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Evaluating The Efficacy Of Bateleur Gold 650 Ec Flumetsulam (*Triazolopyrimidine Sulfonanilide*) And S-Metolachlor (*Chloro-Acetanilide*) As A Pre-Emergent Herbicide Used In Maize (*Zea Mays*)

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DEDICATION

This project is dedicated to my beloved parents and my brother Walter.

ACKNOWLEDGEMENTS

I would firstly like to express my gratitude to the Almighty for the opportunity he has granted me and from whom all wisdom and knowledge flows and whose mercy has made it possible.

I would also sincerely thank my supervisor; Prof. C Karavina for the unyielding support that he extended to me to come up with a quality write-up. I appreciate his efforts because he offered me all the necessary guidelines; I needed during the preparation for this research project.

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ABSTRACT

Small yields are frequently the result of increased weed control difficulty in Zimbabwe's smallholder farming industry. Herbicides are typically the first line of defense against weeds; however, due to the possibility of weed resistance to herbicide management, different application rates must be tested on a regular basis. This study evaluated the herbicide Bateleur Gold, a factory premix of s-metolachlor and flumetsulam, to determine the rate of treatment that would effectively control weeds in Zea mays L. In this study, which used a randomized complete block design, slope was used as a blocking factor (RCBD). Flumetsulam (sulfonanilide) and s - metolachlor were used at different rates of 3.5L, 4.0L, 4.5L, and 5L, with no chemical used as a control. The herbicide was applied immediately after planting, while the soil was still moist, at five different herbicide treatments. The counts began the first week after planting and were completed over a two-week period. The yield of maize from various plots was eventually tallied in order to evaluate the herbicide effect. The findings revealed that there were more weeds in the first week, then a steady decline until the last week, and that species with broad leaves made up a larger proportion of the species than those with grasses. Furthermore, when compared to zero and low application rates, a high rate of herbicide treatment had an effect on weed population and crop output. This study demonstrated the herbicide's effectiveness as a pre-emergent substance and identified the optimal rate for weed control and higher yield. Additional research into the use of this substance in legumes should be conducted for the benefit of groundnut growers. Furthermore, while application rate 4.5L/ha does not provide statistically significant differences in the quantities of weed species when compared to application rate 5L/ha, additional research may be required to demonstrate this with greater certainty.

TABLE OF CONTENTS

CONTENTS **PAGE**

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

Analysis of variance (ANOVA)

Degree Celsius (^{o}C)

Emulsifiable Concentrate (EC)

Gross domestic product (GDP)

Least Significant Difference (LSD)

Nitrogen (N)

Percentage (%)

Phosphorus (P)

Potassium (K)

Weeks After Emergence (WAE)

CHAPTER 1: INTRODUCTION

1.1 Introduction

1.2 Background of study

Maize *(Zea mays L.)* is Zimbabwe's most important crop, with roughly 84 % of the country's total output produced in Natural Regions 2 and 3 (Twomlow et al., 2011). Grain, fodder, green cobs, beverages, and cooking oil are all produced from it (Cheruiyot, 2018). In Zimbabwe, yield levels per unit area are the most important factor in creating a food surplus (Ahmed et al., 2018). Farmers will be able to produce more, boosting yield per unit area and lowering the cost of producing a ton or less of maize grain.

It is renowned as the "Queen of Cereals" because it has the most genetic potential (Sharma et al., 2017). Maize yield is influenced by factors such as insufficient precipitation, high soil acidity, low disease resistance, and the usage of drought-resistant cultivars. Another factor that lowers maize output by 20–60 % is weed infestation (Baudron, et al., 2011). Weed infestation in maize is frequently severe during the rainy season, owing to the frequent rains that induce many weed flushes. Weeds, especially grasses, thrive in the hot and humid temperatures of the summer (Murimwa et al., 2019). Daniel (2012) claims that the role of maize is examined in relation to employment, earnings in foreign currency, food production, input provision, market sector, and GDP contribution. Input-output analysis and dynamic multipliers are used to quantify the effects of changes in the crop (You et al., 2012). Regarding the GDP, it contributes, the market for other goods, and the supply of inputs, the maize industry's influence on the overall economy is negligible (Chirwa and Dorward, 2013). According to Dzanku, (2019) the employment sector is where maize has the greatest impact

Weeds compete for nutrients and light with plants, and certain weeds emit poisons that impede crop growth. Others may be home to crop-destroying insects, diseases, or nematodes (Norsworthy et al., 2012). Weed pressure on crops lowers fertilizer and irrigation water efficiency, lowering crop production and quality (Marongwe et al., 2011). If not controlled, natural weed populations in most maize fields can cause significant yield losses in most crops (Reid, 2014). Weeds' ability to colonize, dominate, and endure in a given area determines their success (Anwar et al., 2021). Troublesome weeds that include Upright starbur, Chickweed, Purple nutsedge and Couch grass we witnessed in maize (Aganze, 2020).

Cultural, biological, mechanical, and chemical weed management options are all available (Mutambara et al., 2017). The use of fumigants and herbicides is one method of chemical control. Early crop-weed competition can be removed with herbicides, resulting in increased yields. They also save time by reducing weeding time, allowing you to focus on other tasks (Lee and Thierfelder, 2017). When other tactics are difficult to implement because to damp weather, herbicides can be utilized. According to Mutambara et al., (2017) herbicides are used in modern farming, because of the ability to increase yields hence farmers will have cost-effective way of cultivating *Zea mays* and boosts production. The use of herbicides reduces the amount of labour required for hand pulling, hence chemical herbicide development must be prioritized in the fight against weeds (Tshewang et al., 2016).

During the majority of the growing season, herbicides provide 90-100 % weed control. Weed control with herbicides is critical for lowering competition and allowing maize plants to establish quickly, but herbicides can be costly, causing smallholder farmers to rely on ineffective cultural and chemical methods (Mohammadi, 2012). Farmers must reapply another herbicide to eliminate the weeds, which takes time. Other weeds that aren't controlled by herbicides suppress the crop, resulting in low or no yields (Yadav et al., 2016). In South Africa and Zambia, a selective pre-emergent herbicide called Bateleur Gold 650 EC which has 2 active ingredients (Flumetsulam, and s – metalachlor) was used to fix challenges encountered in *Zea mays.* The herbicide site of action is acetoacetate synthase and it controls annual grasses, broadleaf weeds in maize.

1.3 Justification

Some farmers are losing hope in herbicides because they aren't getting much less yield than expected. As a result, some farmers are turning to traditional methods, mechanical methods, and biological methods, resulting in lower maize production. It is true, however, that chemical methods, such as the use of herbicides, yield high yields. We will be able to educate farmers about certain herbicides and provide them with recommendations tailored to their region because of this.

1.4 Overall objective

Evaluating the efficacy of Bateleur Gold 650 EC (Flumetsulam (*sulfonanilide*), s – metalachlor as a pre-emergent herbicide used in *Zea mays*.

1.5 Specific objectives

- Assess the effectiveness of different rates of Bateleur Gold 650 EC on weed population.

- Evaluating the effectiveness of different rates of Bateleur Gold 650 EC on the number of weed types/species.
- Evaluating the effectiveness of different rates of Bateleur Gold 650 EC on *Zea mays* yield.

1.6 Hypothesis

- Statistical differences in weed population because of different rates of Bateleur Gold 650 EC herbicide.
- Statistical differences in weed species because of different rates of Bateleur Gold 650 EC herbicide.
- Statistical differences in *Zea mays* yield due to different rates of Bateleur Gold 650 EC herbicide.

CHAPTER 2: LITERATURE REVIEW

2.1 Literature Review

2.2 Maize production and economic importance

Maize is the most important crop in Zimbabwe, according to Rukuni, (2006), occupying 50-70 % of the planted land in natural areas II A, II B and 30-55 % of the harvested farms in natural regions III, and IV. The average acreage in natural regions II A and II B is 1.7 hectares. Maize may be cultivated in pH levels between 5.6 to 7.4 according to Bloom and Skyllberg, (2012). From germination until flowering, maize requires adequate moisture and warmth. For maize germination and seedling growth, a minimum soil temperature of 10 to 13^{o}C is required. The ideal temperature for germination is 16 to 32^{o}C

The main use of Zea mays is food for human consumption as well as livestock as fodder. Zea mays has carbohydrates, and proteins in high proportion hence the grain is extremely nutritious. According to Vaughan and Geissler, (2009), the plant is not just grain but can used in manufacturing alcohol, glucose, soap production as well as lubrication. Because of little gluten in *Zea mays* grain, there is no formation of a dough that is elastic, hence corn flakes make the best breakfast according to Kyei, (2021). *Zea mays* is widely used in the fabrics and paper manufactures as a sizing material. Majoro, (2016) specified that *Zea mays* is used to make dextrose and working as a diluent in hospitals. In make-ups, *Zea mays* produces an element in several formulas of toilet substance material(Cissé, 2013).

Maize yield has been declining across all agro-ecological regions of Zimbabwe due to climate change unavailability of labour, poor seed quality, and fertilizer shortages. Weed infestation is another major challenge in maize production among smallholder farmers (Ortega et al., 2016).

2.3 Weed interference in maize crop growth

Wild plants, weed plants rogue plants, crop plants, and are the four categories of plants that can be found in a natural ecosystem. Crop plants are those that man has carefully tended for his benefit. Wild plants are those that willingly and uncontrollably spread throughout the environment without interfering with human activity. In the same agriculture fields, rogues are untyped economic crop plants (Rana and Rana, 2016).

Weeds are undesirable, unsuitable, unusable, persistent, competitive, dangerous, and even poisonous plants. They impede agricultural operations, increase labour costs, lower yields, and reduce quality of life amenities. Weeds are described in different behaviours, but best of them highlight behaviours which affect people (Upasani and Barla, 2019). The most basic concept of weed science is embodied in the word "weed" itself (Norsworthy, 2012). There is no agreed-upon definition of "weed scientist" among scientists (Ervin and Jussaume, 2014). A weed is a plant whose populations have grown entirely or mainly in the presence of human disturbance and not intentionally grown in any particular geographic area (Richardson et al., 2011). Due to their physiological, reproductive, reproductive and mimetic properties, these weeds are considered opportunistic native plants in maize cropland (Pimentel, 2012).

The critical period during which weed interference can occur is the maximum length of time during which weeds emerging soon after the planting of crops can exist without causing significant yield loss (Amare, 2011). Knowing the critical period of weed intervention is an advantage to decrease losses of yield (Gantoli, 2013). Cultivating weed control in maize fields is an important cultural practice that can improve the quality and quantity of maize grain yield (Jha, 2017). The competition between weeds and maize caused a reduction in the quality and quantity of maize yield. Weeds also act as alternative hosts for insects, pests, diseases and other microbes. (Rana et al., 2016). Some pests and diseases, for example, Downy Mildew, can be found on *Sacharum spontaneum* as an alternate host according to Subedi, (2015). Weeds can release chemicals that inhibit the growth of poisonous plants, people, and animals (Kumar et al., 2019).

Weeds compete for limited resources such as water, nutrients, light, and space with maize (Kurwakumire et al., 2014). They influence maize seedling growth even before resource competition begins. The critical period of weed interference, according to Hussen (2021), is the maximum length of time that weeds that emerge soon after crop planting can coexist with the crop without causing unacceptable yield loss. The weed-free period is the minimum amount of time required to keep the crop weed-free before yield loss due to late-emerging weeds is no longer an issue (Ghanizadeh et al., 2010). Knowing when weed interference is most crucial can help farmers reduce weed-related yield losses. Weeds growing close to *Zea mays* may alter the quality of sunshine reflected by their foliage, lowering maize yield. This could explain why losses are often greater than predictable because of the scarcity of when, water, nutrients and light. It reduces yields and harvest efficiency while also producing a seed that has the potential to affect future crops (Liu et al., 2012). Norsworthy, (2012) claims that broadleaf weeds compete more aggressively than grasses

2.4 Characteristics of weeds

Weeds, according to Maroyi, (2012) are similar to other plants but have unique characteristics that classify them as undesirable plants. Knowledge of these characteristics will aid in the development of appropriate methods for their control by studying the most vulnerable stage of their life cycle (Swanton, 2015). According to Todero et al., (2018) knowing the characteristics of weeds will aid in the study of their adaptation mechanisms as well as the extent of loss that these weeds can cause to humans. Weed seedlings grow quickly and have the ability to reproduce when they are young. When redroot pigweed (*Amaranthus retroflexus*) is less than 8 inches tall, it can flower and produce seeds. Crops are unable to do either. According to Rana and Krishi, as cited by Raffik et al., (2021). *Phyllanthus niruri* grows faster in groundnut. Many weeds can tolerate and grow in a wide range of climatic and edaphic conditions, owing to their environmental plasticity. Weeds can withstand harsh field conditions because they can adjust their seed production and growth to the availability of moisture and temperature (Jimu et al., 2009). They can germinate in low-moisture soils, have a short period of plant growth, grow at a faster rate, and produce seed earlier than most crops growing in association (Nyakudya et al., 2014). According to Mbangi, (2016). *Rumex spinosus* is capable of germinating in acidic soil. Many weeds have evolved both long-distance and short-distance seed dispersal mechanisms. Weed seeds have an incredible ability to spread from one location to another via wind, water, and animals, including humans. Weed seeds frequently resemble crop seeds in size and are transported from one location to another with them. A special structure is being formed for effective dissemination. According to Rana and Rana, (2016) *Physallis minima* forms a balloon structure.

2.5 Problems encountered in weed management by smallholder in Zimbabwe

Weed problems in *Zea mays* is still the most important and pervasive productivity issues that smallholder maize farmers in Southern Africa face (Moswetsi et al., 2017). Smallholder communal area farmers employ hoe weeding as their primary weed management practice (Ronald et al., 2011). This procedure is slow, labour-intensive, inefficient, and burdensome because of labour shortages, a postponed first hoe weeding in the crop row causes the majority of the weed competition (Tibugari et al., 2020). Due to labour shortages, smallholder farmers are forced to weed a considerable amount of their crop after it has already experienced severe yield loss (Gandure et al., 2013). Weed competition can be so severe in the early stages of crop growth that crops become stunted and yields fall short of their real potential (Williams, 2018).

Due to the lower effectiveness of hoe- and machine-weeding in wet conditions, farmers may have to weed more frequently in wet seasons to get high yields. For smaller farmers, biological control can be temperamental. They will never be able to control any natural enemy released into an ecosystem (Ng'etich, 2011). While it is designed to control one weed, there is always the chance that your predator will move to different prey. They may decide that eating your crops rather than the insects that infest them is a better idea. Furthermore, there is a risk of upsetting the natural food chain when introducing a new species to an ecosystem (Britton, 2013). Besides other factors, yield is greatly affected by weeds in the field. Weeds being injurious, harmful or poisonous are a constant source of trouble for the successful growth and development of economic crops (Arif et al., 2011). Weeds not only increases yield losses but also inhibit agricultural procedures. Mechanical sowing is made a tough practice, harvesting hard, hence increased spending on chemicals, equipment and labour (Rana and Rana, 2016).

Weeds in the aquatic environment obstruct the flow of water in canals, water-transport systems, and drainage systems, making navigation difficult. Aquatic weeds pollute the water by deoxygenating it and killing the fish (Khan et al., 2019). Weeds are also a nuisance and a fire hazard along railway lines, roads and right-of-ways, airports, forests, and industrial sites, according to Rana and Krishi, as cited by Raffik et al (2021). Mechanical weed control alters the surrounding environment, which can have both positive and negative consequences. The eradication of the targeted weeds will open up environmental niches, allowing other weeds to thrive by reducing competition and improving their environment. If the desired plant does not fill the niches, another weed will eventually take over. These weed management strategies also have an impact on soil structure.

2.6 Beneficial effects of weeds

Despite all of the problems that weeds cause, they can have some beneficial properties, especially when present in low densities. These elements should be incorporated into the farming system, though they may make organic management more difficult than chemical-based systems (Scavo and Mauromicale, 2020). Weeds may help to conserve soil moisture and prevent erosion, among other benefits. Weed ground cover reduces the amount of bare soil exposed, which helps to conserve nutrients, particularly nitrogen, that would otherwise be leached away, particularly on light soils (Rana and Rana, 2016). Furthermore, food and shelter for natural pest enemies, as well as alternative food sources for crop pests, can be provided. The presence of weed cover may play a role in increasing the effectiveness of biological pest control and reducing pest damage (Nicholls and Altieri, 2013). Most importantly, weeds can be useful indicators of field growing conditions, such as water levels, compaction, and pH (Raffick et al., 2021).

2.7 Chemical control

According to Mafongoya, (2016) herbicide spraying is the most essential weed management strategy in maize. Most farmers of *Zea mays* in Zimbabwe including other countries use herbicides due to their effectiveness and cost-effective. Alebrahim, (2012) observed that herbicides can be administered before planting but before emergence of weeds, or after planting. Norsworthy, (2012) found that time of herbicide application is influenced by farmer to farmer and farm to farm. *Zea mays* farmers apply multiple pesticide sprays throughout the season to keep weeds at bay. According to Mavunganidze, (2014) using herbicides as a pre-emergence treatment can suppress weeds before they emerge from the soil, allowing maize crops to sprout and grow in a weed-free or low-competition environment during their tender and seedling stages. Other weed control methods do not allow for this. Herbicides are effective in controlling weeds in both the inter-row and intra-row areas. Overall, maize yield generally responded positively to increases weed control (Burgos, 2013).

2.7.1 Selectivity of herbicide

Different plant species respond differently to the same herbicide, and the same plant species respond differently to different herbicides, according to Boutin (2012). This lays the groundwork for phenomenal success in modern chemical vegetation (weed) management, where the goal is to kill weeds while retaining others at the same time and place (Hussen, 2021). Selectivity, on the other hand, is undesirable in mixed populations of weed species. This resulted in the accumulation of tolerant species. Herbicide selectivity refers to the differential response of plants to herbicide. Herbicides, in other words, harm or kill weeds while having no effect on crop plants due to selectivity (Pazmino, 2011). The basic principle is that more toxicant should reach the site of action in active form inside target plants than non-target plants. The selective mechanism could be caused by differences in herbicide absorption rates, herbicide translocation rates, herbicide deactivation rates, and protoplasmic resistance to a specific herbicide (Duke, 2020).

2.7.2 Differential absorption of herbicides

Differential herbicide absorption may occur in the field due to differences in plant species morphology and growth habits, as well as timing of herbicide application by different methods (Hess, 2018). The use of antidotes and adsorbents to prevent herbicide absorption by non-target plants, as well as differences in herbicide formulations' ability to contact non-target plants. (2015); Rana and Rana). The selectivity could be caused by one or more processes (Rana and Krishi, 2018). According to Ugbede Itodo (2019), narrow upright leaves, corrugated or eventually ridged leaf surfaces, waxy leaf surface, and pubescent leaves allow for limited retention of aqueous herbicides on their foliage. The above morphological characteristics are found in pea, onion, sugarcane, cabbage, and colocasia. Limited spray retention with translocated herbicides is ineffective in protecting non-target plants from herbicide injury (Duke, 2020). In recent years, the importance of crop plant wetting as a factor in herbicide selectivity has waned (Matthews et al., 2014).

2.7.3 Growth habit differences of plants

Directed application is a common process of attaining selective weeds when plants rows have a clear height advantage over interrow weeds, (Rana and Rana, 2015). Herbicide mulches are used in standing crop rows to control germinating weeds selectively (Mohammadi, 2012). Weeds often establish themselves even before crop emergence in slow germinating crops such as potato and sugarcane, so they are controlled selectively by spraying a contact herbicide before more than 10% of the crop plants are visible over the ground (Schonbeck and Tillage, 2011). Specific weed species may grow much higher than crop height in later stages of crop growth (Andrew et al., 2015).

Shoots of nutsedge and other erect weeds can be selectively wiped with herbicides in lawns and gardens using either herbicide-laden wax bars (or) clothed sticks dipped in concentrated herbicide solution (Rana and Rana, 2015). When herbicides are applied to soil, the growth habits of underground parts of weeds and crop plants play an important role in determining their selective absorption (Skiba, 2017). Weed seeds, on average, germinate from the top 1.25-1.5 cm of soil, whereas most crop seeds are planted 5 to 7.5 cm deep. When a recommended pre-emergence herbicide is applied to the soil surface and soil moisture conditions allow it to leach to approximately 2.5 - 3 cm soil depth, it is readily available for absorption by germinating weeds. (Rana and Rana, 2015). Crop plants with roots that grow deeper than 5 cm avoid herbicide absorption and phytotoxicity. This is the fundamental selectivity principle of the majority of pre-emergence herbicides (Chauhan, 2012). The basic principle of pre-emergence herbicide selectivity is a function of herbicide structure, formulation, and rate, as well as soil texture, organisms, inorganic colloids, and rainfall (Elmahdi, 2016).

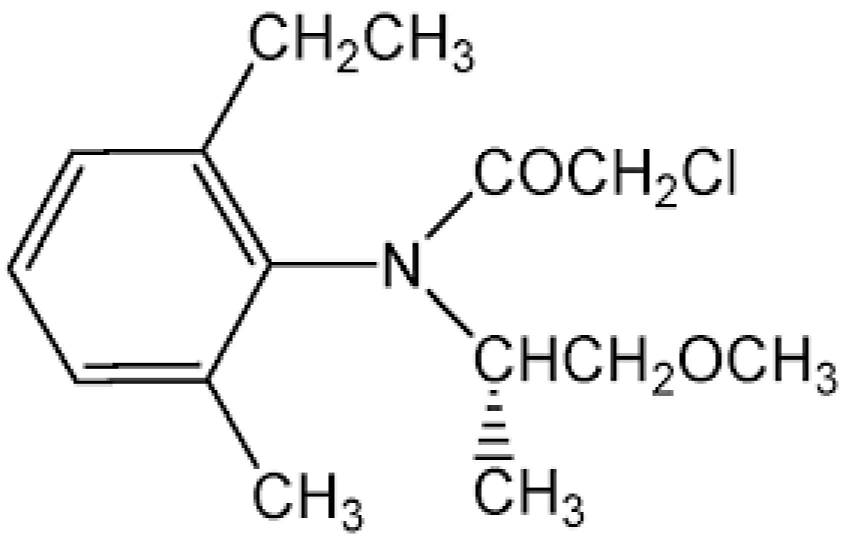
2.8 The Bateleur Gold 650 EC herbicide

Bateleur Gold 650 EC is a pre-emergence herbicide that control of annual grasses, broadleaf weeds and yellow nutsedge in maize (Hadzhi, 2019). The mode of action of Bateleur Gold 650 EC is a selective pre-emergence herbicide. The shoots of the germinating weeds before emergence above ground absorb it. Syngenta Crop Protection AG in Basel, Switzerland manufactured it (LeBaron, 2011). The minimum waiting period between the last application of Bateleur Gold 650 EC and planting of the subsequent crop in beans, soya beans, maize, groundnuts, and tobacco is nil while potatoes, wheat, and sorghum are 3 months and all other crops are 24 months. If weeds emerge during application time, the active ingredients expand the weed control spectrum. When planting into moist soil, Bateleur Gold 650 EC must be applied within three days after planting or at planting (Mofokeng, 2018). It is required that application must be seconded by irrigation or rain before weeds begin to grow.

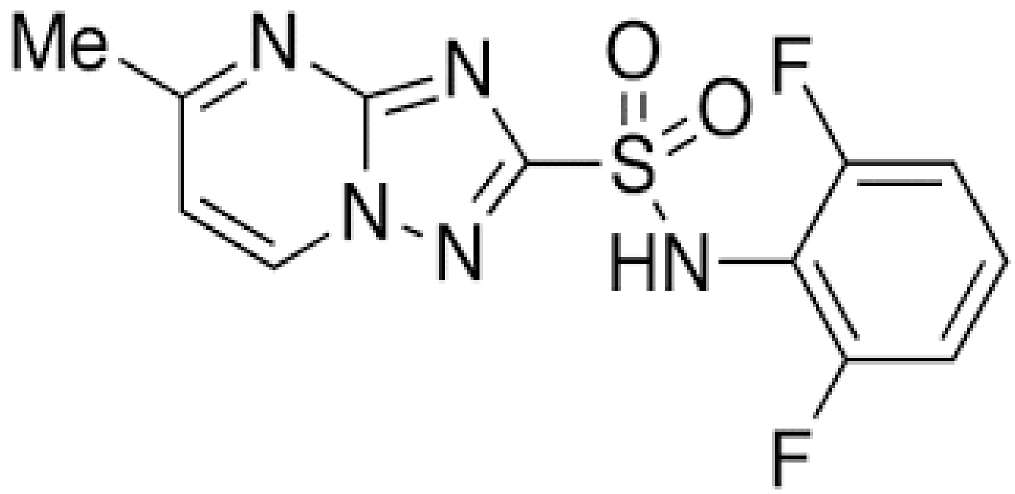
2.8.1 Regulation for use

Bateleur Gold 650 EC can be used as a full ground application or as a strip application. On ground application, Bateleur Gold 650 EC can be applied with any medium to high volume sprayer, properly calibrated and which is equipped with an efficient agitation mechanism. Choice and arrangement of fan type spray nozzles should be such to ensure even distribution and optimal recovery of the herbicide. The recommended amount of Bateleur Gold 650 EC should be applied in at least 200 litres of water per hectare. For proper mixture application of the herbicide, the spray tank should be half-filled with water, and then the required amount of Bateleur Gold 650 EC can be added. The spray tank can be topped up with water until the final volume has been obtained. There should be thorough agitation of the mixture in the tank during mixing or spraying. Bateleur Gold 650 EC should not be used in plants treated with organophosphate insecticides. Bateleur Gold 650 EC cause slight early yellowing and growth retardation of plants but such signs not influence yield (Makuvaro et al., 2017). Low nutritional value of the field for a particular plant can act as a pressure issue for the growth of the plant (Rusinamhodzi, 2012). Soil-applied herbicides results in additional pressure hence reduction in the good growth of the plant.

2.8.2 Chemical structure of s-metolachlor *(Chloro-acetanilide)* molecular formula: $C_{15}H_{22}ClNO_2$ (Figure 2.8.2)



2.8.3 Chemical structure of the chemical structure of flumetsulam (*triazolopyrimidine sulfonanilide*) molecular formula: $C_{12}H_9F_2N_5O_2S$ (Figure 2.8.3)



2.9 Mode of action

S - metolachlor (*Chloroacetamide*) is the chemical family and the mode of action is seedling shoot growth inhibitors used to control broadleaved and grass weeds inhibiting plant growth via shoots (Strom, 2018).

2.9.1 Herbicide selectivity

Bateleur Gold's selective pre-emergence herbicide mechanism is based on differential bio-activation by metabolic conversion to its poisonous form. The chemicals S-Metolachlor (*chloroacetanilide*) and Flumetsulam (*sulfonamide*) provide detoxifying pathways for controlling annual grasses and broadleaf weeds (Munoz et al., 2011). Non-selective herbicides (also known as total weed killers in commercial goods) can be used to remove the waste ground, industrial and construction sites, railways and railway embankments since they destroy all plant material with which they come into contact (Strom, 2018).

2.9.2 Persistence of herbicides

The soil that contains the root zone of weeds is provided with active ingredients even during high rainfall. S-metolachlor has medium mobility in soil hence sandy soils of low organic matter and clay content have high movement of herbicides. It has minimal movement in loam/clay soils with higher organic matter and clay content. This means that the herbicide do not leach significantly in the soil, due to their great water solubility that provides superior early-season control (Tibugari et al., 2020).

CHAPTER 3: METHODOLOGY

3.1 Methodology

3.2 Materials and methods

3.3 Description of study area

The research was done in Checheche Growth Point 80km North-West of Chiredzi town in Zimbabwe. It is in Natural Region 5, which receives a yearly rainfall not more than 500mm and average yearly minimum and maximum temperatures of 15^{o}C and 37^{o}C respectively, summer temperatures range from 27^{o}C to 37^{o}C. The majority of soils consist of dark grey and black self-churning clays (Mugandani, 2012).

3.4 Experimental design and treatment

With a slope as a blocking factor, the experimental design was laid up in a Randomized Complete Block Design (RCBD). Standard chemicals used in Zimbabwe: Flumetsulam (*sulfonanilide*), s – metalachlor, and no chemical as control were employed in the Bateleur Gold 650EC at varying rates (3.5L, 4.0L, 4.5L, and 5L). The experiment was carried out four times, yielding a total of twenty units. The gross plot was 10.0m x 6,0m, and the net plot was 6,0m x 4,0m, of eight rows, four inner rows, and outer rows on each side of the plot. It was DKC 8033 maize that was used.

3.5 Herbicide treatments application rates (Table 3.5)

TREATMENT NUMBER	DESCRIPTION	APPLICATIONRATE/HA
1	Bateleur Gold 650EC	3.5L
2	Bateleur Gold 650EC	4.0L
3	Bateleur Gold 650EC	4.5L
4	Bateleur Gold 650EC	5.0L
5	NO CHEMEICAL	0

3.6 Experimental procedure

3.6.1 Project duration

The project started in October 2021 until May 2022.

3.6.2 Land preparation

Before planting, the land was ploughed and harrowed using a disc to create a beautiful fine seedbed. Absolute field groundwork was achieved by using rakes to break soil cloids.

3.6.3 Planting

Two maize seeds were sown per planting station in this process. The interrow and in-row spacing were both 0.70m and 0.20m, respectively. The basal fertilizer Compound D (N7, P14, K7) was administered at a rate of 400kg/ha for fertilizer application.

3.6.4 Variety selection

DKC 8033 from The Dekalb, which is the most common variety suitable for most maize growing areas in Zimbabwe, was used for this research. This is a fast-growing cultivar that thrives in low-moisture environments.

3.6.5 Application of herbicide

The herbicide was administered shortly after planting at five different herbicide treatments while the soil was still moist to allow for good herbicide uptake. It was applied after every two weeks and was applied using a backpack sprayer with a flat fan nozzle.

3.6.6 Management practices

To achieve a plant population of 37,000 plants per hectare, the maize plant was thinned to one plant per planting station two weeks after emergence (WAE). A top dressing of 200 kg/ha ammonium nitrate (34.5 % N) was sprayed in two stages, the first at 4 weeks following emergence and the second at four weeks after the first treatment. Irrigation was carried out to suit the crop's water needs.

3.6.7 Harvesting

Maize was shelled and then dried to 12.5 percent moisture content. The weight was measured on a digital scale.

3.6.8 Data collection

1. Weed Density - a 1m x 1m quadrant was used to conduct the weed count. Beginning the first week following planting, the counts were done leaving a duration of two weeks. In the plot, the quadrant was thrown three times at random. Plants found in the quadrant were documented.

2. Weed species counted – this was accomplished by using a weed identification guide and keeping track of the number of weed species detected per plot at weekly intervals.

3. Maize grain yield – Maize was shelled and dried when it reached physiological maturity. The weight was measured on a digital scale.

3.6.9 Data analysis

Analysis of variance (ANOVA) was used using Genstat 14th edition. The mean separation will be carried out using the Least Significant Difference (LSD) at a 5 % level of significance ($P<0.05$) test.

CHAPTER 4: RESULTS

4.1 Results

4.2 Effect of herbicide application rate on weed density

Application rates of Bateleur Gold 650 EC had a significant effect ($p<0.001$) on weed density. The highest weed density was recorded in the control rate (0 L/ha) at all times. The lowest weed density was recorded at an application rate of 4.5L/ha, 5.0L/ha at all times (Table 4.2).

4.2.1 Effect of different application rates of Bateleur Gold 650 EC on weed density per m^2 (Table 4.2.1)

Bateleur Gold Rates	Week 1	Week 3	Week 6	Week 9
0L/ha	19.575a	18.515a	18.290a	17.730a
3.5L/ ha	11.325b	10.950b	9.700b	8.875b
4.0L/ha	7.175c	6.625c	5.850c	5.050c
4.5L/ha	4.625d	4.225d	3.600d	2.975d
5.0L/ha	3.950d	3.650d	2.950e	2.375e
P. Value	<.001	<.001	<.001	<.001
C.V%	4.8	4.9	3.6	4.2
L.S.D	0.689	0.6593	0.4518	0.4832

4.3 Effect of herbicide application rate on weed species (number of broadleaves and grasses)

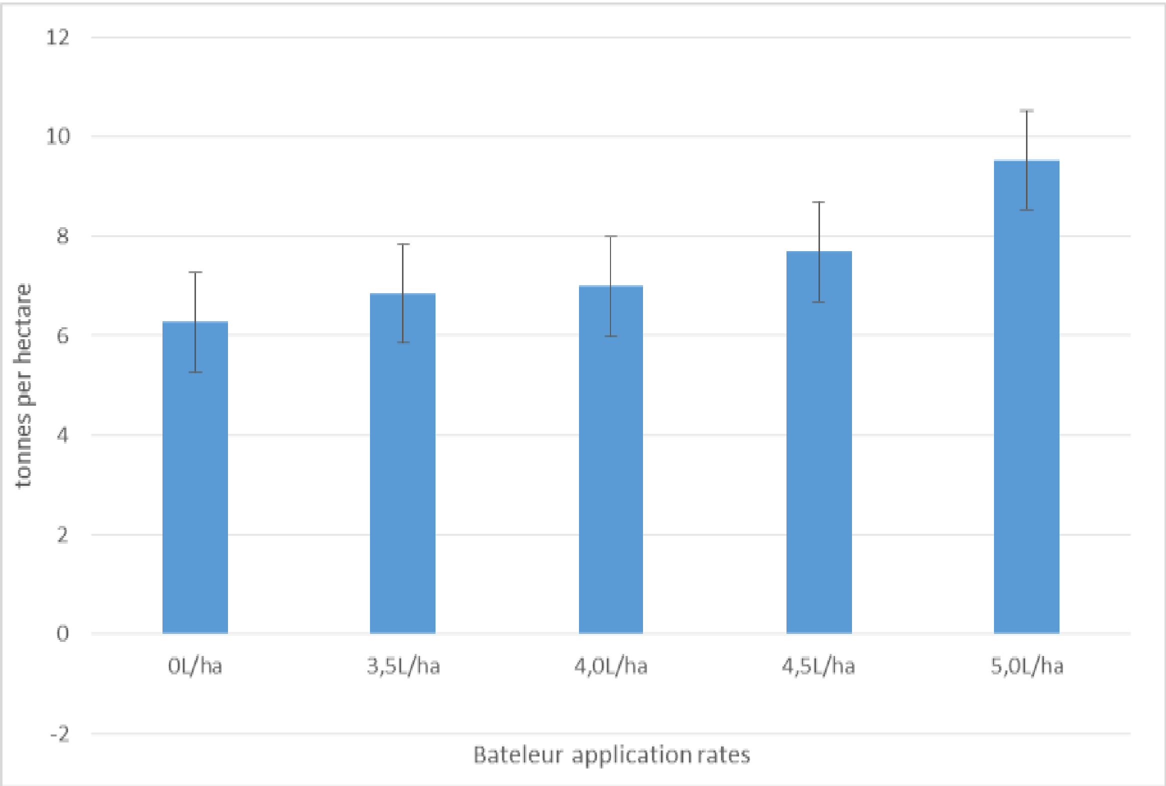
Herbicide application rate had a significant effect (p<.001) on the number of broadleaves and grasses. The weed species numbers decreased with increasing herbicide application rates (Table 4.3). There were no statistical differences in weed species numbers at application rates of 4.5L/ha and 5.0L/ha for broadleaf weed species (Table 4.3).

4.3.1 Effect of different application rates of Bateleur Gold 650 EC on weed species (number of broadleaves and grasses) (Table 4.3.1)

Bateleur Rates	Broadleaves	Grasses
0L/ha	10.447a	8.250a

3.5L/ ha	4.950b	5.000b
4.0L/ha	3.250c	3.025c
4.5L/ha	1.525d	2.500c
5.0L/ha	1.500d	1.725c
P. Value	<.001	<.001
C.V%	21.6	26.2
L.S.D	1.441	1.654

4.4 Effect of herbicide application rate on maize grain yield per tonne (Table 4.4.)



4.4.1 Effect of herbicide application rate on maize yield (Figure 4.4)

Herbicide rate had a ($p<.001$) effect on *Zea mays* grain yield. The highest (9.5t/ha) grain yield was recorded at the rate of 5.0L/ha. An application rate of zero (control) had the lowest (6.1t/ha) maize grain yield (Figure 4.4.1).

CHAPTER 5: DISCUSSION

5.1 Discussion

5.2 Effect of different application rates of Bateleur Gold 650 EC on weed density.

At a zero application rate, the maximum weed density was attained (no chemical). This could have been due to a lack of herbicide application, allowing the weeds to germinate without being chemically suppressed (Shaner et al., 2014). Weed growth is accelerated in favourable conditions, such as when no or little herbicide is applied (Green and Owen, 2011). Because the concentration of Bateleur Gold 650 EC was low, modest application rates result in a high weed population. The results are in analogy with those reported by Haggblade et al., (2017).

He reported that the application of a pre-emergent herbicide provided excellent control of weeds. This raises the issue of weeds developing resistance to the herbicide and becoming tolerant to it (Shaner, 2014). There were no significant differences in application rates of 3.5L/ha, and 4.0L/ha, indicating that the rates were too low, according to research. Weed management will be inadequate at lower rates, resulting in an increase in the weed population (Renton, 2011). It also permits the weed to go through all stages of growth in a short period of time, as well as disseminate its seeds for more weed growth (Qasem, 2011).

The lowest weed density was observed when applying weed control products at rates of 4.5L/ha and 5.0L/ha. It is recorded that the time of application of herbicide is important in order to achieve effective results (Naseer-ud-Din et al., 2011). Pre-germination herbicides create a chemical barrier on the top layer of the soil, covering the seeds and preventing them from growing roots and shoots (Ntombela, 2019). 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. The herbicide application rate is effective in weed control in Zimbabwe (Mhlanga et al 2016). Bateleur Gold 650 EC inhibits weed growth in the germination phase (Hadzhi, 2019).

It is evident that this led to a decrease in the weed population, which in turn allowed maize seedlings to emerge from the soil more slowly (Gianessi, 2013). Herbicide application timing is a major factor affecting weed germination rates (Muoni, 2013). This is because weeds are more sensitive to herbicides at certain stages in their growth cycle, reducing their growth (Mafakheri et al., 2012). The increase in herbicide use means there is a high concentration of herbicides available for maximum weed control (Masters et al., 2013).

Results showed that there were more weeds in the early weeks which decreased gradually until the final week. It was observed that weed density was significantly affected by different treatments.

5.3 Effect of different application rates of Bateleur Gold on the number of weed species.

The different application rates of Bateleur Gold 650 EC show the highest number of broadleaved and grasses weed species at an application rate of zero. It was evident that due to no application of herbicide there is a broad spectrum of weed species. The absence of a herbicide application at the start of the week provides a wide margin for weeds to grow as the conditions are favourable (Cobb and Reade, 2011). The germination of weeds happens as flashes for example salt weed (*oxalis parviflora*) and *cynodon dactylon*. The roots, tubers or bulbs have more food storage such that there is an increased growth with no disturbance from any herbicide to suppress their growth allowing an increased number of weed species. The lowest broadleaves and grass weed species were observed at application rates of 4.5L/ha, and 5.0L/ha. The broadleaved weeds were controlled because the herbicide had an active ingredient of flumetsulam (*triazolopyrimidine sulfonanilide*) and S-metolachlor *(chloro-acetanilide*). Bateleur Gold is a selective herbicide used in the control of broadleaved weeds (Mofokeng and Mashingaidze, 2018).

The lowest grass weed species were recorded at an application rate of 5.0L/ha. The highest rate of Bateleur Gold was effective in controlling grasses; this is due to the active ingredients flumetsulam (*triazolopyrimidine sulfonanilide*) and S-metolachlor *(chloro-acetanilide*). It is an emulsifiable concentrate safened herbicide for the pre-emergence control of annual grasses and broadleaf weeds in maize. These results are in agreement with previous findings where soil-applied flumetsulam (*triazolopyrimidine sulfonanilide*) and S-metolachlor (*chloro-acetanilide*) controlled grasses and broadleaves at high rates (Sarangi and Jhala, 2018). The data indicates that overall, there was an abundance of grasses in the experiment and the broadleaf were in a small percentage of the overall weed count count.

5.4 Effect of different application rates of Bateleur Gold on maize grain yield.

According to the results, using herbicides significantly enhanced maize yield. This may be a characteristic of how pesticides work on weeds that are already there. These results concur with those of Naveen et al., (2019). Bateleur Gold's various application rates reveal that a rate of 5.0L/ha produces the maximum grain production. This might be the case because, as noted by Ganie et al., (2017) the pre-emergent herbicide Bateleur alleviated maize yield loss by reducing weed competition, giving the crop more time to establish. Herbicide spray instantly stops the weeds from sprouting, which ultimately creates a non-competitive environment that allows the crop plant to utilize all of the resources on its own (Dass et al., 2017). Herbicides are the most efficient and successful at controlling weeds in Zea mays, and they also boost grain yield, according to Hassan et al., (2010).

It has been found that applying the herbicide soon after crop planting was an efficient way to defend against early-season weed competition. The result is a weakening and suppression of the weeds. Herbicide-created seal prevents germination, causing weed seed banks to go dormant (Fernandez-Aparicio et al., 2020). This brings up a crucial aspect about Bateleur Gold's numerous modes of operation that should be taken into account. This might have been explained by the fact that it was a selective pre-emergence herbicide, whose method of action involves absorbing it by the shoots of weeds that are germinating before they appear above ground, resulting in a high maize yield (Vermeulen, 2015). At a 0% application rate, the lowest maize grain yield is seen. The competition between weed crops may be to blame for this.

Weeds are more effective at outpacing crops in the competition for nutrients, water, and space. They also harbor pests and illnesses, all of which have a negative impact on the yields determined at the conclusion of the study. Insufficient nutrients for maize crop growth result from this, which lowers crop quality and maize grain output. The root system of the maize crop was affected by weeds like yellow nutsedge, which prevented the crop from absorbing water for the generation of the assimilates it needs, which reduced photosynthesis (Rana and Rana, 2016). Weeds cause the crop to be stressed due to the large weed population, as noted by Muoni and Mhlanga, (2014), which lowers the quantity of maize grain yield.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Herbicides reduced the weed spectrum in maize resulting in realisation of higher yield in flumetsulam (*triazolopyrimidine sulfonanilide*) + S-metolachlor *(chloro-acetanilide*). It can be concluded that different application rates of Bateleur Gold used in Zimbabwe had a significant effect on weed density, the number of weed species and maize grain yield. It was observed that the lowest weed density was attained at application rates of 4.5L/ha and 5.0L/ha. The number of weed species (broadleaved and grasses), was low at an application rate of 4.5L/ha and 5.0L/ha. Maize grain yield was the highest at an application rate of Bateleur Gold 4.5L/ha and 5.0L/ha. Flumetsulam (*triazolopyrimidine sulfonanilide*) + S-metolachlor (*chloro-acetanilide*) proved to be effective in reducing weed density and improving maize yield.

Flumetsulam *(triazolopyrimidine sulfonanilide*) + S-metolachlor (*chloro-acetanilide*) produced a greater yield in maize because herbicides limited the range of weeds in the plant. Weed density, weed species, and maize grain production were significantly impacted by the varied Bateleur Gold application rates employed in Zimbabwe. It was found that treatment rates of 4.5L/ha and 5.0L/ha resulted in the lowest weed density. At treatment rates of 4.5L/ha and 5.0L/ha, there were few weed species (broadleaved and grasses). At application rates of Bateleur Gold 4.5L/ha and 5.0L/ha, maize grain production was the highest. It was discovered that the combination of flumetsulam (*triazolopyrimidine sulfonanilide*) and S-metolachlor (*chloro-acetanilide*) effectively decreased weed density and increased maize production.

6.2 Recommendations

The researcher advises Zimbabwean farmers to use flumetsulam (*triazolopyrimidine sulfonanilide*) + S-metolachlor (*chloro-acetanilide*) at a rate of 5L/ha as a pre-emergent herbicide because it was found to have a higher yield and lower weed control costs in maize fields, and farmers no longer need to return with labour to control weeds. Farmers are advised to use 5L/ha flumetsulam (*triazolopyrimidine sulfonanilide*) + S- metolachlor to achieve the highest maize grain yield (*chloro-acetanilide*). Farmers in Zimbabwe will not spend more money on this herbicide because the application rate of 4.5L/ha is more economical. To determine the effects of the environment and crop on the mode of action of herbicides, the same research must be repeated across multiple crops and environments.

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APPENDICES

Appendix 1: Analysis Of Variance

Variate: Weed density at week 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replications stratum	3	0.2780	0.0927	0.46	
replications.*Units* stratum					
Bataluer_Rates	4	658.6620	164.6655	822.64	<.001
Residual	12	2.4020	0.2002		
Total	19	661.3420			

Variate: Weed density at week 3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replications stratum	3	0.4511	0.1504	0.82	
replications.*Units* stratum					
Bataluer_Rates	4	604.7489	151.1872	825.57	<.001
Residual	12	2.1976	0.1831		
Total	19	607.3976			

Variate: Weed density at week 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replications stratum	3	0.52804	0.17601	2.05	
replications.*Units* stratum					
Bataluer_Rates	4	632.91472	158.22868	1839.58	<.001
Residual	12	1.03216	0.08601		
Total	19	634.47492			

Variate: Weed density at week 9

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replications stratum	3	0.48038	0.16013	1.63	
replications.*Units* stratum					
Bataluer_Rates	4	636.95308	159.23827	1618.66	<.001
Residual	12	1.18052	0.09838		
Total	19	638.61398			

Appendix 2: Analysis Of Variance

Variate: Number of broadleaved weeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	0.7270	0.2423	0.28	
replication.*Units* stratum					
Bateleu_Rates	4	219.4057	54.8514	62.73	<.001
Residual	12	10.4936	0.8745		
Total	19	230.6263			

Variate: Number of grasses

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	10.188	3.396	2.95	
replication.*Units* stratum					
Bateleu_Rates	4	109.555	27.389	23.75	<.001
Residual	12	13.837	1.153		
Total	19	133.580			

Appendix 3: Analysis Of Variance

Variate: Yield of maize in tonnes

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	0.8687	0.2896	2.23	
replication.*Units* stratum					
Bateleur_Rates	4	25.3589	6.3397	48.72	<.001
Residual	12	1.5615	0.1301		
Total	19	27.7890			