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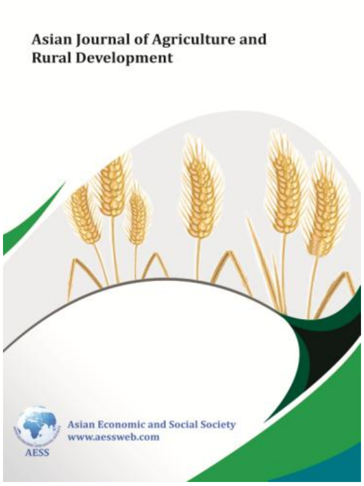

Effect of Sulfentrazone Application Method and Time, on Weed Control and Phytotoxicity in Flue-Cured Tobacco

Upenyu Mazarura (Crop Science Department, University of Zimbabwe, Harare, Zimbabwe)

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Author(s)

Upenyu Mazarura

Crop Science Department, University of Zimbabwe, Harare, Zimbabwe

Abstract

Over a period of three years sulfentrazone, alone and in combination with other herbicides, was evaluated for weed control efficacy under various methods application. The trials were done in granite sandy soils after three years of *Chloris gayana* cv Katambora at Kutsaga Research Station, Zimbabwe. The chemicals were sprayed using a knapsack or a tractor mounted boom. Incorporation after ridging was done with a gang tiller set for shallow incorporation while that before ridging was done using a disk also set for shallow incorporation. Comparisons were made between directed and broadcast sprays, incorporation and no incorporation, timing from before planting to 4 weeks after planting (WAP). Application before holing out (BHO) and after holing out (AHO) was also evaluated. In most cases sulfentrazone gave good to excellent control of all weeds and was comparable to Metolachlor in efficacy. In some cases grass control was somewhat variable but acceptable. With regard to time of application, Sulfentrazone gave better control of broadleaf and grass weeds when applied from 1 to 4 WAP. Yellow nutsedge control was excellent and unaffected by time of application. Weed dry matter was reduced significantly relative to the untreated control for the 1 to 4 WAP applications. There was no significant difference between incorporation and surface or between directed and broadcast applications. The over top (OT) and AHO consistently gave better control than BHO application.

Keywords: Sulfentrazone, Nutsedge, Broadleaf

Introduction

The options for nutsedge control in the farming and even landscape sectors are very limited. In the tobacco sector s-metolachlor or metolachlor and halosulfuron (Servian) are, at best, the only options. S-metolachlor has good pre-emergent efficacy but its persistence is questionable. It also has no effect once the nutsedge has germinated and is not known to affect the nuts buried in the ground. Halosulfuron application can only be directed as it is phytotoxic to tobacco although it has an excellent post emergent activity on nutsedge and is known to be translocated to the buried nuts. Sulfentrazone provides excellent control of yellow and purple nutsedge, most broad-leafed weeds, and some grass weeds. It's efficacy on grasses, however, is very variable (Mazarura, 1999; Fisher et al., 2003) but it extends the arsenal against nutsedge in both tobacco and soya beans. It is also effective at high rates (0.55 kg /ha) under landscape environments (Collins et al., 2001).

Sulfentrazone acts in the chlorophyll biosynthetic pathway by inhibiting protoporphyrinogen oxidase. As a result a phytodynamic toxicant (protoporphyrin IX) accumulates and leads to membrane disruption. Absorption is through roots and shoots. Plants that take up sulfentrazone in this manner turn necrotic and die soon after light exposure (Collins et al., 2001). Crop injury from sulfentrazone has been reported (Fisher & Smith, 2003) especially with pre plant incorporation and less so with surface pre plant applications before transplanting (Fisher et al., 2002). Grey et al. (2004) did not find yield limiting phytotoxicity in peanut cultivars with the pre plant application. In potato, application at emergence caused severe injury while acceptable injury occurred when sulfentrazone was applied pre-emergence (Bailey et al., 2002). In tobacco, Fisher et al. (2003) concluded that injury was almost guaranteed if concentrated zones of the sulfentrazone were found in the root zone at transplanting. This could be as a result of poor incorporation (Fisher et al., 2003), leaching caused by rainfall(Ritter et al., 2005) or any other cause.

Applied post transplanting over the top, pre planting incorporated and post transplanting directed, sulfentrazone gave good control of smallflower momingglory (*Jacquemontia tamnifolia* (L.) Griseb) (94%) and yellow nutsedge (≈90%) at 0.14 to 0.28 kg a.i./ha across all application methods. Efficacy was not affected by method of application but injury was severe (63%) when sulfentrazone was applied post transplanting over the top (Johnson & Mullinix, 2005).

In Zimbabwe, farmers apply herbicides in various ways. Application after ridging but before holing out (BHO), although not widespread, is practiced. This was the case with after holing out (AHO) but before transplanting. The over the top (OT) application after transplanting is the most widespread as it guarantees least traffic on the treated soil surfaces. Such traffic is associated with poor efficacy, perhaps, due to the uneven distribution of herbicide that can result. The present experiments were carried out to establish the effect of various application methods and times on weed control efficacy and tobacco injury.

Materials and Methods

Treatments and design

In all the three year trials the experiments were arranged in a complete randomized design of four blocks. In year two a factorial experiment was used. The treatments for each year and the treatment descriptions are given below:

Year 1	Year 2	Year 3
1. Sulfentrazone - before holing-out (BHO) 2. Sulfentrazone - after holing-out (AHO) 3. Sulfentrazone - after holing-out (hole soil mixed thoroughly with sprayed soil) (AHO-M) 4. Sulfentrazone - after holing-out (sprayed soil layer removed from hole) (AHO-R) 5. Sulfentrazone - (over top) 0-3 days after planting (no incorporation) (OT) 6. Untreated control	1. Pre–ridge application and incorporated by disc set for shallow incorporation (pre-ridge incorporated.) 2. Post-ridge application and incorporated by gang tiller set for shallow incorporation before holing out (post-ridge incorporated, BHO.) 3. Application immediately after planting over the top (IAP surface) 4. Application over the top at 1 week after planting (1 WAP) 5. Application over the top at 2 weeks after planting (2 WAP) 6. Application over the top at 3 weeks after planting (3 WAP) 7. Application over the top at	Factor 1 Levels 1. Sulfentrazone - post-ridge incorporated (before holing-out and incorporated with a gang tiller) (POST-BHO) 2.Sulfentrazone - immediately after planting (no incorporation) (IAP) 3. Sulfentrazone - 1 week after planting (WAP) 4. Sulfentrazone - 2 weeks after planting (WAP) 5. Metolachlor - applied immediately after transplanting @ 1.44 kg a.i./ha (IAP) Factor 2 levels: 1.Directed spray (D) 2. Broadcasted spray (B)

	4 week after planting (4 WAP)	

Varietal and Cultural Activity Considerations
The variety K RK26, a nematode resistant cultivar, was transplanted into late ploughed granite sands after 3 years of a nematode resistant grass, *Chloris gayana* cv Rhodes Katambora. Regardless, EDB 98% was applied at 125 ml /100 m run. Gross plots measuring 4.8 m x 17.92 m (four rows) were used and the harvested/assessed plots measured 2.4 m x 16.80 m (2 rows). Plants were 0.56m apart on ridges 0.2m high and 1.2m apart. In all the trials sulfentrazone was either applied by calibrated knapsack boom at 0.25 kg a.i./ha (Year 1) or tractor mounted boom (Year 2). Incorporation before holing out (BHO) was done by a disc harrow set for shallow incorporation (10 cm) while incorporation after ridging was done using a gang tiller.

Measurements and Statistical Considerations
Two rows of a local control plot were included so that any two treatments had this plot in the middle. The local plot was used for scoring for weed control. Weed counts and dry matter measurements were done on it after 2-3 reapings of the untreated control plot. These measurements (on the local untreated control) were used as a covariate in statistical analyses. Weeds were counted using 7 (0.3 x 0.3m) quadrants at 3 positions in each subplot. In year 1 stalk height was assessed 51DAP while visual assessment of phytotoxicity was done 7 weeks after planting (Mazarura, 2001), and finally weeds assessment (visual assessment, count and dry mass) and yield. In year 1 and 3 all weed count data were square root transformed (Bartlett, 1936) before ANOVA was done and mean separation was done using Fischer's Protected Least Significant Difference (LSD) test at 5%. In year 2 the logarithmic transformation was appropriately used (Bartlett, 1936). SAS software was used for all analyses. Although all statistics was carried out using transformed data, were necessary, all data was back transformed in order to aid understanding and, were appropriate, all tables have been presented using back transformed data.

Results

During the 1st year of testing sulfentrazone, the herbicide was applied after ridging but before holing out (BHO), after holing out (AHO), after holing out and the soil in the hole mixed (AHO-M), after holing out and the sprayed hole soil removed (AHO-R) and sprayed over the top of the transplanted tobacco seedlings (OT). Although all treatments at 34 days after planting (DAP) were better than the untreated control, all the herbicide treatments except the over the top (OT) treatment were the same. By145 DAP the broad leaf control had virtually vanished with all herbicide treatments essentially undistinguishable ($P > 0.05$) from the untreated control although there were significant treatment effects ($P < 0.05$) (Table 1). In this regard, the BHO and AHO treatments outperformed the other herbicide treatments (Table 1). Nutsedge control was not different between herbicide treatments at 34 DAP but better ($P < 0.05$) than the untreated control (Table 1). Nutsedge control persisted to 145 DAP for all treatments except the AHO-M (Table 1). Grass control was better with the herbicide treatments than without and showed significant ($P < 0.05$) effects. In this regard, the OT and AHO-M treatments stood out. At 145 DAP some grass activity was still evident. When all weeds were considered at 34 DAP the OT and AHO-M treatments were significantly ($P < 0.05$) better than the rest of the herbicide treatments. Generally, the above efficacy also persisted to 145 DAP (Table 1).

A complimentary visual weed control score showed that overall weed control was good at 32 and 48 DAP, but phytotoxicity was evident at the both dates in most treatments (Table 2). At 32 DAP, with regards to phytotoxicity, the treatments could be arranged as AHO, AHO-M > BHO > AHO – R > OT. At 48 DAP the OT treatment did not show any phytotoxicity while the other treatments were similar. Stalk height measurements confirmed this observation and showed that the OT treatment was safest while the AHO treatments were the most risky. Essentially, however, the AHO-R and AHO-M, BHO and OT where the same as the untreated control (Table 2). Crop injury was severe with the AHO and AHO-M treatments. However, none of the phytotoxicity caused significant yield reduction (compare weeded clean column, Table 3). A comparison of the weeded and weedy plots showed that only with the OT treatment was the herbicide as effective as a weed free situation.

In the second year the study investigated the effect of a pre-ridging and post ridging incorporation with a gang tiller set for shallow incorporation, the IAP over top application and a series of overtop applications from 1 to 4 WAP. Nutsedge control was not affected by time or method of herbicide application. However, broadleaf and grasses showed such responses. With regards to broadleaf weeds, control could be arranged in order of decreasing control as 4 WAP > 3 WAP, 2 WAP, 1 WAP, IAP surface > pre or post ridge incorporation. Similarly for grasses the control was 4 WAP > 3 WAP, 2 WAP, 1 WAP > IAP surface, pre and post incorporation. There was no yield response to the time and method of herbicide application.

In the third year two methods of application (directed and broadcasted) and four application times were tested. In addition a positive control, Metolachlor, was included. No effect of method of application on weed efficacy and no method by time interaction were observed. Time of application within each method of application did not affect nutsedge, grasses and all weeds but affected broadleaf weeds control. Across application methods the application 1WAP, 2WAP and Metolachlor gave better efficacy than the IAP and post ridge applications. Yield was not affected by method or time of application (Table 6).

Table 1: Weed Counts/m^2 at 34 DAP and 145 DAP, and Dry Mass at Harvest (Year 1)

	34 DAP				145 DAP				Dry Mass (g/m^2)
	B/L	S	GR	ALL	B/L	S	GR	ALL	
Application method									
BHO	3.9b	3.8a	14.0bc	21.8b	3.2a	0.5a	10.4c	14.2a	312.66b
AHO	3.8b	1.2a	13.0b	17.9a	4.4a	0.7a	9.7bc	14.7a	393.45c
AHO mixed	2.5ab	0.8a	8.7ab	12.0a	5.3ab	0.9ab	8.2b	14.4a	386.65c
AHO removed	4.0b	1.3a	18.1c	23.4b	6.0ab	0.5a	7.8b	14.3a	241.80b
OT	1.6a	2.8a	6.4a	10.8a	9.0b	0.7a	4.8a	14.4a	78.76a
None	20.8c	23.4b	48.4d	92.7c	5.8a	1.7b	22.2d	29.8c	530.06d

*means showing the same letter are not significantly different according Fischer's Protected Least Significant Difference (LSD) test at 5%. DAP = Days after planting, B/L = broadleaf weeds, S = Nutsedge, GR = Grasses, ALL = (Broadleaf + Nutsedges + Grasses), BHO = before holing out, AHO = after holing out, AHO mixed = sprayed after holing and chemical mixed with the soil in the hole, AHO remove sprayed after holing and a layer of the sprayed soil removed from the planting hole, OT = sprayed over the top.

Table 2: Weed Control Score (0-10), Phytotoxicity Score (1-10) at 32 and 48 DAP, and Stalk Height at 51 DAP (Year 1)

	32 days after planting					48 days after planting			Stkht51
	BL	GR	SG	Phyto	BL	GR	SG	All	Phyto	
Application method										
BHO	8.8	8.5	9.0	4.3	9	7.8	10	8.8	3.3	51.2
AHO	9.0	8.5	9.0	5.0	8.8	8.3	10	8.8	4.8	44.5
AHO mixed	8.8	8.5	9.0	5.0	9.3	8.3	10	8.3	4.8	46.2
AHO removed	8.5	8.5	9.0	4.0	8.5	7.5	10	7.8	4.0	49.9
OT	9.5	9.3	9.0	1.0	9.3	8.5	9.3	8.8	0.0	58.8

None	-	-	-	-	-	-	-	-	-	54.5
LSD	ns	ns	ns	0.34	ns	ns	ns	ns	1.9	9.38

B/L = broadleaf weeds, S = Nutsedge GR = Grasses ALL = (Broadleaf + Nutsedges + Grasses), stkht51 = stalk height at 51 d.a.p, Phyto = phytotoxicity, BHO = before holing out, AHO = after holing out, AHO mixed = sprayed after holing and chemical mixed with the soil in the hole, AHO remove sprayed after holing and a layer of the sprayed soil removed from the planting hole, OT = sprayed over the top.

Table 3: Saleable Yield (kg/ha) (Year 1)

	Not weeded	Clean weeded	mean
Application method			
BHO	3434	3945	3689
AHO	3146	3623	3385
AHO mixed	3051	3913	3482
AHO removed	3352	3701	3527
OT	3860	3929	3895
None	1930	3726	2828

LSD: herbicide 451.56, Weedy vs. weeded 229.22, Interaction 726.88

B/L = broadleaf weeds, S = Nutsedge GR = Grasses ALL = (Broadleaf + Nutsedge + Grasses) BHO = before holing out, AHO = after holing out, AHO mixed = sprayed after holing and chemical mixed with the soil in the hole, AHO remove sprayed after holing and a layer of the sprayed soil removed from the planting hole, OT = sprayed over the top.

Table 4: Weed Counts/m^2 and Yield (Year 2)

	Sedges	Broadleaf	Grasses	Yield
Application method or time				
Pre-ridge inco.	7.78a	9.81d	335.9e	2702a
Post-ridge inco. (BHO)	0.93a	6.48cd	233.7de	2542a
IAP surface	0.19a	5.93bcd	216.5de	2824a
1 WAP	0.56a	1.48bc	99.1c	2750a
2 WAP	0.19a	2.78b	149.3cd	2785a
3 WAP	1.11a	4.81bcd	139.4cd	2785a
4 WAP	0	0.93a	10.7a	2532a

*means showing the same letter are not significantly different according Fischer's Protected Least Significant Difference (LSD) test at 5%. S = nutsedge, BL = broadleaf, GR = grasses, WAP weeks after planting, inco. = incorporated, BHO. = before holing out, IAP= immediately after planting.

Table 5: Weed Counts/m^2 for Broadleaf, Sedges and Grasses (Year 3)

	Broadleaf		Nutsedge		Grasses		All Weeds	
	Application method							
	D	B	D	B	D	B	D	B
Time of application								
Sulfentrazone post-ridge	9.5b	7.8c	1.6a	2.4a	4.1a	8.2a	20.2a	18.4a
Sulfentrazone immediate	7.5ab	11.8c	5.2a	5.0a	3.4a	3.7a	16.1a	20.5a
Sulfentrazone 1 WAP	5.6a	5.2ab	1.2a	8.5a	6.6a	2.4a	13.4a	16.0a
Sulfentrazone 2 WAP	6.0a	5.4ab	1.7a	7.4a	3.8a	4.2a	11.5a	17.1a
Metolachlor immediate	6.3ab	4.81a	26.7a	4.4a	0.9a	0.9a	34.0a	10.1a

*means showing the same letter are not significantly different according Fischer's Protected Least Significant Difference (LSD) test at 5%. D = directed spray, B = broadcasted spray, Ave. = mean, ns = not significant

Table 6: Saleable Yield (kg/ha) (Year 3)

		Application Method	
	Directed	**Broadcast**	**Mean**
Time of application			
Sulfentrazone post-ridge	2722	2771	2747
Sulfentrazone immediate	2585	2716	2650
Sulfentrazone 1 WAP	2856	2676	2766
Sulfentrazone 2 WAP	3072	2825	2948
Metolachlor immediate	2759	2810	2785
LSD: application time	ns		
Application method	ns		
Interaction	ns		

Discussion

During the first year, the results showed early season (34DAP) good broadleaf weeds control across application methods but the OT and 'AHO mixed' treatments gave the best control. Late season control (145 DAP) was not evident. Early season nutsedge control was also good across all methods and all treatments. Late season (145 DAP) control was only evident with the treatments BHO and AHO-R. Grey et al. 2009a reported good control of yellow nutsedge at all rates (112 to 280 g a.i. /ha) with a pre-plant incorporated and pre-emergence (similar to OT in the current trials), thus agreeing with the current findings. Post emergent control of purple nutsedge is documented and so is the effect on buried nuts (Rahnavard et al., 2010; Brecke et al., 2005). Early season grass control was good except the AHO-R treatment. Control persisted only with the OT treatment. Overall control was good for all treatments but did not persist to 145 DAP. Since grass control is known to be variable (Fisher et al., 2003; Mazarura, 1999) it was conceivable that grass control would not be persistent.

Overall injury was worst with AHO and AHO-M treatments at 32 and 48 DAP, followed by the BHO and AHO-R treatments. That the AHO and AHO-M treatment caused more injury was likely because these treatments placed chemical in the root zone. These findings corroborate the findings by (Fisher et al., 2003) that transplanting seedlings in any soil that had sulfentrazone would cause some injury in tobacco more than when the roots grew in such soil. This explains why injury was least with the OT treatment at 32 DAP and 48DAP. The stalk heights measurement further confirmed the data from scores and showed that the OT treatment would be less risky. However, it is likely that this treatment would injure plants somewhat if there are excessive rains that would leach the chemical into the root zone just after transplanting. However, contrary to the findings by the current work, in Cantaloupe, the POST-OTT treatment (similar to OT in the present study) was more injurious than the pre plant incorporated treatment (Johnson & Mullinix, 2005). This injury was reported for a higher rate (0.28 kg a.i. /ha) than used in the current work and further, perhaps their test crop was more sensitive. The current studies showed no reduction in yield in all years of study and this is corroborated by many reports that show that observed injury rarely cause yield reduction (Ritter, Menbere & Momen, 2005; Bailey, Wilson & Hines, 2002b; Grey, Bridges & Brecke, 2000; Wilson et al., 2002; Grey et al., 2009b; Fisher & Smith, 2001)

In the second year, generally, efficacy improved with application after planting and was best at 4WAP and was lower with incorporation while yield was the same for all treatments. The findings that efficacy improved with time from transplanting are consistent with findings from the first year of this trail and that sulfentrazone has a good post emergent activity (Ellis et al., 2001). Further, in the third year it was evident that, were treatments differences were detected, better control was associated with application after transplanting. In addition incorporation and application IAP reduced efficacy, perhaps because the contribution of post weed emergent activity is significant in the control of this weed.

Conclusions and Recommendations

In summary, the herbicide controlled better after transplanting and more so with delay in this application. This, however, is not good because of the risk of residues in tobacco leaf since by 4 weeks after planting some tobacco varieties would be ready for their first harvest. It is there, not advisable, for farmers to utilize the improved efficacy with delay in application. Further, applications that leave the herbicide in the root zone must be avoided. This work showed three definite things: first that transplanting into soil which has sulfentrazone may cause injury; second that nutsedge control was good in the granite sand with soil organic carbon of about 4% as was the case in this study; third that broadleaf control with sulfentrazone was satisfactory to very good; fourth that grass control was somewhat variable and; finally that persistence of control was good only with nutsedge. This work points at the need for more work in finding out why persistence is poor with grass and broadleaf control as well as the impact on residues on spraying tobacco late after planting.

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