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Full Length Research Paper

Evaluation of the use of herbicide (Imazapyr) and fertilizer application in integrated management of *Striga asiatica* in maize in Malawi

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The parasitic weed species *Striga asiatica* (L.) Kuntze is one of major constraints in maize production in Malawi. Studies were conducted from 1999/2000 to 2001/2002 seasons to evaluate the effects of seed dressing with imazapyr (an acetolactate synthase [ALS] - inhibiting herbicide) at 0 and 45 g ha^{-1} and two fertilizer rates (0 and 69N:21P_2O_5:0+4S kg ha^{-1}) on maize with ALS target site resistance on *Striga* suppression and grain yield at Chitedze Research Station and farmers' fields. In the first season, imazapyr suppressed *Striga* emergence across all sites but did not increase yield. In contrast, fertilizer application had no effect on *Striga* emergence (P>0.05), but significantly increased yield (P<0.05). In the second season results were similar, but in addition the use of herbicide increased yield. In the third season a local hybrid (SC627) was included to compare yield potential of the untreated Imazapyr Resistant (IR) variety. The local check yielded higher than the IR hybrid with or without herbicide treatment, but sustained the highest emergence of witchweeds. The untreated IR hybrid had less *Striga* than SC627 and more than the treated. Overall, fertilizer use is found to be the single most important factor in increasing maize yield under *S. asiatica* infection, while herbicide use is important for reducing emergence.

Key words: *Striga asiatica*, imazapyr, *Zea maize* (L), Malawi, acetolactate synthase.

INTRODUCTION

Maize is the stable food crop in Malawi. The parasitic weed *Striga asiatica (L.*)` Kuntze. (witchweeds) is among the major constraints in its production. Recommended approaches in the control of witchweeds include the use of herbicides, high rates of fertilizer, long term trap cropping and hand pulling. These are usually not feasible for most smallholders who grow maize on over 80% of the arable land with sub-optimal inputs and minimal rotations. Also, these measures do not offer complete control and may require several seasons for substantial *Striga* reduction (Parker, 1984; Kabambe, 1991; Odhiambo and Ransom, 1996; Kabambe et al., 2000).

The damaging effects of *Striga* sp. on cereals are more pronounced under low fertility conditions (Parker, 1984; Pieterse and Verkleij, 1991). There are only few reports on maize resistance to *S. asiatica* (Ransom et al., 1990; Berner et al., 1995; Kabambe et al., 2000) reported a 100% yield advantage of a resistant maize variety over a susceptible one under *S. hermonthica* infection. Delaying *Striga* attachment by 3 weeks gave over 50 and 100% yield gains with resistant and susceptible maize varieties, respectively. One possible way to suppress parasitic weed emergence and prevent damage to the existing crop is through the use of herbicides which inhibit the activity of acetolactate synthase (ALS) (Garcia-Torres and Lopez-Granados, 1991) on maize varieties with resistance to ALS inhibiting herbicides, examples include Imazapyr (Abayo et al., 1996) Sulfonylureas (Adu-Tutu and Drennan, 1991) or Imazaquin (Berner et al., 1997). The herbicide is applied to maize that has target site

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Table 1. Herbicide * fertilizer effects on maize plant count m^{-2} at harvest, 1999/2000

	Fertilizer rate (F), kg ha^{-1}	
Imazapyr rate (H) g ha^{-1}	0	59:21:0+4S
0	2.52	3.04
45	2.24	2.32
SED H*F	0.12	

resistance to the herbicide activity. Maize with ALS resistance developed from tissue culture mutation (Newhouse et al., 1995). Since the herbicide is applied to seed, low dosages in the range 10 - 30 g ha^{-1} (Abayo et al., 1996) or 0.01 mg/g seed are possible (Berner et al., 1997). Estimates in Kenya have shown that 30 g a.i. may cost USD 5.00 (Kanampiu, 2005, personal communication,). Studies were therefore conducted with the following main objectives: 1). determine the effect of Imazapyr seed treatment and fertilizer application on *Striga* asiatica suppression and maize yield and 2) determine interaction or relative importance of the two factors on *Striga* suppression and maize yield.

MATERIALS AND METHODS

Trial sites

A herbicide x fertilizer (H x F) trial was conducted in 1999/2000, 2000/'00 and 2001/2002 seasons. In 1999/2000 the trial was conducted at Mbawa, Chitedze Station, Chitedze farmer's field, Mponela, Chitsime and Linthipe. In 2000/2001 there were only two sites, Chitedze Station and Mponela. In 2001/'02 the sites were Chitedze Research Station, Chitedze farmer's field (Mphimbi), Mponela, Namitete, Mulanje. All sites, except Chitedze station, were on-farm sites and were selected on basis of verified history of notable *Striga* infection.

Design and treatments

In 1999/2000 and 2000/'01 seasons, the trial was a 2 x 2 factorial. Levels for the imazapyr factor (H) were no seed treatment (H0, the control) and imazapyr seed coating at 45 gha^{-1} rate (H1). The maize hybrid IntA/IntB//Pioneer325irMZ98F2, which bears target site resistance to the ALS inhibiting herbicide (IR maize) was used. In the third season the imazapyr factor had the following 3 levels; H0: normal maize (SC627) with no seed treatment; H1: imazapry resistant maize with no seed treatment (the control); and H2: imazapyr seed coating at 45 gha^{-1} rate. All seeds were coated with insecticide (20% Lindane) and fungicide (26% Thiram dust) by mixing a sticker, insecticide and some water. The fertilizer levels were no fertilizer and 69:21:0+4S. In the fertilizer treatments the basal dressing was of 23:21:0 + 4S kg ha^{-1} N: P:K:S applied in a band made on the side of the ridge at or before planting day. For top dressing 46 kg ha^{-1} N from urea was applied using the point placement method.

Trial management and plot sizes

At Chitedze Research Station, each planting station was infested with 0.035 g (approx 3,500) seeds per station. Plots had four rows, each 4.0 m in length and 90 cm between rows. Maize stations were 50 cm apart, with 2 seeds per station (target density of 44,444 plants ha^{-1}). The net plot consisted of the two middle rows excluding end-of ridge stations (6.3 m^{-2}). Plots were kept free of weeds by hoe weeding at least 2 times within the first 3 weeks. Thereafter weeds (except *Striga*) were controlled by hand pulling.

In 1999/2000 the trials were planted on 17th December 1999 at Mponela, 14th December at Chitedze Research Station , 12th December at Chitedze on-farm, 15th December at Chitsime and Linthipe, and 31st December at Mbawa. In 2000/2001 planting dates were 24th and 30th November for Chitedze Research Station and Mponela, respectively. In 2001/2002 planting dates were 18th December for Chitedze Station, 20th December for Chitedze on-farm, 20th November for Mulanje, 15th December for Namitete, and 22nd December for Mponela.

Maize variables included in this report are grain yield ha^{-1} adjusted to 12.5% moisture content, and plants harvested. *Striga* emergence data reported is mainly from the second count, which reflected peak emergence. At some sites only the first count was available due to inaccessibility of site later in the season. Dates of *Striga* counts are reported as days after planting (DAP). The analysis of variance was done on all data. Treatment differences were regarded significant at the 5% level unless otherwise stated. Mean comparisons were between pertinent treatment means using the least significance difference.

RESULTS AND DISCUSSION

First season (1999/2000)

There were significant Herbicide (H) * Fertilizer (F) and Site (S) * H effects on harvest count. The S*H effects showed a decline in plant stand with imazapyr use at most sites except Chitedze on-farm (data not shown). The H*F interaction indicated that fertilizer use and non-herbicide dressing favored good plant stand (Table 1), however, the maximum average stand achieved was 3.0 plants m^{-2} only. The expected stand count m^{-2} was 4.44 plants. Thus in general there was low establishment with the maize genotype.

Results on yield showed a significant S, F and S*F effect on yield (Table 2). There were differences in response to fertilizer between sites, and differences in yield between sites, within the same fertilizer level. This is expected due to the differences in yield potential of sites owing to variable inherent fertility status.

Results on *Striga* emergence gave a significant and S*H effects. The S*H effects showed that H significantly suppressed emergence at all sites except at Mbawa, where pressure was very low anyway (Table 2). *Striga* suppression was quite notable at most sites. For example, at Mponela, *Striga* was suppressed from 21 plants m^{-2} to nearly nil. Similar results were obtained at Chitedze on-farm.

In summary, the first season results showed that use of herbicides is very important to reduce *Striga* emergence, while use of fertilizer is very important for higher yields. The results also show poor crop stand due to use of the IR hybrid.

Table 2. Site * fertilizer effects on maize yield (kg ha^{-1}) and Striga emergence across 6 sites, 1999/2000.

Factor	Sites					
Fertilizer Kg ha^{-1}	**Chitsime**	**Mponela**	**Chitedze Station**	**Chitedze on-farm**	**Linthipe**	**Mbawa**
	Maize grain yiled, $kgha^{-1}$					
0	730	835	2137	1132	1638	680
59:21:0+4S	1793	2425	3100	2332	3725	2399
SED	746					
Imazapyr rate g ha^{-1}	**Striga emergence, plants m^{-2}**					
0	1.84	21.81	11.8	16.42	4.71	0.39
45	0.00	0.05	6.97	0.08	0.00	0.13
SED S*H	2.8					

Striga emergence data is from second count, which reflected the peak emergence, except for sites where second count was not available.

Table 3. Effect of site x fertilizer and herbicide x fertilizer on second Striga count 2 (plants m^{-2}), 2000/01.

Site	Fertilizer level (kg ha^{-1}) $N:P_2O_5:K:S$	
	0	69:21:0+4S
Mponela	0.52	2.46
Chitedze Station	2.92	2.25
SED	0.59	
	Imazapyr rate, g ha^{-1}	
	0	45
Mponela	1.91	1.07
Chitedze Station	4.44	0.73
SED	0.74	

Second season (2000/2001)

There was a significant H*F effect on maize establishment. The interaction was similar to the first season in that good maize establishment was favoured by non-application of herbicide and fertilizer application (Table 3). For yield, there were significant differences recorded between sites. Yields at Chitedze station averaged 3087 kg ha^{-1} compared 1184 kg ha^{-1} for Mponela. The use of imazapyr had no effect on yield, while fertilizer application significantly increased yield from 1377 to 1857 kg ha^{-1} across the sites.

There was significant suppression of *Striga* due to imazapyr seed dressing from 3.17 to 0.9 plants m^{-2}. However there was a significant S*F (P = 0.09) and S*H effect at P = 0.067 shown in Table 3. The S*F showed that fertilizer application promoted *Striga* emergence at Mponela, and not Chitedze. The S*H interaction showed that there was no effect of the herbicide at Mponela, but at Chitedze. At Mponela, however, *Striga* was quite low.

Third season (2001/2002)

Maize establishment was significantly influenced by site and S*F interaction. The site means (Table 4) show satisfactory emergence, ranging from 3.8 to 4.38 plants m^{-2}. It appears therefore that the phytotoxicity declined considerably, compared to other seasons. The S*F interaction came about due a lower establishment of 3.38 plants without fertilizer at Mbawa. At other sites establishment ranged between 4.2 to 4.4 plants m^{-2} with or without fertilizer (data not shown).

Grain yield results were available from 4 of the 6 sites. Yields were significantly influenced by S, H and S*H. The highest yields were recorded at Chitedze Research Station. The herbicide effects showed that the local hybrid SC627 gave the highest yield of 2113 kg while the IR hybrid without herbicide yielded similarly to IR maize with herbicide (1583 vs 1564 kg ha^{-1}). The S*F effect on yield is shown in (Table 5). There was significant response to fertilizer application at all sites. There were differences in yield amongst sites within a fertilizer rate.

Striga emergence was influenced by S*H*F interaction (Table 6). The differences came about due to differential site pressure and the very low emergence of herbicide treated treatments compared to untreated. In the treated means, emergence was very low and there were no responses to site or fertilizer factors. However in the untreated plots differences occurred mainly due to site differences. Fertilizer effects were inconsistent.

DISCUSSION

Results in all three years consistently showed significant yield increases with fertilizer and occasionally with herbicide use. This suggests that the most important constraint to productivity even under *Striga* pressure is the low soil fertility. This is in agreement with the general observations that the damaging effects are more pronounced under low fertility condition (Parker, 1984). In other studies, Kanampiu et al. (2000, 2003) reported significant yield and *Striga* suppression due to use of imazapyr. The high suppression of witchweed emergence

Table 4. Effect of site on maize harvest count, yield and *Striga* emergence across 6 sites, 2001/02.

Site	Maize emergence Count, m^{-2}	Grain yield Kg ha^{-1}	*Striga* emergence Plants m^{-2}
Schitedze Station	4.38	3127	13.7
Chitedze on-farm	4.28	1238	5.8
Mponela	4.12	1119	13.8
Mulanje	-	-	0.9
Namitete	-	-	11.0
Mbawa	3.84	1530	2.0
SED	0.28	148	2.8
P	0.0008	0.0001	0.0001

Table 5. Site x fertilizer effects on maize yield (kg/ha), 2001/02 season.

Site	Fertilizer rate	
	0	69:21:0+4S
Chitedze Research Station	2304	3951
Chitedze on-farm	997	1479
Mponela	630	1609
Mbawa	467	2590
SED	178	

Table 6. Site*fertilizer*herbicide effects on Striga emergence (plants m^{-2}), 2001/02 season.

	Imazapyr use x fertilizer rate					
Site	Local hybrid SC627 No herbicide use		IR resistant maize No herbicide use		IR resistant maize 45 g ai ha^{-1} imazapyr	
	0	69:21:0+4S	0	69:21:0+4S	0	69:21:0+4S
Chitedze Station	25.1	20.0	10.2	18.1	6.1	2.9
Chitedze on-farm	11.6	7.3	4.1	12.0	0.05	0.10
Mponela	41.9	16.4	4.3	19.9	0.00	0.00
Namitete	2.22	1.32	0.05	0.84	0.00	0.00
Mulanje	12.1	63.3	2.11	5.29	0.32	0.10
Mbawa	1.80	4.28	2.18	2.65	0.42	0.58
SED	5.2					

observed with imazapyr is of great significance to integrated management by small scale farmers in Sub-saharan Africa as most of the control options such as fertilizer use, rotations with trap crops, resistant varieties or hand pulling, do not offer complete control, particularly in same season (Parker, 1984; Kabambe, 1991; Odhiambo and Ransom, 1996; Kabambe et al., 2000). Therefore ALS-inhibiting herbicides have an important role to improve yields as well reduce amount of seed return to the soil. The reason why the herbicide was not associated with significant yield increases is that the ALS-resistant hybrid used was not locally adapted, and fell prey to grey leafspot (GLS) (*Cercospora zeae-maydis*) GLS attack at most sites. This was well demonstrated in the third season when we introduced a local hybrid in the trial. The local hybrid had better yield without protection against *Striga*. There are on-going efforts by CIMMYT to improve the tropical adaptation of these genotypes. The other reason was the negative effect on maize stand associated with the herbicide, especially in the first two seasons. The laboratory germination of the seeds was excellent (95%) before and after the experiment. It is therefore possible that the hybrid was simply not able to germinate and establish well under tropical field conditions. Yield gains from ALS herbicides are expected not only due to *Striga* suppression, but also due to delay in emergence (Berner et al., 1985; Kanampiu et al., 2000, 2003). The damaging effects of witchweed are most pronounced before emergence (Parker and Riches, 1993; Kabambe, 1997).

The other benefit with reduction *Striga* emergence is that seed return to soil is reduced hence reducing the drudgery for hand pulling.

Conclusion

Fertilizer use has the highest impact on maize yield even under *Striga*. Therefore avenues to furnish fertilizer by organic or inorganic sources should be encouraged. Imazapyr had the highest impact in suppressing witchweed emergence, and increased yield in two of the three seasons. The two factors are therefore simultaneously critical for integrated management which seeks to enhance yields and manage witchweed dynamics. There is need for further work to increase yield potential of such genotypes.

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