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Original Research

Phytotoxicity effects of Topramezone and Dicamba herbicide on selected legumes

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ABSTRACT

Weeds in agriculture are responsible for yield reduction and poor crop quality if not controlled. In maize production, new user-friendly herbicides are being adopted by smallholder farmers. Stellar star whose active ingredients are Topramezone and Dicamba is a selective, systemic post-emergence herbicide used in maize. This poses a threat to crop rotation, especially legumes, due to residual effects. Therefore, the study was carried out to evaluate the phytotoxicity effect of Topramezone and Dicamba herbicide on selected legumes. The trials were conducted in the field and greenhouse. Topramezone and Dicamba herbicide was applied at 4 rates (0, 1.0, 2.0 and 4.0 L ha^{-1}) while legumes were planted at 0, 30, 60, 90 and 120 days residual period. The experimental designs used were CRD for the greenhouse trial and split-split plot design for the field experiment, replicated three and two times respectively. Phytotoxicity effects on legumes were highest at 0, 30 and 60 days residual periods. The coefficient of determination (R^2) indicated 96-100% variation in the relationship between days and plant stand count. 4 L ha^{-1} had the worst average phytotoxicity score of 98%, with control having the lowest at 0%. Results showed whitish, greyish, pale germinated plants which mostly dried after 3 to 5 days. There were highly significant differences ($p \leq 0.01$) amongst the treatment means for all parameters. This means that within 120 days residual period, legumes under study should not be rotated with maize as the herbicide has phytotoxicity effects both at varying application rates and residual period.

Introduction

Numerous plant species are considered weeds in agronomic cropping systems. The major undesirable feature of weeds is the reduction of crop yields and quality through competition for

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resources such as sunlight, water, nutrients and space (Gallandt and Weiner, 2015). Integrated weed management includes all practices that enhance a crop's competitive ability and decrease weeds' ability to reduce yield (Ayodele and Olubunmi, 2017). These weed control methods can be preventive, cultural, mechanical, biological and chemical.

Herbicide weed control, when compared to hand weeding, is effective, efficient and less costly. Herbicides control unwanted plants and can be selective, non-selective, pre-or post-emergence (Rana 2018). One of the most important features to be considered in the use of chemicals include persistence or residual action. Residual herbicide activity often describes the unintended stay of the chemical in the environment even when the effect is no longer wanted, thereby causing phytotoxicity to the rotational crops (Mehdizadeh et al., 2016). The length of time the herbicide remains in the soil, varies greatly with climatic conditions, soil type, and cultural practices. These factors make it difficult to predict herbicide persistence. Agro-chemical companies sometimes make combinations of herbicides, especially the selective ones so that they more effectively deal with a wide range of weed problems faced by farmers (Damalas et al., 2015). Stellar Star, active ingredients Topramezone (pyrazolone) and Dicamba (benzoic acid compound) is one such herbicide which is recommended for weed control under smallholder farming conditions. In Zambia, herbicide use by smallholder farmers is increasing partly driven by the adoption of conservation agriculture (CA) (Nkhoma et al., 2017). Topramezone and Dicamba studies done have shown that the residual herbicides used for controlling weeds in maize crops can sometimes persist in the soil (Rahman et al., 2014). Despite this, there is little information on the residual effects of Topramezone and Dicamba and how this could affect the principles of conservation and sustainable agriculture. Herbicide persistence adversely affects the follow up crops, hence impacting negatively on crop rotation (Mehdizadeh, 2019). Furthermore, smallholder farmers have a tendency of applying sub-optimal or super-optimal rates (Bari, 2012). This implies that the residual effect of Topramezone and Dicamba may be worse than anticipated. Therefore, a study was conducted to evaluate the phytotoxicity effect of Topramezone and Dicamba herbicide application rate on legumes. The findings of the study will help agronomists to make decisions on the benefits or drawbacks (phytotoxicity) of using Topramezone and Dicamba at different application rates.

Materials and Methods

Description of Study site

The field study and greenhouse trials were conducted at Mt. Makulu Central Research Station in Chilanga. Mt. Makulu is in agro-ecological region II a of Zambia and lies on latitude 15.550˚S, longitude 28.250˚E and elevation 1213 m above sea level. Annual rainfall in Region II a averages 800-1000 mm, moderately leached sandy loam and the growing season was 100-140 days long. The temperature during the season ranged from 14 ^{o}C to 35 ^{o}C.

Experimental Design and Treatments

Description of the treatments

For the field experiment, a Split - Split Plot Design (SSP) was used with herbicide rate laid in the main plot and residual period in the sub-sub plot and legume as the sub-plot. The treatments were replicated twice. In the green house, the experimental design used was a Complete Randomized Design (CRD), replicated three times. The treatments used in the study were Herbicide rate, applied at 0, 1, 2, 4 L ha^{-1}. The legumes, namely beans, soybeans and groundnuts were planted at 0, 30, 60, 90 and 120 days after applying the herbicide, herein called residual period. The physical and chemical characteristics of the soils used in the study are shown in Table 1.

Table 1. Physical and chemical properties of the soil sample***.**

Sample	pH	OM %	P mg/kg	N %	K cmol/kg	Sand %	Clay %	Silt %	USDA Class
G/ house	7.52	2.4	0.62	0.81	0.96	55.6	26	18.4	Loam
Field	7.64	1.6	11.68	0.67	0.9	51.6	28	20.4	Loam

* Soil analysis of samples taken from UNZA soil Science Laboratory. Source: UNZA, 2019.

Trial Management

The land preparation comprised tillage to control weeds and improve soil structure in readiness for planting. This was to ensure uniform seed bed preparation and uniform weed growth stages at the time the herbicide was to be applied. The field was then mapped and pegged according to different blocks and plots. Rows were then made per plot and followed by basal dressing using compound D at planting. Soil was mixed in plastic pots for the green house experiment.

Data collection and analysis

Green house experiment

Data on plant stand, phytotoxicity score and percent of dead plants was collected. According to Jiddimani et al., 2017, Phytotoxicity was scored on a scale of 1 to 9, as shown in table 2 below.

Table 2. Phytotoxicity score.

Rating	phytotoxicity %	Description
1	0-10	No to very slight discoloration
2	11-20	More severe but not lasting
3	21-30	Moderate and more lasting
4	31-40	Medium and lasting
5	41-50	Moderately heavy
6	51-60	Heavy
7	61-70	Very heavy
8	71-80	Nearly destroyed
9	81-100	Destroyed.

Field experiment

In the field trials, data on Stand Count (SC), hundred seed weight (HSWT), dry biomass and grain yield was collected. The number of plants in a plot were taken at 7, 14 and 28 days after planting and expressed as a percentage of the total number of seeds planted in a plot. Dry biomass was collected by carefully uprooting selected plants, drying them in an oven at 50 ^{o}C and noting the weight after drying. Grain yield was calculated by weighing the total plot weight of grains in kilograms. In each plot, a sample of 100 seeds were selected and weighed to obtain the HSWT. The data collected was analyzed using R statistical computing software, version 3.6.3.

Results and Discussion

Field experiment results in Table 3 showed some significant differences among the treatment means on HSWT, yield and some on stand count, implying that the herbicide could have some residual effects. Figure 1 shows a trend of polynomial among the three crops (soybeans, groundnuts and beans) in terms of low stand count at 7 days, high at 14 days and low at 28 days. This was seen in the coefficient of determination (R^2) which indicated 96 -100% variation in the relationship between days and plant stand count. Therefore, we could most likely predict what would happen to plant stand count after 28 days for each crop.

This may suggest that Topramezone and Dicamba herbicide had some residual effects on delayed germination on soybeans, groundnuts and beans at 7 days, prevented germination of seeds at 14 days and caused death of some germinated plants at 28 days. This agrees with studies done by Barber (2016), who highlighted that dicamba herbicide affects the germination of soybeans. When seeds were planted in the greenhouse and the field, germination and vigor were greatly reduced based on the data collected (Barber, 2016).

Table 3. Summary of Analysis of Variance (ANOVA) for different parameters.

Source	DF	SC (7days)	SC (14days)	SC (28day)	Dry biomass	HSWT	Yield
Rep	1						
Herbicide Rate (R)	3	109.8^{ns}	194.3^{ns}	472.4^{ns}	27964^{ns}	655.85*	2877815**
Error a	3						
Residual period (P)	4	5093.1**	5662.6**	3261.6**	6836^{ns}	560.11**	1614817**
R x P	12	182.1^{ns}	282.2*	205.3^{ns}	3039^{ns}	160.56**	621509**
Error b	16						
Crop (C)	2	24013**	25185.2**	19188**	3981^{ns}	2238.69**	7654385**
C x R	6	91.2^{ns}	51.4^{ns}	89.7^{ns}	11858**	182.27**	481464**
C x P	8	1760.5**	1767.9**	1812.6**	2921^{ns}	335.31**	323889**
C x R x P	24	62.9^{ns}	115.9^{ns}	111.2^{ns}	1559^{ns}	31.35^{ns}	281664**
Error c	40						

**highly significant at p≤ 0.01, * significant at p ≤ 0.05, ^{ns} not significant at p > 0.05.

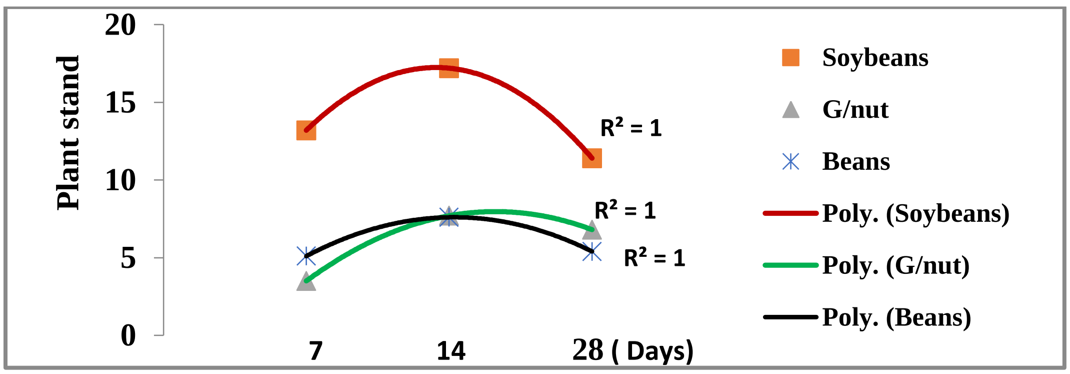

Figure 1. Plant stand count at zero-day residual period.

Topramezone is a 4-Hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor and prevents the biosynthesis of carotenoid that protects chlorophyll molecules from dangerous UV rays and excess light (Grossmann and Ehrhardt, 2007). There is nothing to prevent sunlight from penetrating into the leaves, which results in the photo-oxidation of chlorophyll molecules (Wang et al. 2018). Consequently, the legumes turned white and some died. Dicamba takes effect through stimulating the outgrowth of plant, which causes the exhaustion of nutrients supplies and plant death (Nishimura et al. 2015). This is based on the nature of Dicamba, which is a synthetic mimic of natural auxin (a plant hormone used for stimulating plant growth). Upon response to this kind of herbicide, the plant develops abnormalities such as leaf epinasty, leaf abscission and growth inhibition of the root and shoots (Harp, 2010).

Phytotoxicity effect of the herbicide eventually affected yield as shown in figure 2 during the interaction between herbicide rate and residual period.

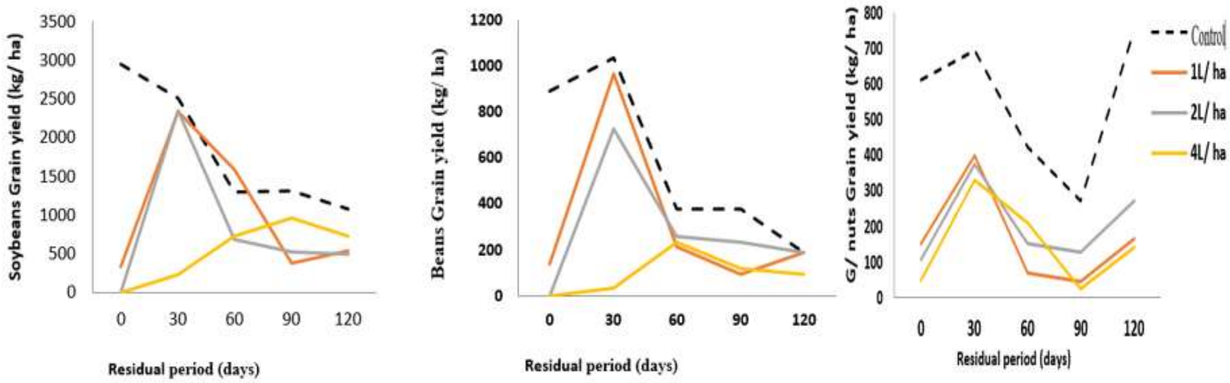

Figure 2. Effect of Herbicide rate and residual period on grain yield of legumes.

In Figure 2, it seemed that amongst the three selected succeeding crops used, groundnut (*Arachis hypogaea* L.) was the most sensitive crop. The highest grain yield of the crop was 350 kg/ ha at herbicide residual period of 30 days whereas the control had 700 kg/ ha. Yields of groundnut vary from about 400 kg to several tons per hectare, depending on the production system, but on the average, the global yield is 2500–2700 kg per hectare (Aransiola et al. 2019). The lower grain yield was across the entire herbicide application rates throughout the residual periods. There seems to be enough evidence also that all the selected succeeding legumes were affected by Topramezone and Dicamba herbicide.

Green House Experiment

The results for the different parameters of the study were illustrated in Table 4.

Table 4. Summary of the analysis of variance (ANOVA) for the different parameters.

Source	DF	(plant stand)	(Phytotoxicity)	(% dead)
Herbicide Rate	3	562.7**	431.5**	56268**
Residual period	4	145.6**	73.7**	14564**
Crop	2	21.4**	9.3**	2141**
Herb Rate*Res period	12	10.9**	10.9**	1092**
Herb Rate*Crop	6	4.5**	2.6**	448**
Res period*Crop	8	5.5**	2.4**	546**
Herb Rate*Res period*Crop	24	1.92**	1.7**	192**

** highly significant at $p \le 0.01$, * significant at $p \le 0.05$, ^{ns} not significant at $p > 0.05$.

The results in the green house experiment showed that there were highly significant differences among all the sources of variation for all the parameters (plant stand, phytotoxicity and percent dead plants).

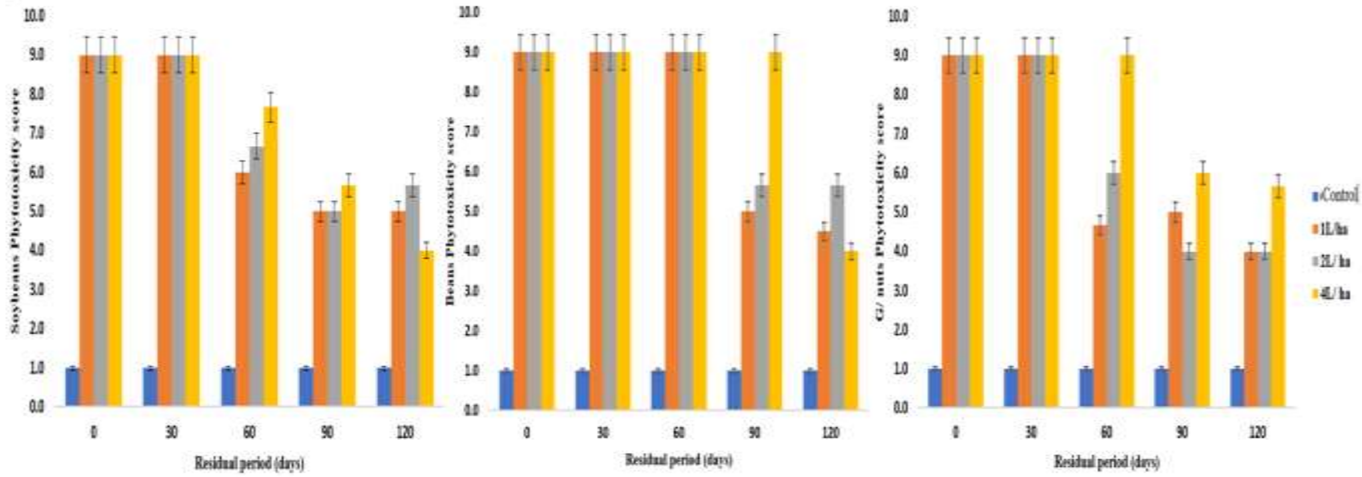

Figure 3. Phytotoxicity effect caused by herbicide rate and residual period on legumes.

The residual phytotoxicity effect of Topramezone and Dicamba herbicide was high in the 0, 30 and 60 days residual period for all the crops. 4 L ha^{-1} treatment rate had the worst and highest phytotoxicity score of 9 whereas the control had the score of 1 (no phytotoxicity effect). The phytotoxicity effect could be seen from the whitish, greyish, pale germinated plants which mostly dried after 3 to 5 days. In this study, it appears that Topramezone and Dicamba herbicide has severe residual phytotoxicity effect on soybeans (*Glycine max* L.), common beans (*Phaseolus vulgaris*) and groundnuts (*Arachis hypogea* L.) at all residual periods.

The various application rates of Topramezone and Dicamba herbicide showed different phytotoxicity effects. The recommended herbicide rate of Topramezone and Dicamba herbicide (1 L ha$^{-1)}$ showed moderate effect compared to the overdosed rate of 4L ha^{-1}. Therefore, judicious use of herbicides is essential to ensure proper weed control, crop growth and yield and environmental safety. Some researchers suggest that overdose use of herbicides prolong the residual phytotoxicity or carryover effect. Neve and Powles (2005) demonstrated that by repeatedly using reduced herbicide rates, resistant weed populations increased more compared to when a full, recommended rate of the herbicide was used.

Conclusion

The residual phytotoxicity effect of Topramezone and Dicamba herbicide was high particularly in the 0, 30 and 60 days residual period for all the legumes. The 4 L ha^{-1} treatment rate had the worst and highest phytotoxicity score of 9 whereas the control had the score of 1 (no phytotoxicity effect). The study showed that farmers would attain full benefits of the herbicide at the recommended rate of 1 or 2 L ha^{-1} as overdose usage (4 L ha^{-1}) may prolong the residual effect.

Soybeans, beans and groundnuts cannot be rotated with maize where Topramezone and Dicamba was previously used, at least not within the residual period of 120 days to attain optimal crop yields.

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Conflicts of Interest

No conflicts of interest have been declared.

References

Aransiola E. F, Ehinmitola E. O, Adebimpe A. I, Shittu T. D, Solomon D. O. 2019. Prospects of biodiesel feedstock as an effective eco-fuel source and their challenges. Woodhead publishing series in Energy. Department of Chemical Engineering, Obafemi Awolowo University, Nigeria.

Ayodele O. and Olubunmi A. 2017. Weed Management Strategies for Conservation Agriculture and Environmental Sustainability in Nigeria. IOSR-JAVS Volume 10 (8): 1 – 8.

Barber T. 2016. Dicamba effects on soybeans seed and offspring. Division of Agriculture, Research and Extension. University of Arkansas system.

Bari M. N. 2012. Evaluation of herbicide use in Bangladesh agriculture with special reference to wetland rice. Krishi Gobeshona Foundation, Dhaka, Bangladesh.

Damalas C. A, Gitsopoulos T. K, Koutroubas S. D and Georgoulas I. 2015. Annual grasses control with topramezone in mixture with ALS-inhibiting herbicides. Democritus University of Thrace.

Gallandt E. R. and Weiner J. 2015. Crop-Weed Competition. Wiley and Sons Ltd.

Grossmann K. and Ehrhardt T. 2007. On the mechanism of action and selectivity of the corn herbicide Topramezone: a new inhibitor of 4-Hydroxyphenylpyruvate dioxygenase. PMS 63, 429-439.

Harp P. R. 2010. Handbook of Pesticide Toxicology (Third Edition). University of California, USA.

Jiddimani L, Chandranath H. T. and Chogatapur S. V (2017). Phytotoxicity Ratings and Weed Control Ratings as Influenced by Chemical Weed Control Treatments in Greengram (*Vigna radiata* L.). J. Pure App Biosci 5(5): 1578-1581

Mehdizadeh M. 2019. Sensitivity of oilseed rape (*Brassica napus* L.) to soil residues of imazethapyr herbicide. International Journal of Agriculture, Environment and Food Sciences. 3: 46-49.

Mehdizadeh M, Alebrahim M.T, Roushani M, Streibig J.C. 2016. Evaluation of four different crops' sensitivity to sulfosulfuron and tribenuron methyl soil residues. Acta Agric Scand B Soil Plant Sci. 66: 706-713.

Neve P. and Powles S. B. 2005. Recurrent selection with reduced herbicide rates results in the rapid evolution of herbicide resistance in *Lolium rigidum*. TAG 110, 1154-1166.

Nishimura J, Gazzo K. and Budd R. 2015. Environmental Fate and Toxicology of Dicamba. Department of Pesticide Regulation, Environmental Protection Agency, California.

Nkhoma S, Kalinda T. and Kuntashula E. 2017. Adoption and Impact of Conservation Agriculture on Smallholder Farmers' Crop Productivity and Income in Luapula Province, Zambia. Department of Agricultural Economics and Extension, University of Zambia. *Journal of Agricultural Science*; 9 (9): 168-170.

Rahman A, Dowsett C. A, Trolove M. R. and James T. K. 2014. Soil residual activity and plant-back periods for the herbicides saflufenacil and topramezone. AgResearch, Ruakura research centre, Hamilton, New Zealand.

Rana S. S. 2018. Selectivity of herbicides and factors affecting it. Published by Department of Agronomy. CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, India.

Wang H, Lui W, Zhao K, Yu H, Zhang J. and Wang J. 2018. Evaluation of Weed control efficacy and crop safety of the new HPPD – inhibiting herbicide. Scientific Report 8, 7910.

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