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Efficacy of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) as pre-emergence herbicides in controlling weeds in maize at Chisumbanje Estate

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Abstract

Field trials were conducted during the 2019-2020 cropping season to assess the efficacy of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) pre-emergence herbicides in controlling weeds in maize at Chisumbanje estate. The experiment was laid out as a randomised complete block design (RCBD) with three treatments and replicated thrice. Treatments used include hand weeding (control), S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) herbicide. The data collected was based on weed density, plant height, maize grain yield indicating significant differences ($p<0.05$) amongst the treatments. Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) scored the least weed density per m^{-2} as compared to S-metolachlor showing that it is an effective pre-emergence herbicide (33, 27 and 22) on Mexican marigold (*Tagetes minuta*), shamva (*Rottboellia cochinchinensis*) grass and wild jute (*Corchorous tridens)* respectively. The control (hand weeding) scored the highest weed density per m^{-2}, indicating that the method was not effective as compared to S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) treatments. Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) scored the highest yield of 10 tonnes/hectare whilst S-metolachlor and control scored 7.6 and 5.6t/ha respectively. Herbicides reduced the weed spectrum in maize resulting in realisation of higher yield in flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) experiment followed by S-metolachlor. Farmers are recommended to use flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) as a pre-emergence herbicide in controlling weeds in maize so as to realise higher yields and low weed density.

Keywords: Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide), S-metolachlor, pre-emergence, herbicide

Introduction

Maize is ranked first in Zimbabwe and is the staple food not only for Zimbabwe but for many countries in Southern Africa (Tapiwa *et al*., 2020). Maize production has been declining in recent years due to drought and weed competition in some areas. Weeds continuously interfere with the normal growth of crops (Patel, 2013; Sakadzo *et al*., 2018). The knowledge in weed management is essential if enough food is to be produced at minimum costs to both the farmers and the consumer (Laizer *et al*., 2019).

Hand weeding is the predominant weed control practice in Sub Saharan Africa and about 50%-70%

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of the labour in crop production is spent on weeding (Chivinge, 1991; Mashingaidze, 2004). Maize requires 276 hours per hectare of hand weeding to get optimal yields. To weed one hectare a man or woman walks 10 kilometres in a stooped position. Maize is a widely spaced crop which gets infestated, resulting in reduced yield which varies from 18%-85%, depending on the type of weed flora, density and function of crop weed competition (Sunitha *et al*., 2012).

Integrated weed control was introduced around 1980s, despite all of these developments, the weeds are still one of the farmer's biggest problems (Saiz-Rubio *et al*., 2020). Mortensen *et al*. (2012) and Storkey *et al*. (2021) herbicides must be used judiciously in an integrated weed management framework because of the high cost and environmental concerns, Timeliness of weeding are often a problem among farmers hence the need to consider herbicide technology (Steckel *et al*., 2019). S-metolachlor (chloro-acetanilide) pre-emergence interferes with ezymes thereby inhibiting cell division and elongation (Lowry et al., 2013). Flumetsulam (triazolopyrimidine sulfonanilide inhibit acetolactate synthase which catalyses biosynthesis of amino acids. It has been used in controlling weeds in tobacco and has proven to be effective (Mazarura, 2013). Therefore the objectives were to assess the efficacy of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) pre-emergence herbicides in maize production.

Materials and Methods

Study site

The trial was done at Chisumbanje small scale farmers' Section in Chipinge rural during the 2019/2020 cropping season. Experimental site is located within the following geographical coordinates with latitude 20º 48º 0" South and 32º 14º 0" East. It is along the Tanganda-Chiredzi highway, on the eastern bank of the save river, about 95 km south of Birchenough Bridge. It is a semi-arid area which lies in the Save valley receiving rainfall < 450 mm and is in natural region V (Mugandani *et al*., 2012). The precipitation is correspondingly lowand irrigation is essential throughout the year to supplement rain water (Nyagumbo *et al.*, 2019; Tapiwa *et al*., 2020). The area is characterised with heavy clay soils in the classification of vertices which have good agronomic potential. Temperature ranges from 18-30 ºC with temperature above 40^0 C in the hottest months of October and November (Mugandani *et al*., 2012). The vegetation is dominated by Marula tree (*Sclerocarya birrea* (Caffra) and Mopane (*Colophospermum mopane*) with other tree species such as Baobab (*Adansonia digitata*), Acacia (*Acacia karroo)* and Mnondo (*Julbernadia globiflora*). Evaporation rates are high and can exceed 13mm/day.

Experimental design and treatments

The experiment was laid out as a randomised complete block design (RCBD) and replicated thrice. Weed control methods used includes hand hoeing (control) and use of herbicides. Two herbicides were used which include S-metolachlor (Dual magnum) and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) (Bateleur gold) with application rates of 1 litre and 1.2 litres per hectare respectively (Table 1) as recommended by Syngenta Crop Protection (2020). This usually depends on clay content of the soil. The maize variety used was SC649 a hybrid maize medium variety. It was offered freely by the Seedco agronomist for use in demonstration plots so as to enhance their marketing. Field history indicated that the land has been under sugarcane for 5 years and was fallowed for a year. Predominant weed species included yellow nutsedge (*Cyperus esculentus*), Purple nutsedge (*Cyperus rotundus*) due to persistent flooding by irrigation water. Shamva grass, Wild jute, shamva and Mexican marigold were also prevalent. Common weed management practised was chemical greatly dominated by use of sulfonyurea herbicides. The plots were ploughed using an ox drawn plough during early November 2019. Maize was planted on plots measuring 7 m by 4.5 m where the treatments were randomly allocated. Row spacing of 0.9 m between rows and 0.3 m within row was used to achieve a plant population of 37037 plants/ha. This spacing was selected because it lies within the recommended row spacing for maize considered for household consumption.

Table 1. Herbicide Rates (l/ha)

Treatments	Herbicide rates (l/ha)
Control (hand hoeing)	Nil
S-metolachlor	1.0
Flumetsulam (triazolopyrimidine sulfonanilide) +S-metolachlor (chloro-acetanilide)	1.2

Plot management

This was done following procedures by Sakadzo *et al*. (2018). An application rate of 1.2 litres per hectare of flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) was sprayed to 100% or full cover and 1.0 litre per hectare of S-metolachlor was sprayed also to fully cover. Herbicides were applied using a hand operated knapsack sprayer with a flood jet nozzle. The Beaufort scale guide was used to assess the wind speed (Table 2). It is best to spray when there is a steady light breeze blowing (Force 2). Hand hoeing was done three weeks after planting and all weeds were removed from the field. This was also repeated when maize attained six weeks after planting. Ammonium nitrate (AN) was applied as a top dressing fertiliser three weeks after emergence at a

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rate of 350 kg AN/ha as the soils were depleted in nutrients due to sugarcane monocrop.

Table 2. Beaufort Scale

Beaufort scale	Description	Visible signs	Approx. air speed
Force 1	light air	the direction shown by smoke drift	up to 1.6 km/hr
Force 2	light breeze	leaves rustle wind felt on face	3.2 to 6.4 km/hr
Force 3	gentle breeze	leaves and small twigs in constant motion	6.4 to 9.7 km/hr
Force 4	moderate breeze	Small branches moved. Raises dust and loose paper	

Source: Nyanhete, 2004

Table 3. Modified European Weed Research Council Ratings

Category number	% kill of weed	Herbicide effectiveness on weeds
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 adequate
6	75.0 – 80.0	Poor
7	65.0 – 70.0	Very poor
8	35.0 – 65.0	Useless
9	0 – 33.0	Almost no effect

Source: (WSSA, 2002)

Data collection

The weed density was determined by physically counting weeds in the quadrant ($1m^2$) and scoring on the European Weed Research Council scale (EWRC) (Table 3). Herbicide effectiveness was determined by scoring the level of phytotoxicity and recording percentage of killed weed species following the procedure by Sakadzo *et al.* (2018). Two weeks after application of the pre-emergence herbicides, weeds which were emerging were physically counted and recorded through the aid of a quadrat with an area of $1m^2$. Plant height of maize was determined from week one up to week 12 by using a metre rule from five maize plants randomly selected from each plot. Mean plant height was determined for each plot. Randomly selected plants were marked so that they were measured throughout the experiment. Maize was harvested using a Dickey, John moisture metre. Maize was harvested from a net plot measuring 4.5 m by 3.0 m. Yield was determined at harvesting by using a scale adjusted to 12.5% moisture and converted to tonnes per hectare (Sakadzo *et al.*, 2018).

Data analysis

Data analysis was done using the Genstat 14th version edition. Mean separation was done using Fischer's least significant difference (LSD) at the 5 % significance level.

Results

Effects of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) herbicides on weed emergence density in maize crop

Herbicide effectiveness was determined by the EWRC scale of scoring phytotoxicity (Table 4). Results indicated that there were significant differences ($p<0.05$) across all the treatments on weed density. Control (hand hoeing) treatment scored the highest weed density of Mexican marigold (86.67 plants per m^{-2}), shamva (113.00 plants per m^{-2}) and wild jute (66.00 plants per m^{-2}) whilst flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) treatment had the least weed density of Mexican marigold (33.67 plants per m^{-2}), shamva (27.33 plants per m^{-2}) and wild jute (22.67 plants per m^{-2}) respectively as shown in Table 4 below.

Effects of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) herbicides on plant height of maize

Results show that there were significant differences ($p<0.001$) across all the treatments in terms of plant height (Figure 1). Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) treatment recorded the highest plant height as from week one up to week twelve, whilst control (hand hoeing) treatment had the least plant height (Fig 1).

Effects of S-metolachlor and flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) herbicides on final yield of maize

High maize yield was obtained from plots applied flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) with a high of 10 t/ha followed by plots applied S-metolachlor produced 7 t/ha and lastly the control treatments which had 5.7 t/ha (Figure 2). Results show that there was a significant ($p< 0.05$) difference on the effects of different weed control methods. Results also show that the use of flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) was better than the use of S-metolachlor and hand hoeing.

Table 4. Weed Density (plants/m²) in Maize after Spraying Herbicides

	Weed density (plants/m²)		
Treatments	**Mexican marigold**	**Shamva**	**Wild jute**
Flumetsulam(triazolopyrimidine sulfonanilide) +S-metolachlor (chloro-acetanilide)	33.67a	27.33a	22.67a
S-metolachlor	47.33b	95.67b	34.00a
Control (Hoeing)	86.67c	113.00c	66.00b
Grand mean	55.9	78.7	40.9
p-value	<.001	<.001	0.007
LSD	10.58	7.91	19.18
CV%	8.3	4.4	20.7

*Means followed by the same letters are not significantly different at 5% significance level.

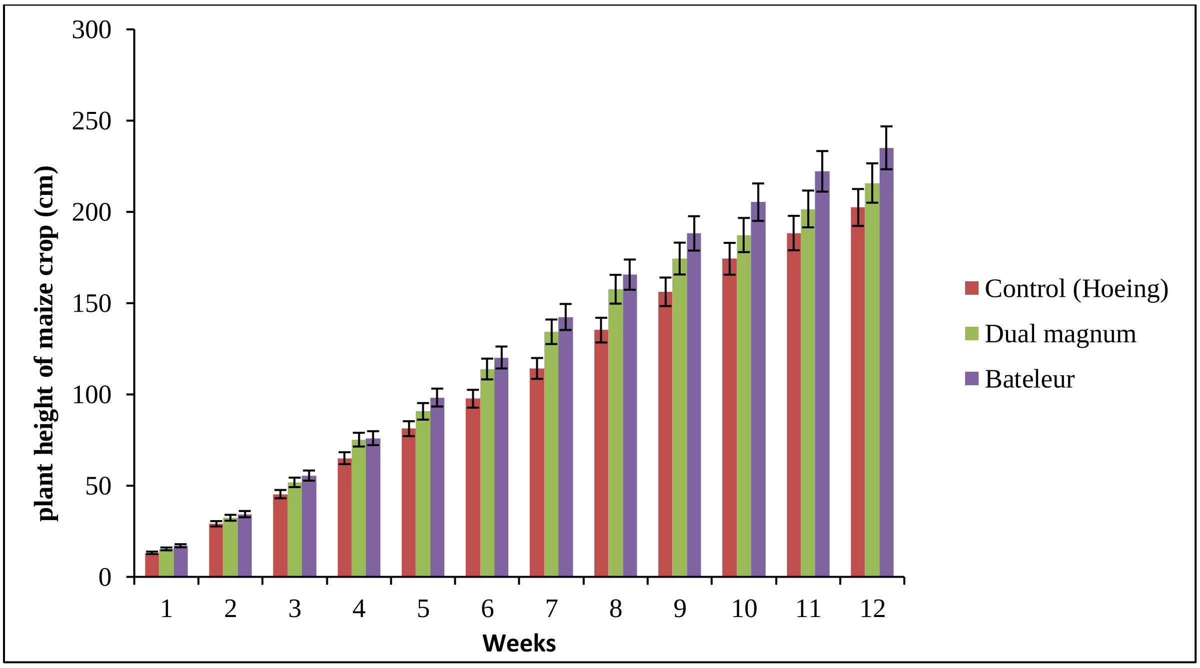

Figure 1. Plant height of maize from week one up to week 12.

Discussion

Effects of herbicides on weed density

Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) and S-metolachlor had the least weed density as compared to the control. This proved that herbicides are effective in reducing the weed spectrum in maize fields. This is in agreement with results by Mazarura (2013) who reported that flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) was effective in controlling weeds on flue cured tobacco. On the second assessment done 14 days after the application of the pre-emergence herbicide, the flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) treatment scored a 98% on the EWRC scale in terms of weed density and S-metolachlor treatment scored 90%. Results also concurs with findings by Shinggu *et al*. (2009) who reported that more weed types and grasses were observed in the control treatments (hand weeding) than in the herbicide treated plots. Results from this study were also in agreement with findings by Rana *et al*. (2016) who reported minimum weed densities on herbicide treatments than in hand weeding treatment. Results might vary in relation to predominant weed species in the field as indicated in the experiment under study where shamva was prevalent.

Effects of S-metolachlor and Flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) herbicides on plant height of maize

Results showed that use of S-metolachlor and Flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) herbicides increased plant height of maize. This variation might have been as a result of elimination of resource competitors (weeds). Plant height reflects the efficiency of the plant for photosynthetic radiation interception and vegetative growth character of crop plants in response of various applied inputs like fertilizer and herbicides. There were significant differences in plant height amongst the weed control treatments. The difference in height could be the varying effects of weed competition, duration of available resources offered by different weed densities in different weed control practices. These results are in line with those of Simic *et al*. (2020) who observed that plant height was significantly higher in the herbicide treatment plots.

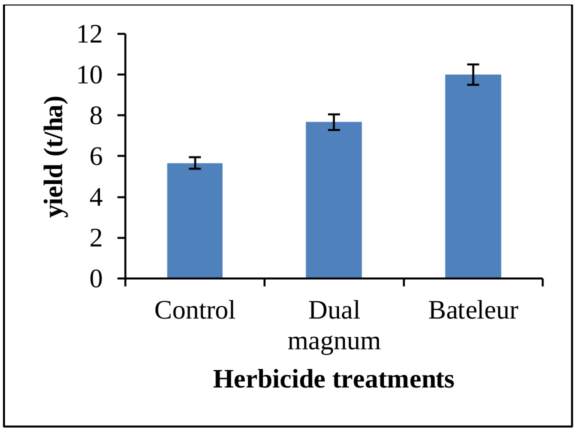

Figure 2. Effects of herbicides on yield of maize.

Effects of S-metolachlor and Flumetsulam (triazolopyrimidine sulfonanilide)+S-metolachlor (chloro-acetanilide) herbicides on maize yield (tonnes/hectare)

Results indicated that the use of herbicides significantly increased yield in maize. This might be an attribute of mode of action of herbicides on prevailing weeds. These findings are in line with those of Naveen *et al*. (2019). Competition for resources were reduced herbicide weed applied plots as compared to hand weeding. Results are also in agreement to those of Sakadzo *et al*. (2018) who concluded that grain yield of maize crop was increased with the use of herbicides. Herbicide application quickly suppresses the weed germination and ultimately provides a competitive free environment for the crop plant to get all the available resources alone. Hassan *et al*. (2010) also reported that herbicides are the most efficient and effective in controlling weeds in *Zea mays* and also increase grain yield, crop growth and canopy development.

Conclusion

Flumetsulam (triazolopyrimidine sulfonanilide)+ S-metolachlor (chloro-acetanilide) and S-metolachlor proved to be effective in reducing weed density of prevalent weeds (Mexican marigold, shamva and wild jute) as compared to manual weeding. Herbicides reduced the weed spectrum in maize resulting in realisation of higher yield in flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) experiment followed by S-metolachlor.

Recommendations

The researcher recommends farmers to use flumetsulam (triazolopyrimidine sulfonanilide) + S-metolachlor (chloro-acetanilide) and S-metolachlor in order to reduce weed density in maize, realise higher yield and less costs on weed control in maize fields. There is need to repeat the same research across a multiple environment to determine the effects of environment on mode of action of herbicides.

Areas for future research

Since the use of herbicides was not popular in most rural areas in Zimbabwe, there is need to evaluate the effectiveness of herbicides in controlling weeds and their effects on grain yield. There is need to evaluate this in various regions with different soil types because some herbicides persist in soils. There is also need to look on the effects of integrated nutrient management, rainwater harvesting and herbicides on maize productivity to see how herbicides affect nutrient uptake by crops and yields.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the aurhors to the present study is equal. All the authors verify that the text, figures, and tables are original. The authors read and approved the final manuscript.

Ethical approval

Not applicable

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Data availability

Not applicable

Consent for publication

Not applicable

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