l/ha) showed the highest significant ($p<0.05$) *Amaranthus viridis* percent control, although it was not statistically different from Extreme plus (0.8l/ha) + Pendimethalin (2l/ha) and Extreme plus (0.8l/ha) as shown in Table 3. Atrazine in the tank mix is known to control broadleaf weeds and thus effectively reduced *Amaranthus viridis* which is a broadleaf weed. The mode of action for atrazine is that it inhibits photosynthesis causing interveinal chlorosis, necrotic leaf margins and leaf burn (Senseman, 2007). Extreme plus (0.8l/ha) contains metribuzin and chloromuron ethyl. Metribuzin in this tank mix have the same mode of action as atrazine and therefore effectively controll *Amaranthus viridis*. Both atrazine and metribuzin are triazine herbicides which can mix well with other herbicides for broad spectrum weed control (LeBaron et al., 2008). Chlorimuron ethyl (90g/ha) exhibited the poorest *Amaranthus viridis* percent control and was not significantly different from no weeding (control), pendimethalin (2l/ha) and ExtremePlus(0.8l/ha)+Pendimethalin(3l/ha) as shown in Table 3. Chloromuron ethyl (90g//ha) is known to control mainly the sedges and therefore was not effective against *Amaranthus viridis*, a broadleaf weed. The results also show that Extreme plus alone can perform better rather than combining it with Pendimethalin in controlling *Amaranthus viridis*.

Effect of herbicide tank mix on percent Ipomoea sinensis control at 4WAS

Ipomoea sinensis control was generally very poor for all treatments as shown in Figure 1. Hoagland et al., (2011) and Burgos et al (2011) confirmed that *Ipomoea* species are problematic weed species and perhaps why its control is difficult. However, Metribuzin (2l/ha) had the highest significant ($p<0.05$) *Ipomoea sinensis* percent control followed by Extreme plus (metribuzin and chlorimuron) (0.8l/ha) although there were statistically different from each other as shown in Figure 1. Bhullar *et al.* (2012) revealed that *Ipomoea* species can be effectively controlled by pre- emergent herbicides like metribuzin or atrazine and should be followed by post-emergent herbicide like 2.4-D amine salt or 2.4D- sodium salt. Other tank mixes were not effective in controlling morning glory as their performance were not significant ($p<0.05$) or below the control (No weeding) as shown in Figure 1. Perhaps pendimethalin was antagonistic to the performance of atrazine and metribuzin in controlling *Ipomoea sinensis*.

Table 3. Effects of herbicide tank mix on percent *Amaranthus viridis* control.

Treatments	% Control 4WAS
Extreme Plus(0.8l/ha)	96.3a
Pendimethalin+ Atrazine	98.83a
Extreme Plus 1l/ha	68.78b
Metribuzin (2l/ha)	89.12a
No weeding (control)	39.2b
Pendimethalin (2l/ha)	55.1b
Extreme Plus(1l/ha)+Pendimethalin(3l/ha)	61.4b
ExtremePlus(0.8l/ha)+Pendimethalin(2l/ha)	97.3a
Chlorimuron ethyl (90g/ha)	21.38b
CV%	9.8
LSD	27.54
p-value	P< 0.005

Effect of herbicide tank mix on Boerhavia erecta percent control at 4WAS

All the herbicide mix significantly ($p<0.05$) controlled *Boerhavia erecta* with Pendimethalin + Atrazine showing the highest control as shown in Table 4. The presence of the triazine herbicides, metribuzin and atrazine contributed to the high efficacy of tank mixes in controlling *Boerhavia erecta*. This weed *Boerhavia erecta* has been reported to be easily controlled by many herbicide chemicals (Schmelzer, 2006). Pendimethalin and Chlorimuron ethyl alone failed to control *Boerhavia erecta* since their percent control is not significantly different ($p<0.05$) from the control (no weeding) as shown in Table 4. Pendimethalin (2l/ha) could not control *Boerhavia erecta* because of its nature as a seedling inhibitor of coleoptiles of grasses and less of broadleaf weeds. The hypocotyl of *Boerhavia erecta* lacks the receptor molecules which are targeted by Pendimethalin as a shoot inhibitor (Clowes and Blackwell, 2009).

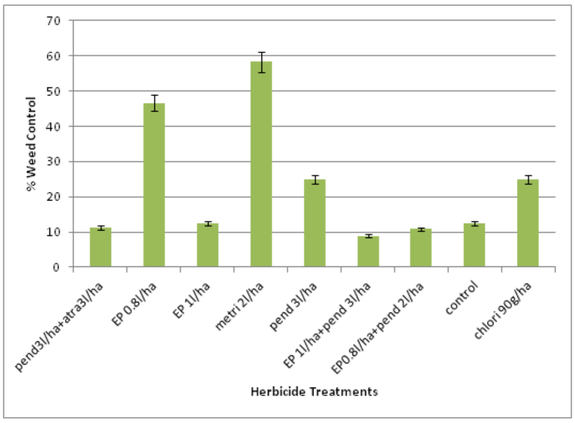

Fig. 1. Effects of herbicide combinations on percent *Ipomoea sinensis* control.

Effect of herbicide mix on Rotboellia conchinchinensis percent control at 8WAS

All herbicide tank mix with pendimethalin significantly ($p<0.05$) controlled shamva grass (*Rotboellia conchinchinensis*) at 8WAS with pendimethalin +atrazine exhibiting the highest percent control as shown in Table 5. Pendimethalin mode of action on grasses and some broadleaf weeds is to inhibit cell division on the meristematic tissue of emerging shoot (Peterson *et al.*, 2013). Metribuzin, atrazine and chlorumuron ethyl failed to control shamva grass since they are specific in controlling broadleaf weeds and nutsedges. *Rotboellia conchinchinensis* has the ability to recover after 1 to 2weeks when Chlorimuron ethyl was applied due to an alteration of the 4-chloro-6-methoxypyrimidin ethyl of Chlorimuron (Green, 2001).

Effect of herbicide mix on Commelina bengalensis percent control at 4 WAS

Pendimethalin + Atrazine achieved the highest significant ($p<0.05$) percent control of *Commelina bengalensis* followed by pendimethalin (3l/ha) although they were statistically different as shown in Figure 2. Presence of pendimethalin seems to be influencing the control of this grass weed. Chloromuron ethyl was significantly ($p<0.05$) ineffective in controlling *Commelina benghalensis* owing to the specificity of the herbicide in reducing nutsedge.

Table 4. Effects of herbicide mixes on *Boerhavia erecta* percent control at 4 WAS.

Treatments	4WAS
No weeding	38.38b
Pendimethalin + Atrazine	81.68a
Chlorimuron ethyl (90g/ha)	41b
Metribuzin(2l/ha)	75a
Extreme Plus (0.8l/ha)	75a
Pendimethalin (2l/ha)	49b
Extreme Plus(1l/ha) +Pendimethalin (3l/ha)	67a
ExtremePlus(0.8l/ha)+Pendimethalin (2l/ha)	80.9a
Extreme Plus (1l/ha)	71.1a
CV%	6.5
LSD	27.9
P value	P<0.005

Effect of herbicide mix on nutsedge percent control at 4WAS and 8WAS

At both 4WAS and 8WAS, Extreme plus (chlorimuron ethyl and metribuzin)(0.8l/ha) + Pendimethalin (2l/ha) showed the highest nutsedge (yellow and purple) percent control as shown in Table 6. The effectiveness of all herbicide mix containing Extreme plus in control of nutsedge is attributed to the presence of the sulfonylurea herbicide in chlorimuron ethyl, which is mainly a nutsedge killer (Finnegan, 2009). Chlorimuron ethyl controls nutsedge very well when used in compatible tank mixtures (Clowes and Breakwell, 2009). This displays great additivity and synergy between chlorimuron ethyl and metribuzin because when the two were tank mixed they performed better than when chlorimuron was used singly. When Metribuzin is tank mixed with Chlorimuron, Chlorimuron adopts an aphosphatic and copper group bearing a positive charge. This improves its absorption rate by the crop and also its efficacy in disrupting the metabolism of the seed and seedling. The results also indicated that pendimethalin + atrazine significantly ($p<0.05$) reduced nutsedge as shown in Table 3.6. Elsewhere, pendimethalin used alone had shown poor control against nutsedge (Bhullar *et al.*, 2006).

Table 5. Effect of herbicide mix on *Rotboellia conchinchinensis* percent control.

Treatments	% control 8WAS
Extreme Plus(1l/ha)	46.9b
Extreme Plus(0.8l/ha)	49.58b
Chlorimuron ethyl(90g/ha)	33b
Extreme Plus(0.8l/ha)+ Pendimethalin(2l/ha)	91.45a
Pendimethalin +Atrazine	93a
Extreme Plus (1l/ha) +Pendimethalin(3l/ha)	90.05a
Pendimethalin(3l/ha)	91a
Metribuzin(2l/ha)	43b
No weeding	22b
CV	9.5
LSD	41.1
p value	p<0.005

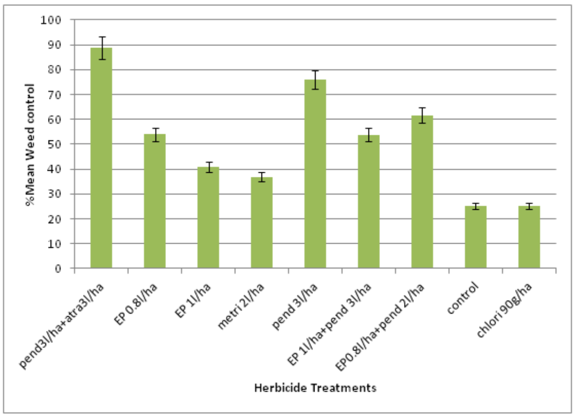

Fig. 2. Effect of herbicide mix on *Commelina bengalensis* percent control at 4WAS.

Conclusions

The major weeds observed in this experiment are *Amaranthus viridis, Ipomoea sinensis, Boerhavia erecta, Rotboellia conchinchinensis, Commelina bengalensis* and *Cyperus spp* (purple and yellow).

The herbicide tank mix of pendimethalin (2l/ha) + atrazine (2l/ha) significantly controlled all weed species in this study except *Ipomoea sinensis* which was effectively reduced by metribuzin and Extreme plus (0.8l/ha). Extreme plus (0.8l/ha) also effectively controlled all broadleaf weeds and *Cyperus spp*. Generally, spraying herbicides without mixing resulted in reduced control of weeds.

Table 6. Effect of herbicide mix on nutsedge percent control.

Treatments	4WAS	8WAS
Pendimethalin + Atrazine	64.88a	67.98a
Metribuzin (2l/ha)	40.6b	52.8b
Pendimethalin(2l/ha)	37b	50b
Extreme Plus (0.8l/ha)	61.5a	71.43a
No weeding	24.93b	22b
Extreme plus (1l/ha)	25b	67a
Extreme Plus(0.8l/ha) + Pendimethalin (2l/ha)	67.88a	73.33a
Extreme Plus(1l/ha) + Pendimethalin (3l/ha)	47b	61.75b
Chlorimuron ethyl (90g/ha)	26b	41b
CV%	6.9	6.89
LSD	16.1	14.99
p value	$p<0.005$	$p<0.005$

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