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Full Length Research Paper

Imazapyr (herbicide) seed dressing increases yield, suppresses *Striga asiatica* and has seed depletion role in maize (*Zea mays* L.) in Malawi

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The parasitic weed species, *Striga asiatica* (L.) Kuntze, also known as witchweed, is one of the major constraints in maize production in Malawi. Most of the control measures do not protect a current crop from damage. In 1998/99 season, a trial was initiated at Chitedze Research Station under artificial infection, to evaluate the effects of seed dressing with imazapyr (an acetolactate synthase {ALS} inhibiting herbicide) using three seed treatment methods (coating, priming or drenching) and three herbicide rates (15, 30 and 45 g active ingredient ha^{-1}) on *S. asiatica* suppression, maize growth and yield. The maize hybrid IntA/IntB//Pioneer325irMZ98F2, bearing target site resistance to imazapyr (IR maize), was used as test crop. In the subsequent season, normal or non-IR maize was planted on the same plots of 1998/99, to assess the residual or spill-over effects on *Striga* emergence, maize growth and yield. In the first season, results showed that imazapyr seed dressing suppressed ($P < 0.05$) *Striga* emergence to < 1.0 plant m^{-2}, compared to 4.8 plants m^{-2} in untreated plots at 69 days after planting (DAP). At 86 DAP, use of imazapyr suppressed ($P < 0.05$) *Striga* emergence to $\geq$ 6.7 plants m^{-2} compared to 14.7 plants m^{-2} in untreated control. At 106 DAP, the number of *Striga* that flowered in untreated plots was 6.2 plants m^{-2}, compared to < 1.0 in all treated plots. The use of imazapyr gave no significant ($P > 0.05$) yield differences. In the subsequent season, imazapyr treatments gave no residual or spill-over effects on maize growth and yield ($P > 0.05$. There were significant ($P < 0.05$) effects on *Striga* emergence similar to the first season. The results therefore suggest that the use of ALS inhibiting herbicides not only suppresses *Striga* emergence, but also has a seed depletion role in integrated management of *Striga* without any spill-over or, herbicide injury in subsequent unprotected maize. This technology would be simple for farmers to adopt.

Key words: Witchweed, imidazolinone, *Zea mays* (L.), imazapyr rates, seed dressing.

INTRODUCTION

Maize (*Zea mays* L.) is the staple food crop in Malawi. It is grown on 1.2 million hectares with an average yield of 1.61 tonnes ha^{-1} (MoAIFS, 2005). Maize yields of six to seven ha^{-1} are possible under farmers' conditions (Kabambe and Nhlane, 2003; MoAIFS, 2005). Low or declining soil fertility arising from continuous cultivation of maize with minimal fertility replenishment, is one the major reasons for low yields (Kumwenda et al., 1997). Other constraints include recurring droughts, poor crop management, diseases such as grey leafspot (caused by *Cercospora-zea-maydis*), leaf blights (caused by *Helminthosporium turcicum*), rusts (caused by *Puccinia sorghi*), streak (caused by *Maize Streak Virus*) and pests such as stalk borers (caused by *Busseola fusca*), witchweed and termites (Ngwira et al., 1999). The parasitic weed, *Striga asiatica* (witchweed), is one the major constraints in maize production. Damage due to witchweeds can be very high in maize in Malawi, and in some cases farmers abandon fields (Kabambe, 1991).

There is a general agreement (Parker, 1984; Farina et al., 1985; Kabambe, 1991; Pieterse and Verkleij, 1991) that the damaging effects of *Striga* spp on cereals are

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most pronounced under low fertility conditions.

Some resistance to *Striga* has been reported (Ransom et al., 1990; Kabambe et al., 2000; Kabambe and Ganunga, 2003). Berner et al. (1995) reported that delaying *Striga* attachment by three weeks gave over 50 and 100% yield gains with resistant and susceptible maize varieties under *S. hermonthica* infection, respectively. Recommended control measures of witch-weeds in Malawi include the use of herbicides, high rates of fertilizer, long-term trap cropping and hand pulling (Kabambe et al., 2002). Most these measures are usually not feasible for most smallholders, may not offer complete control and may require several seasons for substantial *Striga* reduction to occur (Kabambe, 1991; Odhiambo and Ransom, 1996, Kabambe, 1997). Therefore integrated management is considered as the best approach for low input farmers (Pierterse and Verkleij, 1991). One possible way to suppress parasitic weed emergence and prevent damage to the existing crop is by using herbicides that inhibit the activity of acetolactate synthase, ALS (Garcia-Torres and Lopez-Granados, 1991; Abayo et al., 1996). These herbicides work by specifically inhibiting the biosynthesis of branched chain amino acids (Saari et al., 1994). 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 resistance to the herbicide activity. Maize with ALS inhibiting herbicides resistance was developed from tissue culture mutation (Newhouse et al., 1991). These herbicides may be may be applied to seed, such that low dosages in the range of 10 - 30 g active ingredient ha^{-1} are possible (Abayo et al., 1996; Berner et al., 1997). Investigations in Kenya have shown that at optimum rates of 30 g active ingredient ha^{-1}, the extra cost would be US $ 5.00 (Dr F. Kanampiu 2005, CIMMYT-Nairobi, personal communication).

When dealing with herbicides, there is always concern with chemical effects spilling over to non-target crops. In this case, there was interest on whether non-imazapyr-resistant (non-IR) maize grown after imazapyr-treated maize would be adversely affected. It was also of interest to monitor if imazapyr applied to a crop can influence *Striga* population in the subsequent crop. Studies were, therefore, conducted with the following objectives: (1). to determine the effect of application rate and seed dressing protocol on *Striga* incidence and maize growth and yield and (2) to evaluate residual or spill-over effects on non-IR maize stand and yield, and on *Striga* emergence in the subsequent season.

MATERIALS AND METHODS

Trial site, treatments and experimental design

A trial evaluating the effects of imazapyr application rate and seed dressing protocol on maize growth, yield and *Striga asiatica* suppression was conducted at Chitedze Research Station (13°58'S, 33°38'E) in 1998/99 cropping season from November 1998 to May 1999. This trial compared three herbicide seed dressing methods of coating, priming and drenching at three application rates of 15, 30 and 45 g active ingredient. ha^{-1}, in comparison to no seed treatment. There were 10 treatments evaluated in a randomized complete block design, with three replications. The complete list of treatments is presented in the results section. The maize hybrid used was IntA/IntB//Pioneer325irMZ98F2, which bears target site resistance to the ALS-inhibiting herbicide. All seeds were coated with Murtano™, a commercial seed dresser, containing insecticide (20% Lindane {gamma HCH}) and fungicide (26% Thiram dust) and a sticker, and some water, according to label instructions. For the coating method, seeds were air dried for 3 h after coating (Kanampiu et al., 2000). In the priming method, each seed imbibed 1.0 mL of solution, containing appropriate rates of herbicide. To do this, seeds were left overnight in a tray containing herbicide solution at a ratio of 1.0 mL to one seed. By morning all herbicide solution was fully absorbed and seeds were dry. In the drenching method the 1.0 mL per seed of right amount of herbicide solution was drenched using a syringe, directly to seeds in the planting hole.

Plots sizes and trial management

Each treatment was planted in two rows, 2.5 x 0.9 m, and the net plot size was 3.6 m^2. All rows were infected with approximately 3,500 seeds of *S. asiatica* per station. To infest *Striga* seeds, a 10 cm wide x 10 cm depth hole was dug. The *Striga* seeds (mixed with some sand for ease of handling) were then uniformly sprinkled in the hole which was then half buried with soil. Maize seed was planted on top and covered, as is recommended (Malawi Government, 1994). Maize stations were 50 cm apart, with two seeds/station, giving an expected density of 44,444 plants ha^{-1}. A total of 40 kg N and 21 kg P_2O_5 ha^{-1} was applied. The basal dressing was 23:21:0 + 4S kg ha^{-1} N: P: K: S applied as a band made on the side of the ridge before planting. For top dressing nitrogen was applied as urea using the dollop method and covered up, as is recommended (Malawi Government, 1994). A modest fertiliser rate was used to encourage *Striga asiatica* parasitism on the maize (Kim, 1991). Planting was done on November 24, 1998. The trial was kept free of weeds by hoe weeding at least two times within the first three weeks. Thereafter weeds (except *Striga*) were controlled by careful hand pulling. Termites were also controlled by drenching with Phoskill (monotropos) every two weeks. Maize plants were sprayed with a fungicide "Tilt" after every ten days, to prevent fungal disease for which the maize hybrid was susceptible (Dr D.C. Jewel, Personal CIMMYT-Harare, 1998, personal communication). The rates used were according to label instructions.

Evaluation of the residual or spill-over effects

In 1999/200, maize was grown on old plots as described above. The objective was to study the residual or spill-over effects of the treatments applied in 1998/99 season on maize growth and on *Striga* emergence. Ridges were not disturbed. Instead, the soil was loosened by had hoe to approximately 15 cm depth, and planting was done as in first season. No fertiliser was applied in order to encourage *Striga* emergence. There was no artificial inoculation of *Striga*, and the maize hybrid used was normal, non-IR MH17. Planting was done on December 5, 1999. Plant density and other cultural practices were as in the first season.

Data recording and analysis

Maize variables reported were plant height, plant count, number of ears grain yield in kg ha^{-1} adjusted to a storage moisture of 12.5% (MoAIFS, 2005). Data on *Striga* recorded was emergence count and numbers flowered, expressed on m^{-2}. Mean monthly rainfall

Table 1. Mean monthly rainfall (mm) for Chitedze Research Station, 1998 - 2000.

Month	Year		
	1998	**1999**	**2000**
January	330.5	336.1	195.8
February	215.6	216.1	174.9
March	101	392.5	141.6
April	2.6	46.4	46
May	1.1	0	0
June	0	6.8	0
July	0	0.3	0
August	0.2	1	0
September	0	0.1	0
October	24.5	0	17.3
November	29.4	99.2	148.4
December	246.7	53.7	79.8
Mean annual	**951.6**	**1152**	**803.8**

was also recorded. The analysis of variance was done on all data. Treatment differences were considered at the 5% level. Mean comparisons were between pertinent treatment means using the least significance difference, LSD.

RESULTS

Rainfall

The mean monthly rainfall from 1999 to 2000 is presented in Table 1. The ten year mean annual rainfall between 1994 and 2005 was 955 mm. The rainfall during the duration of the study can be considered as normal. In both seasons planting was done in good moisture and, routine observations showed that that there was no notable stress in both seasons, especially during crop establishment.

First season results

Striga results

Striga emergence (Table 2) in the untreated plots was significantly ($P < 0.05$) higher than the rest of the treatments at 69, 81, and 86 days after planting (DAP). At 69 DAP *Striga* emergence in the control was 4.8 plants m^{-2} compared to a maximum of 0.9 plants m^{-2} in the rest. At 86 DAP emergence in the control was 14.7 plants m^{-2} compared to a maximum of 6.6 plants m^{-2} in the imazapyr treatments. There were no significant differences between the imazapyr-treated plots. The results showed distinct suppressive effects of the herbicide on *Striga* even at the lowest rates for all seed dressing protocols. At 103 DAP the effectiveness of the herbicide was wearing off with time, as *Striga* emergence was building up in applied treatments. There was high suppression of number of *Striga* flowered at 103 DAP. In all imazapyr-treated plots, the mumber of Striga with flowers was < 1.0 plant m^{-2}, compared to 6.2 plants m^{-2} in the untreated plots.

Maize results

The effects of treatments on grain yield and ears/100 plants are presented in Table 3. There were no significant effects on plant height at six weeks after planting (mean, 115 cm), ear height (mean, 90.0 cm) and plant height at harvest (mean, 205 cm). There were significant ($P < 0.05$) treatment effects on number of ears/100 plants. The untreated treatment had 138 ears/100 plants, compared to an average of 177 ears/100 plants for the treated plots. Lower imazapyr rates were associated with greater numbers of ears. Treatment effects on maize yield were only marginally significant ($P < 0.10$). The highest yield of 5898 kg ha^{-1} was recorded with seed coat method at highest imazapyr rate. The imazapyr treatments averaged 4621 kg ha^{-1}.

Spill-over effects study

Striga results

Significant ($P < 0.05$) treatment differences on *Striga* emergence and number flowered were detected. At 65 DAP *Striga* emergence in untreated plots was 12 plants m^{-2}, compared to an average of 3.7 plants m^{-2} in imazapyr plots. The residual effects appeared to be more pronounced at higher herbicide rates. Average *Striga* emergence at 15 g ha^{-1} application rate was 15.9 plants m^{-2}, compared to 2.7 and 2.9 plants m^{-2} at 30 and 45 g ha^{-1} rates. The trend was similar at 84 DAP and for number of flowered *Striga* at 84 DAP. At 84 DAP *Striga* emergence in untreated plots was 34 plants m^{-2}, compared to an average of 11 plants m^{-2} in imazapyr-treated plots. Flowered Striga was 9.4 plants m^{-2} in untreated plots, compared to an average of 3.1 plants m^{-2} for imazapyr plots.

Maize results

The effect of treatments on *Striga* emergence and grain yield is presented in Table 4. There were no significant ($P > 0.05$) effects on plant height at harvest (mean, 191 cm), maize emergence count (mean, 4.3 plants m^{-2}), number of ears harvested (mean, 4.4 ears m^{-2}). Maize grain yields were only marginally different ($P < 0.10$). The lowest yield was 1875 kg ha^{-1}, recorded with the untreated control, while the imazapyr plots gave an average yield of 2756 kg ha^{-1}. The highest yield was 3365 kg ha^{-1}, recorded with priming method at 15 g ha^{-1} imazapyr rate.

Table 2. Effect of maize imazapyr seed treatment on *Striga* count and number of flowered *Striga* (m^{-2}) at various days after planting (DAP) at Chitedze Research Station, 1988/89 season.

Treatment	*Striga* count 69 DAP	*Striga* count 81 DAP	*Striga* count 86 DAP	*Striga* count 103 DAP	Number flowered *Striga* 103 DAP
1 =no seed treatment	4.8	15.9	14.7	62.9	6.2
2 = Imazapyr 15 g ha^{-1}, drench	0.1	2.6	4.9	35.8	0.1
3 = Imazapyr 30 g ha^{-1}, drench	0.9	0.1	1.0	20.7	0.1
4 = Imazapyr 45 g ha^{-1}, drench	0.0	0.1	0.7	30.2	0.0
5 = Imazapyr 15 g ha^{-1}, Prime	0.7	6.4	6.6	48.0	0.7
6 = Imazapyr 30 g ha^{-1}, Prime	0.1	1.2	1.8	31.0	0.2
7 = Imazapyr 45 g ha^{-1}, Prime	0.2	0.0	1.3	29.5	0.3
8 = Imazapyr 15 g ha^{-1}, Coat	0.0	1.9	1.3	33.0	0.3
9 = Imazapyr 30 g ha^{-1}, Coat	0.1	0.8	2.0	25.6	0.3
10 =Imazapyr 45 g ha^{-1}, Coat	0.1	0.1	1.4	25.4	0.4
Mean	0.7	2.9	2.19	34.2	0.8
P level	0.014	0.003	0.009	0.207	0.06
LSD 5%	2.40	6.97	6.7	29.8	0.06
CV%	196	140	107	51	260

DICSUSSION

Suppression of *Striga* emergence

The suppression of *Striga* emergence up to 12 weeks was in agreement with previous studies (Abayo et al., 1996; Berner et al., 1995; Kanampiu et al., 1999). Kanampiu et al. (1999), reported on significant yield gains with 30 g ha^{-1} active ingredient of imazapyr from on-farm trials. Due to land pressure existing in Malawi, many farmers would require to grow maize before *Striga* is completely eradicated, as long periods of fallow or rotation with trap crops, such as cotton, sunflower or legumes) are not feasible. Kabambe and Drennan (2003) reported reduction of *Striga* from 19 plants m^{-2} to 4.1, 0.5 and 3.8 plants m^{-2} after one, two and three seasons of continuous groundnut cropping, respectively. The lack of complete control by one method, therefore, necessitates the use of other methods such as using herbicide seed dressings. In this study, yield gains by using imazapyr were, statistically, quite marginal. However, yield gains were expected due to delay in emergence of *Striga*. Berner et al. (1995) reported that delaying *Striga* attachment by three weeks (simulated by transplanting maize unto a *Striga*-infected field) gave over 50 and 100% yield gains with resistant and susceptible maize varieties, respectively. The results are important for small-scale farmers in that yield could be improved and *Striga* could be managed simultaneously. Other control measures for possible inclusion in integrated management systems include hand weeding and deliberate efforts to amend or improve fertility. Other practices are cowpea intercropping (Carsky et al., 1994; Oswald et al., 2002; Kabambe and Drennan, 2003). The large reductions in *Striga* emergence, particularly numbers flowering are important in reducing seed return to the soil. Build-up of *Striga* was apparent after 12 weeks (86 DAP) (Table 2). This eventual build-up in imazapyr plots was also observed by Kanampiu et al. (1999), who attributed this to reductions in concentration of the herbicide within the plant as the plants grow big in biomass.

Table 3. Effect of imazapyr seed treatment, application method and rate on maize grain yield ($kgha^{-1}$), ears/100 plants in 1998/99 season.

Treatment	Grain yield (kg/ha)	Ears/100 plants
1 = no seed treatment	4305	138
2 = Imazapyr 15 g ha^{-1}, drench	4464	113
3 = Imazapyr 30 g ha^{-1}, drench	4175	124
4 = Imazapyr 45 g ha^{-1}, drench	4633	106
5 = Imazapyr 15 g ha^{-1}, Prime	4644	120
6 = Imazapyr 30 g ha^{-1}, Prime	5220	125
7 = Imazapyr 45 g ha^{-1}, Prime	3420	119
8 = Imazapyr 15 g ha^{-1}, Coat	4521	102
9 = Imazapyr 30 g ha^{-1}, Coat	4617	122
10 =Imazapyr 45 g ha^{-1}, Coat	5898	118
Mean	4546	119
P level	0.071	0.003
LSD 5%	1357	14
CV%	17	7

Effects on maize growth and yield

In the first season, herbicide treatments (methods and rates) gave similar effects on *Striga* up to 12 weeks, and

Table 4. Effect of imazapyr seed treatment, application method and rate applied in 1989/99 on maize grain yield (kg/ha) *Striga* count and number of flowered *Striga* (m^{-2}) at various days after planting (DAP) in 1999/2000 season.

Treatment	Grain yield	*Striga* count 65 DAP	*Striga* count 84 DAP	Number flowered *Striga*, 84 DAP
1 = no seed treatment	1875	12.0	33.9	9.4
2 = Imazapyr 15 g ha^{-1}, drench	2243	1.6	6.3	1.8
3 = Imazapyr 30 g ha^{-1}, drench	2161	3.7	9.5	2.7
4 = Imazapyr 45 g ha^{-1}, drench	2880	3.8	13.7	3.8
5 = Imazapyr 15 g ha^{-1}, Prime	3365	8.8	26.8	7.5
6 = Imazapyr 30 g ha^{-1}, Prime	3172	1.5	6.6	1.8
7 = Imazapyr 45 g ha^{-1}, Prime	2580	3.4	9.4	2.6
8 = Imazapyr 15 g ha^{-1}, Coat	2223	6.2	14.6	4.1
9 = Imazapyr 30 g ha^{-1}, Coat	3265	3.0	10.6	3.0
10 = Imazapyr 45 g ha^{-1}, Coat	2921	1.5	4.4	1.2
Mean	2668	4.5	13.6	3.8
P level	0.09	0.0067	0.0001	0.0001
LSD 5%	1100	5.24	18.29	1.75
CV%	24	67	27	27

maize yield. For practical purposes, the seed-coating method is much easier to perform, and is already a routine seed treatment protocol for insecticides and fungicides by the seed industry in Malawi. In theory, the priming method would be less prone to leaching or washing away of the herbicide before uptake, but would be technically more complicated to achieve. Therefore, the seed coating method would be recommended as it is already being used for dressing with fungicides and insecticides by the seed industry in Malawi.

Spill-over or residual effects on *Striga* emergence and maize growth and yield

The spill-over study results were of significance in integrated *Striga* management. First, the excellent maize stand (mean, 4.3 plants m^{-2}, compared to the expected stand of 4.4 plants m^{-2}) in the unprotected maize confirms of the absence of residual toxic effects in subsequent crops. Secondly, this absence of damage suggests that the observed low *Striga* emergence in imazapyr plots was due to seed reduction occurring in the first season. Seed depletion occurs when *Striga* germinates but fails to attach to its host root. This is in agreement with Kanampiu et al. (2002) who showed that *Striga* seeds are almost completely killed in the top 10 cm of soil below treated seed, and by up to 80% at 30 cm depth. The use of imazapyr, therefore, has a seed depletion role. The seed depletion role was associated with higher imazapyr rates. Farmers could take advantage of this low emergence by complementing it with measures such as intercropping to reduce the *Striga* seed bank every time maize is grown. Kanampiu et al. (2002) reported that using imazapyr-treated maize seed in an intercropping system with susceptible (non-IR) cowpea was safe for cowpeas at distances of 15 cm from the seed or station. This makes the technology suitable for smallholder farmers who may need to grow more that one crop, or must practice continuous maize cropping.

Conclusions and recommendations

This was the first study to evaluate the use of imazapyr or any form of herbicide seed dressing to control *Striga* in Malawi. Importantly, *S. asiatica* was used in the study, while most the of previous studies in the region were on *S. hermonthica* (Kanampiu et al., 1999; 2000; and 2002). The studies have therefore shown that imazapyr seed dressings can also suppress *S. asiatica* emergence by up to 12 weeks, as shown in the other studies. There were are no residual or spill-over effects in a subsequent unprotected (non IR) crop, and the herbicide effects help to reduce the *S. asiatica* seed bank in the soil. The hybrid used was non-adapted to the area. It is therefore recommended that research efforts should focus on identifying adapted varieties which should then be advocated to farmers, along with imazapyr seed dressings.

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REFERENCES

Abayo GO, Ransom JK, Gressel J, Odhiambo GG (1996). *Striga hermonthica* control with acetolactate synthase-inhibiting herbicides seed-dressed on maize with target site resistance. In: Toreno MT, Cubero JI, Berner D, Joel DM, Musselman L, Parker C (eds) Advances in Parasitic Weed Plant Research. Junta De Andelucia. Consejeria da Agriculturally Pesca. Cordova, Spain, pp. 762-768.

Adu-Tutu KO, Drennan DSH (1991). Effect of Sulfonyurea Herbicides on *Striga*. In: Ransom JK, Musselman AD, Worsham Parker C (eds) Proceedings of the Fifth International Symposium of Parasitic Weeds. Nairobi: CIMMYT, pp. 361-371.

Berner DK, Ikie FO, Aigbokhan EI (1995). Some control measures for *Striga hermonthica* utilizing critical period on maize. In: Maize research for Stress Environments. Proceedings of the 4th Eastern and Southern Africa Regional Maize Conference held at Harare, Zimbabwe, 28 March –1 April, 1994. pp. 267-272.

Berner DK, Ikie FO, Green JM (1997). ALS-Inibiting Herbicide Seed Treatments Control S*triga hermonthica* in ALS-Modified Corn (*Zea mays*). Weed Technol. 11: 704-707.

Carsky RJ, Singh L Ndikawa R (1994). Suppression of *Striga Hermonthica* on sorghum using a cowpea intercrop. Exp. Agric. 30: 349-359.

Garcia-Torres L, Lopez-Granados F (1991). Control of *bromerape (Orobanche crenata* Forsk.) in broad bean (*Vicia faba* L.) with imadazolines and other herbicides. Weed Res. 31: 227-235.

Farina MPW, Thomas PEL, Channon P (1985). Nitrogen, phosphorus and potassium effects on the incidence of *Striga asiatica* (L.) Kuntze in maize. Weed Res. 25: 443-447.

Kabambe VH (1991). The Development of cultural methods for control Striga in maize. In: Ransom JK, Musselman AD, Worsham Parker C (eds.) Proceedings of the Fifth International Symposium of Parasitic Weeds. Nairobi:CIMMYT, pp. 46-56.

Kabambe VH, Drennan DSH (2003). Control of *Striga asiatica* in maize by means of crop rotation and intercropping in Malawi. In: Mloza-Banda HR, Salanje GF (eds.). Proceedings of the Nineteenth Biennial Weed Science Society Conference for Eastern Africa. Lilongwe, WSSEA, pp. 105-111.

Kabambe VH, Ganunga RP (2003). Evaluation and development of late and intermediate maize varieties for tolerance/resistance to *Striga asiatica* in Malawi. In: Mloza-Banda HR, Salanje GF (eds.) Proceedings of the Nineteenth Biennial Weed Science Society Conference for Eastern Africa. Lilongwe, WSSEA, pp 97-103.

Kabambe VH, Nhlane WG (2003). Malawi-Mother and Baby Trials. In: Banziger M, Mwala M, Gwabi I (eds). Annual Report for The Southern Africa Drought and Low Soil Fertility Project SAFLF – Phase II. CIMMYT, Harare.

Kabambe VH, DeVries J, Kling, JC, Ngwira P, Nhlane WG (2000). Development of maize genotypes resistant or tolerant to *Striga asiatica* in Malawi. In: Haussmann BIG, Hess DE, Koyama ML, Grivet L, Rattunde HFW, Geiger HH (eds). Proceedings of a workshop held at IITA, Ibadan, Nigeria, 18-20 August 1999. Margraf Verlag, Weikersheim, Germany, pp. 313-323.

Kabambe VH, Mloza-Banda HR Nyandule Phiri GY (2002). Controlling witchweeds in cereals in Malawi. An extension bulletin for field staff. Department of Agricultural Research and Technical Services, Extension Bulletin no. 1/2002. Ministry of Agriculture and Irrigation, Lilongwe, Malawi.

Kanampiu FK, Ransom JK, Gressel J (2002). Imazapyr and pyrithiobac movement in soil and from maize seed coats controls *Striga* in legume intercropping. Crop Prot. 21: 611-619.

Kanampiu FK, Friessen DK, Ransom J, Kabambe V, Jewell D, Gressel J (2000). Herbicide seed dressing of corn as an appropriate treatment for *Striga* control while allowing intercropping. Proceedings of the Third International Weed Science Congress; 2000 June 6-11; Foz do Iquassu., Brazil. Manuscript number 282. p. 7.

Kanampiu FK, Ransom JK, Gressel J (1999). Advantages of seed-primed imazapyr for *Striga hermonthica* control on maize bearing target site resistances. In: CIMMYT and EARO (1999). Maize Production Technology for the Future: Challenges and Opportunities. Proceedings of the 6th Eastern and Southern Africa region maize Conference, 21-25 September, 1998. CIMMYT and EARO, pp. 172-179.

Kim SK (1991). Breeding maze for striga tolerance and the development of a field infestation technique. In: Kim SK (ed). Combating *Striga* in Africa. Proceedings of an international workshop organized by IITA, ICRISAT and IDRC, August 1988, Ibadan, Nigeria, pp. 96-108.

Kumwenda JDT, Waddington SR, Snapp SS, Jones RB, Blackie MJ (1997). Soil Fertility Management in Southern Africa. In: Byerlee and C.K. Eicher (eds) Africa's Emerging Maize Revolution. Lynne Reiner Publishers, Colorado, pp. 157-172.

Ministry of Agriculture and Livestock Development (MoALD) (1994). A Guide to Agricultural Production in Malawi. Agricultural Communications Branch, (MoALD). Lilongwe, Malawi.

Ministry of Agriculture, Irrigation and Food Security (MoAIFS) (2005). A Guide to Agricultural Production and Natural Resources Management in Malawi. Agricultural Communications Branch, MoIFS, Lilongwe, Malawi.

Ngwira P, Pixley KV, DeVries J, Kanaventi CM (1999). Major maize disease problems and farmers' varietal preferences in Malawi. In: CIMMYT and EARO (1999). Maize Production Technology for the Future: Challenges and Opportunities. Proceedings of the 6th Eastern and Southern Africa region maize Conference, 21-25 September, 1998. CIMMYT and EARO, pp. 1109-112.

Newhouse KE, Singh B, Shaner D, Stidham M (1991). Mutations in maize (*Zea mays* L.) conferring resistance to imidazolinone herbicides. Theor. Appl. Genet. 83: 65-70.

Odhiambo GD Ransom JK (1996). Effect of continuous cropping with trap crops and maize under varying management systems on the restoration of land infested with *Striga hermonthica*. In: Toreno MT, Cubero JI, Berner D, Joel DM, Musselman L, Parker C (eds) Advances in Parasitic Plant Research. Junta De Andelucia. Consejeria da Agriculturally Pesca. Cordova, Spain. pp 834-841.

Oswald A, Ransom JK, Kroschel J, Sauerborn J (2002). Intercropping controls *Striga* in maize based farming systems. Crop Prot. 21: 367-374.

Parker C (1984). The influence of *Striga spp*. On sorghum under varying nitrogen. In: Parker C, Muselman LJ, Polhill RM, Wilson AK (eds) Proceedings of the Third Intenational Symposium on Parasitic Weeds. ICARDA/International Parasitic Weeds Research Group, 7-8 May, 1984, Allepo, Syria, pp. 90-98.

Pieterse AH, Verkleij, JAC (1991). Effects of soil conditions on *Striga* Development - a review. In: Ransom JK, Musselman AD, Worsham Parker C (eds) Proceedings of the Fifth International Symposium of Parasitic Weeds. Nairobi: CIMMYT, pp 329-339.

Ransom JK, Eplee RE, Langstom MA (1990). Genetic variability for resistance to *Striga asiatica* in maize. Cereal Res. Comm. 18: 329-333.

Saari LL, Cotterman C, Thill DC (1994). Resistance to acetolactate-synthase-inhibitor herbicides. In: Powles SB, Holtum JA (eds). Herbicide Resistance in Plants: Biol. Biochem. Chelsea M1: Lewis, pp. 80-139.