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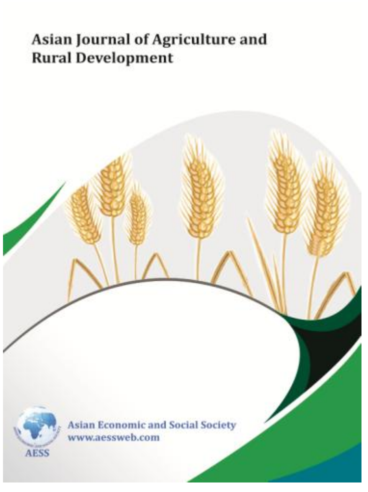

The Effect of Two Formulations of Sulfentrazone on Soil and Leaf Residues and Phytotoxicity in Tobacco (*Nicotiana Tabacum* L.)

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Abstract

Field studies were done to compare a wettable granular formulation (Authority 75 WG) and a suspension concentrate formulation (Authority 48 SC) of the herbicide sulfentrazone. A 6 x 2 factorial experiment was laid out in a split plot design to evaluate the effect of herbicide levels on phytotoxicity and residues in both leaves and the soil. One rate of the wettable granular formulation (0.225 kg/ha), four different rates of the suspension concentrate formulation (0.165 kg/ha, 0.205 kg/ha, 0.185 kg/ha, 0.225 kg/ha) and the control (0.00 kg/ha) were tested. Tobacco phytotoxicity at 27 days after transplanting (DAT) and soil residues at 12 WAT was measured. There was significantly higher ($P<0.05$) phytotoxicity in all treatments where herbicides were applied compared to the control. The WG formulation showed significantly higher phytotoxicity than the SC formulation. Residues in both the soil and leaves were significantly higher in the herbicide applied plots as compared to the control for both formulations. The SC formulation of sulfentrazone at a rate of 0.225 kg/ha was significantly less phytotoxic than the same rate of the WG formulation at 27 DAT. The SC formulation of sulfentrazone can replace the WG formulation for broad spectrum weed control in tobacco in Zimbabwe at a recommended rate of 0.225 kg/ha.

Keywords: Broadleaf Weeds, Grass Weeds, Sedges, Efficacy, Phytotoxicity, Residues

Introduction

One of the most effective strategies for early weed control in tobacco is to use chemicals. The benefits resulting from using herbicides include increased yields and improved crop quality.

Chemical weed control, if properly managed, is efficient and can enable the farmer to create a weed free crop environment for the whole season. According to Chivinge (1984), herbicides are very effective in controlling early season weeds particularly in wet weather and this has enabled farmers to increase the area under crops.

Selection of a herbicide for use depends on three factors namely; efficacy, phytotoxicity and residues. A desirable herbicide is one that has a high efficacy against weeds, causes little phytotoxicity to the crop, and leaves no or low residues in the soil and the crop. This is particularly important for tobacco where any damage to the leaf due to phytotoxicity would cause a reduction in leaf quality, consequently reducing saleable yield. A build up of agro-chemicals in the leaf could also be detrimental to the health of the smoker when residues remaining on the leaf are inhaled in cigarette smoke.

Sulfentrazone has been evaluated for control of weeds in tobacco and is registered for directed post planting application. Although an overtop application has shown better or comparable efficacy the directed application is meant to address concerns about phytotoxicity. Sulfentrazone phytotoxicity can be in the form of stunted growth, leaf discolouration and necrosis, leaf or stand loss and in some cases death of the plant (Mazarura, 1999)

Sulfentrazone is a member of the aryl triazolinone herbicides and its mode of action is similar to that of diphenyl ether herbicides in that it inhibits protoporphyrinogen oxidase (PPO), an enzyme involved in chlorophyll biosynthesis. Recent studies have reported differences in phytotoxicity levels of 28 soybean cultivars caused by soil applied sulfentrazone on seedling growth parameters such as the hypocotyl and root length (Dayan *et al*., 1997).

Studies by Grey *et al*. (1997) showed that crop tolerance of sulfentrazone was dependent on soil type and pH. Peanut (*Arachis hypogaea* L.) was found to be tolerant to sulfentrazone on sandy loamy soils but severe injury in loamy sand soils in a separate trial was recorded.

Studies to examine the effects of soil properties on sulfentrazone phytotoxicity and soil dissipation were conducted in Saskatchewan. The phytotoxicity of sulfentrazone to sugar beets (Beta *vulgaris* L.) determined using a shoot length bioassay, was reduced when soil pH was lowered and was greater when soil pH was increased, demonstrating a relationship between soil pH and phytotoxicity.

The present study sought to compare the phytotoxicity and the soil and leaf residue levels associated with the use of two different formulations of sulfentrazone.

Materials and Methods

Site Description

This experiment was done on a sandy loam soil (72.8% sand, 8.8% silt and 18.4% clay) at Kutsaga Research Station (17^0 55` S, $31^0$ 08`; Altitude 1480m, Average annual rainfall 882mm, Zimbabwe) from 2007 to 2008. The area has light, well drained sandy soils of granite origin and resembles those found in most tobacco growing areas in Zimbabwe. These soils are very low in clay content and have low water-holding capacity.

Land Preparation and Fertilization

The land was ploughed, disked and treated with a nematicide as is standard practice. The nematicide ethyl di-bromide (EDB) was applied at 3l/ha. Tobacco was grown as a dry land crop on ridges 0.2m high, 1.2 m apart and the plants were 0.56 m apart in the row. The tobacco variety used was T66; a slow ripening cultivar with a yield potential of more than 3500kg/ha of cured leaf. The fertilizer management was as described by Mashayamombe *et al*. (2013).

Treatment Description, Design and Herbicide Applied

The experiment was a split plot of two main factors and six subplots. The treatments consisted of six levels of sulfentrazone and two levels of weeding to give a 6 x 2 factorial experiment. Two plots, one weeded and the other left weedy, were the main plots. The sulfetrazone treatments were:

1. 0.000kg/ha sulfentrazone
2. 0.225 kg/ha WG formulation
3. 0,165 kg/ha SC formulation
4. 0.205 kg/ha SC formulation
5. 0.185 kg/ha SC formulation
6. 0.225 kg/ha SC formulation

The treatments were arranged in a split plot design replicated four times with the weeding as the main plot and the herbicide the sub-plot. Herbicide application was done by calibrated knapsack a day after transplanting of the T66 variety. Weeding was done every fortnight for the weeded plots, starting two week after transplanting. All phytotoxicity was measured from the weed free plots.

Phytotoxicity assessments 27 days after spray application to assess the level of phytotoxicity caused by each herbicide level. Rating was done using a rating scale suggested by Camper (1986).

At 4 and 8 weeks after transplanting (WAT) a sample of ten plants per plot (3 rows) was selected randomly and the stalk height was measured. At 12 WAT tobacco leaves were removed from the plants in each plot and placed in labelled bags. These were oven dried at 85°C for 72 hours and weighed.

Soil samples were taken at 12 weeks after transplanting at a depth of 40 cm in each plot. A soil and leaf residue analysis was done using the High Performance Liquid Chromatography (HPLC) method as described by Ohmes and Mueller (1999)

All data were subjected to ANOVA using Genstat Version 9.2. Mean separation was conducted using Fischer's Protected Least Significant Difference (LSD) test at P<0.05.

Results

Phytotoxicity Scores (Dry Weights and Stalk Heights)

There were no significant differences among treatments for phytotoxicity of tobacco at three DAT (data not shown). There were significant differences (P<0.05) among herbicide treatments in phytotoxicity at 27 DAT (Table 1). The highest rate (0.225 kg/ha) of the wettable granular (WG) formulation gave phytotoxicity that was significantly higher (P<0.05) than the control. This phytotoxicity score was also significantly higher (P<0.05) than that for the suspension concentrate (SC) formulation at the same rate. Reduced rates of the SC formulation also gave phytotoxicity scores that were not significantly different from each other but different from the control (see 0.205 kg/ha SC formulation) (Table 1).

Table 1: Mean Phytotoxicity Scores, Dry Mass, Stalk Height, Soil and Leaf Residues

Herbicide level	Phyto. 27DAT	Dry-mass (g) 12WAT	Stalk Height (cm) 4WAP	Stalk Height (cm) 8WAP	Soil residues (ppm)	Leaf residues (ppm)
kg/ha of sulfentrazone						
0.00(Control)	1.02	54.0	29.7	75.70	0.83	0.59
0.225(WG formulation)	2.29	115.2	34.1	100.20	2.72	0.89
0.165(SC formulation)	1.39	140.5	47.8	100.60	3.04	0.91
0.205(SC formulation)	1.52	145.5	46.2	95.70	2.97	0.83
0.185(SC formulation)	1.40	167.8	46.7	100.50	3.14	1.02
0.225(SC formulation)	1.75	135.0	46.0	102.10	2.76	0.85
$LSD_{0.05}$	0.40	36.85	7.3	7.7	0.89	0.25

* denotes significant differences at P<0.05, WG-Wettable Granular, SC-Suspension Concentrate, WAP- weeks after planting, Phyto.- phytototxicity

There were significant differences (P<0.05) among herbicide treatments in tobacco leaf dry-mass at 12 WAT. The highest rate of the SC formulation (0.225 kg/ha) gave tobacco leaf dry-mass that was significantly higher (P<0.05) than the control. However this was not significantly different from that for the WG formulation at the same rate. The reduced rate of the SC formulation at 0.165 kg/ha, 0.185 kg/ha and 0.205 kg/ha gave tobacco leaf dry-mass that was significantly higher (P<0.05) than the control but not significantly different from each other or from the highest rates (Table 1).

There were significant differences (P<0.05) among herbicide treatments with regards to tobacco stalk height at 4 WAT. The highest rate (0.225 kg/ha) of the SC formulation gave tobacco stalk height that was significantly higher than the control. This was also significantly higher (P<0.05) than that for the WG formulation at the same rate. Reduced rates of the SC formulation also gave a tobacco stalk height that was significantly higher (P<0.05) than the control but these were not significantly different from each other. The highest rate (0.225) of the WG formulation gave a tobacco stalk height that was not significantly different (P>0.05) from the control (Table 1).

There were significant differences (P<0.05) among herbicide levels in tobacco stalk height at 8 WAT. The highest rate (0.225 kg/ha) of the SC formulation gave tobacco stalk height that was significantly higher (P<0.05) than the control. However, this was not significantly different (P>0.05) from that for the WG formulation at the same rate. All herbicide rates gave tobacco stalk heights that were significantly different (P<0.05) from the control but none of them significantly differed from each other.

Leaf and Soil Residues

There were significant differences ($P<0.05$) among herbicide treatments in soil residues at 12 WAT (Table 1). The highest rate (0.225 kg/ha) of the SC formulation gave soil residues that were significantly higher ($P<0.05$) than the control. However, these were not significantly different ($P>0.05$) from that for the WG formulation at the same rate. All the reduced herbicide rates were significantly different ($P<0.05$) from the control for soil residues but none of them significantly differed from the other.

There were significant differences ($P<0.05$) among herbicide treatments for leaf residues at 12 WAT (Table 1). The highest rate (0.225 kg/ha) of the SC formulation gave leaf residues that were significantly higher ($P<0.05$) than the control. However, these were not significantly different ($P>0.05$) from that for the WG formulation at the same rate. All the herbicide rates except the SC formulation at 0.205 kg/ha were significantly different ($P<0.05$) from the control for leaf residues but none of them significantly differed from the other.

Discussion

Phytotoxicity Scores, Dry Weights and Stalk Heights

At 3 DAT there were no significant differences in tobacco phytotoxicity among herbicide treatments. Perhaps these readings were done before the transplants had developed any new roots and were too early to show such a response as Krausz, *et al*. (1998) revealed that sulfentrazone was primarily taken up by the roots of the plants.

At 27 DAT, the wettable granular (WG) formulation showed significantly more ($P<0.05$) phytotoxicity than the suspension concentrate (SC) formulation. This difference in phytotoxicity could have been as a result of the change in formulation that resulted in differential uptake or the inclusion of solvents that made the material unsafe or both. Knox (1986) discovered that a change in formulation of the herbicide oxadiazon from a granular to a wettable powder reduced phytotoxicity while maintaining efficacy. Different phytotoxicity levels of the two herbicide formulations could also have been as a result of different rates of uptake and metabolism by the tobacco plants. Morner (2008) stated that herbicide metabolism rates influenced the phytotoxic action of herbicides rendering them less or more phytotoxic.

Thomas, *et al*., (2005) discovered that different plants had different uptake, translocation and metabolism rates of root-absorbed sulfentrazone. This translated to the different tolerance or susceptibility levels of the plants to the herbicide. In a similar investigation Moseley, *et al*., (1993) observed that differences in uptake and initial metabolism could explain the level of tolerance or susceptibility of soybean to the herbicides chlorimuron. The SC formulation could have a higher initial uptake and metabolism rate than the WG formulation, explaining why plants developed less severe phytotoxic symptoms. The differences in herbicide uptake and metabolism rates can be influenced by herbicide chemical make-up, the nature of active ingredient and the inert ingredient composition of the formulation (Hulting, *et al*., 1997).

We must point out that although herbicides showed differences in phytotoxicity amongst each other, they actually had a stimulatory effect on stalk height relative to the control. This could be a result of improved weed control, since despite that such measurements were done on the weeded plots the weeding frequency allowed for some build up of weeds between successive weeding events.

Leaf and Soil Residues

Results from this study show that both formulations of sulfentrazone left residues in the soil that were significantly higher than those detected in the control. This verifies the suggestion by Mazarura (1999) that sulfentrazone was the most persistent of the nutsedge herbicides that were on the market at that time. Similarly in the current study both formulations left high residues although this was after only 12 WAT. Hatzios (1998) attributed high residues to the fact that sulfentrazone is relatively non-volatile (1×10^{-9} mm Hg at 25^{o} C). Reddy and Locke (1998) also discovered that sulfentrazone was not susceptible to photo-decomposition having a half life of 110 - 280 days. The fact that sulfentrazone is highly mobile and can move to depths where microbial activity is low can also contributes to its high persistence. Ohmes, *et al*.

(2000) reported that sulfentrazone in the soil at a depth of 20- 30 cm was highly susceptible to microbial degradation and that at greater depth degradation was slow. This, perhaps, partly explains the higher residues that were picked in this trial from samples taken 40 cm deep.

In this study, residues were not influenced by rate of application of the herbicides. This implies that perhaps even the lowest rate of sulfentrazone was not safe from an environmental point of view. In fact some residues were picked up even in the control, showing, perhaps that sulfentrazone has high soil mobility or that some chemical drift could have occurred at spraying or both. Miller (1997) reported that sulfentrazone is high in solubility (7.8×10^2 ppm) and mobility and therefore has a strong potential to migrate off-site. Considering the high mobility of sulfentrazone the heavy rains (876.3 mm) that were received during the trial period could have moved the sulfentrazone from the higher rate plots to the plots that received reduced rates.

The leaf residues levels were within the acceptable range of the standard for sulfentrazone residues set by CORESTA which is 1 ppm (Brinson, 2008). Leaf residues ranged from 0.60 to 1.04 ppm. These leaf residue levels for sulfentrazone are said to be safe for flue-cured tobacco as they will be further reduced during curing of the leaf (Porterfield, *et al*., 2005).

Summary, Conclusions and Recommendations

This study established that the SC formulation of sulfentrazone was less phytotoxic than the WG formulation. Leaf and soil residues were not affected by rate of application or formulation. Reduced doses did not reduce soil and leaf residues while leaf residues were acceptable according to international standards. These results mean that the use of sulfentrazone must be monitored in terms of soil residues and perhaps soil samples should be taken over a long period of time in order to establish the impact that the herbicide could have on the environment. Perhaps, water samples from the water table may need to be taken to find out how much of the chemical and its breakdown products end up in drinking water. Further research could explore the use of lower rates especially with consideration of mixing sulfentrazone with other herbicides.

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