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CROP SCIENCE DEPARTMENT

Evaluation On The Effects Of Different Doses Of Ash In Controlling Fall Armyworm In Maize Production

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DECLARATION

I, Mhamhiwa Boniface do hereby declare that this research project is a result of my original research work undertaken by myself, except where clearly and specifically acknowledged. It is being submitted in partial fulfillment of the Bachelor of Agricultural Science Honours Degree (Crop Science). It has not been submitted before for any degree or examination at any other university.

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I have supervised the research project for the above mentioned and I am convinced that the research project:

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I certify that I have checked the Research project and I am satisfied that it conforms to the Department of Crop Science guidelines for project preparation and presentation. I therefore authorize the student to submit this dissertation for marking.

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DEDICATION

I dedicate this to my beloved wife Ashel Chinorira and my son Brighton for their aspirations and support in every level that I attained and achieved in my studies.

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Special thanks go to the Almighty God for enabling me to finish up my research project. Without him, the researcher could not have done anything worth writing about. My deep gratitude goes to my mother, brother and sister for the financial support, love, encouragement they showed me through the period of study. My project would not have been a success without his grace. In the same measure I also appreciate the advice, supervision and encouragement that were received from my supervisors Professor R Mandumbu and Mr Mutsengi.

ABSTRACT

A field trial was carried out in ward 13 in Zimbabwe, to evaluate the efficacy of different doses of ashes for control of the fall armyworm (FAW). The ash dosages were 2g, 5g, 10g and an untreated control. The experiment was laid out in a Randomized Complete Block design with four treatments which were replicated 3 times. Data was collected once at four weeks after crop emergence. All treatments were significant ($P<0.05$). Ash at 10g effectively controlled FAW larvae with mean percentage mortality rate of 89.33%. Some FAW larvae were tolerant to lower dosages of ash and recorded a number live larva. The least performing dosage was 2*g* which recorded an average mean number of live larva of 8 as compared to 10g which had lower than 2 mean number of live larva over the same exposure period. The results suggest potential of ash at 10g as an effective dosage for control of FAW larva populations in Zimbabwe and its side effects on crops must be examined before dissemination of information to farmers.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
FAW	Fall armyworm
g	gram
LSD	Least significant difference
pH	Potential hydrogen
RCBD	Randomized complete block design
s.e.d	Standard errors of differences of means

CHAPTER 1: INTRODUCTION

1.1 Background

The fall army worm *(Spodoptera frugiperda)* is a lepidopteran pest that feeds widely on leaves and stems of more than 80 plant species, causing major damage to maize, rice, sorghum, sugar-cane cotton and other vegetable crops, (Goergen *et al* 2016). The fall army-worm is native to tropical and subtropical regions of the Americas. In 2016, it was reported for the first time in Africa where it caused significant damage to maize crop, (Abrahams *et al*., 2017).

Although the fall armyworm is an extremely polyphagous pest, it prefers to feed on gramineous plants, in particular the economically important crops such as maize (Hardke *et al*., 2017). Zimbabwe has been fighting an outbreak of fall armyworm since December 2016 (FAO, 2017). The pest can reduce maize production and availability, leading to price increases affecting food access and national food security (ACAPS, 2017).

Hardke *et al*. (2017) and Venter (2017) reported that fall armyworm larvae are susceptible to cold temperatures and are unable to survive even the mildest winter since pupation is affected by low temperature and radiation. Vilella *et al*. (2002) reported that the critical stages where pesticides should be applied to protect maize are the early vegetative stage and the reproductive stage because that is when the larvae feeds. Fall armyworm is a migratory lepidopteran pest specie with a high potential of continuing to spread due to its natural distribution capacity and trade of the maize seed between countries (Monsanto Technology, 2017). Farmers need support to sustainably manage fall armyworm in their cropping systems (Abrahams *et al*., 2017). Witt (2016) recommended that the national authorities should promote awareness of fall armyworm, the identification, damage and control to farmers, extension agents, plant health inspectors and other stakeholders as well as to assess preferred crop varieties for resistance and tolerance of fall armyworm.

To date farmers in the commercial sector in Zimbabwe are using different chemicals that are found on the market to control the pest. However, the majority of farmers in the smallholder farming sector are using ash for controlling FAW. As a result, the researcher used different doses of ash to find out the correct amount of that is significant in controlling the pest.

1.2 Problem statement

Maize is the major cereal crops grown in Zimbabwe, providing a perfect host for the survival of the fall armyworm (Vilella *et al*., 2002). This raises concern for national food security if no effective methods are available to maize producers to control the pest. Farmers are failing to effectively control the pest using ash as a cheap cultural method because of using undefined quantities of ash. Further, loses and damage to the crop had been experienced by many farmers as result of applying undefined doses of ash to the crop.

1.3 Justification

Cultural methods of controlling fall armyworm are affordable and environment friendly. The idea comes in because of the efforts that was done by most farmers in trying to control the pests using certain chemical pesticides which polluted the environment as well as harming non-targeted species. More so, the use of pesticides increased costs of production to resource-constrained smallholder farmers.

1.4 Objectives

1.4.1 Overall Objective

- To evaluate the efficacy of different doses of ash for the controlling of fall armyworm in maize production.

1.4.2 Specific objectives

- To determine the number of live FAW larvae after the application of different doses of ash to the maize plant
- To come up with the specific dosage rate of ash that can effectively control FAW larvae in maize production.

1.5 Hypothesis

- There is significant difference in the number of live FAW larvae on maize applied different doses of ash.
- There is significant difference in the number of dead FAW larvae on maize plant applied different doses of ash.
- Doses of ash have a significant effect on the mortality rate of FAW in maize.

CHAPTER 2: LITERATURE REVIEW

2.1 Fall armyworm description, biology and lifecycle

The fall armyworm lifecycle includes the egg, six growth stages of caterpillar development known as instars, pupa and the adult moth (William, 2016)**.** The life cycle is completed in 30 days during the summer, but 60 days in the spring and autumn, (Rose *et al.* 1975). The number of generations occurring in an area varies with the appearance of the dispersing adults. The ability to diapause is not present in this species. The pest undergoes complete metamorphosis.

2.1.1 Egg stage

The female moth lays eggs in 'egg masses' on the host plant in batches of about 150-200. The eggs hatch in 2-4 days at optimum temperature. The egg is dome shaped the base is flattened and the egg curved upward to a broadly rounded point at the apex. The egg measures about 0.4mm in diameter and 0.3 in height. The total egg production per female averages about 1500 (FAO, 2016). Oviposition is usually on the underside of leaves, typically near the base of the plant, close to the intersection of the leaf and the stem (William, 2016). The eggs are covered in a protein sheath for protection against chemicals and natural enemies (Maiga, 2017). According to Witt, (2016) FAW eggs are pale green or white at the beginning, get covered in scales and turn clear brown to brown before hatching and they hatch within 2 – 3 days. When populations are high, then the eggs may be laid higher up the plants or on nearby vegetation (Monsanto Technology, 2017).

2.1.2 Larval stage

Barlow and Kuhar (2009) stated that there are six developmental instars in fall armyworm as shown in Table 2.1 below. Young larvae are difficult to identify morphologically as the early instars look like those of several other noctuids (Venter, 2017). The larval stage is the feeding stage and this stage is destructive as it feeds on the soft tissue of plants. The rate of larval development is influenced by a combination of diet and temperature conditions, and usually takes 14 to 28 days where the colour changes from green to dark brown (Capinera, 2015; Witt, 2016). To differentiate this larva from other armyworm species, one needs to look at the head of the insect. The fall armyworm's head has a predominantly white, inverted Y-shaped suture between the eyes, black dorsal pinacule with long primary silk and four black stems set into squares on the last abdominal segment (Figure 2.1). Young larvae are greenish or brownish in colour and smooth-skinned. Mature larvae vary from light tan or green to nearly black. They have three yellow-white hairlines down their backs. On each side and next to the yellow lines is a wider dark stripe. The moths have a wingspan of 32 to 40 mm. The mature larvae are usually 3-4 cm long and have 8 pro-legs with an extra pair at the last abdominal segment (Bohnenblust and Tooker, 2012). The identification of fall armyworm larvae and their instar stages was crucial in this experiment and this is shown in Figure 2.1 and Table 2.1 below.

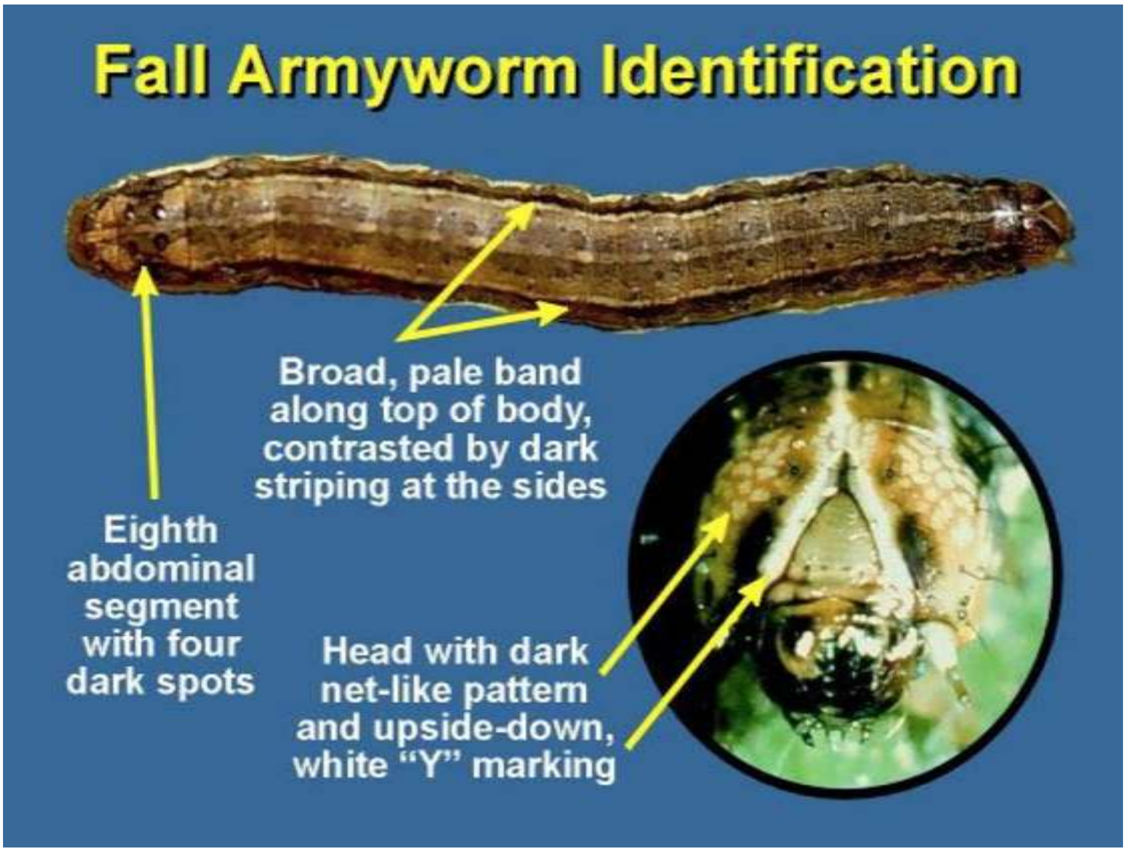


Figure 2.1 Picture identification chart of the fall armyworm. (Photo courtesy of University of Nebraska Department of Entomology)

Table 2.1: Fall armyworm larvae description at different instar stages

Instar number	Body length (mm)	Colour	Markings
1, 2	1.5-3.5	Green with black head	None
3, 4	6-10	Dorsal area tan colour, ventral area green, lateral white/beige stripes visible	Four dark pinacula or raised spots arranged in a square on the 8th abdominal segment and in a trapezoid on the 9th
5, 6	15-40	Light tan,green,black	Four dark pinacula or raised spots arranged in a square on the 8th abdominal segment and trapezoid on the 9th.

Source: (Capinera, 2015)

2.1.3 Pupal stage:

According to Kasina *et al*. (2017), pupation takes place in a soil cell, or rarely between the leaves on the host plant. The pupa requires 7 to 14 days to fully develop. According to Maiga (2017), pupation normally takes place in the soil, at a depth of 2 to 8 cm. The pupal stage of fall armyworm cannot withstand harsh conditions.

2.1.4 Adult stage:

Adults are active during the night especially during warm, humid evenings (Capinera, 2015). The adult female moths are active at night and usually use their natural pre-oviposition period to fly several kilometres before settling for egg-laying. In the male moth, the forewing generally is shaded gray and brown and has triangular white spots at the centre and tip of the wings. Duration of adult life is estimated to average about 10 days (Maiga and Ndiaye, 2017).

2.2 Damage caused by fall armyworm

Abrahams *et al.* (2017) reported that fall armyworm can cause yield losses which range from 8.3 to 20.6 million tonnes in a year if the pest is left uncontrolled in the 12 main maize-producing African countries. The larval stage is the most dangerous stage in the life cycle. The larva causes damage by consuming maize leaf foliage. Young larvae consume leaf tissue from one side, leaving the opposite epidermal layer intact. The second or third instar, larvae begin to make holes in leaves, and eat from the edge of the leaves inward. Feeding in the whorl of maize often produces a characteristic row of perforations in top leaves (Capinera, 2015).

Larval can feed and damage the growing point, a symptom called ‘dead heart’ which prevents any cobs from forming (Maiga, 2017). According to Witt (2016), young larvae hide in the funnel during the day but come out at night to feed on the leaves and therefore control options may be effective at this time. In young plants the stems may be cut, providing evidence of the damage (Reynolds and Merchant, 2015). Large larvae can bore into the developing reproductive structures, such as maize cobs, reducing yield quality and quantity (Maiga, 2017). Figure 2.2 shows the damages that the pest causes on maize plants.

Figure 2.2: Pictures showing damage caused by fall armyworm larvae on maize

Source: FAO (2017)

2.3 Monitoring of fall armyworm

Early fall armyworm damage appears as ‘window paning’ and shot-holes in leaves. If whorl damage exists, scouting of 20 successive plants at 5 different points in the field is recommended. Determination of percentage plants damaged by fall armyworm is important. Whorls are pulled and the leaves are unrolled for larval counting (Monsanto Technology, 2017). Once moths are detected it is advisable to search for eggs and larvae (Capinera, 2015).

2.4 Prevention and control

The literature on control of this pest is extensive (Witt, 2016) due partly to the importance of maize and the importance of lepidopteran pests.

2.4.1 Biological control

Capinera (2015) reported that although several pathogens have been shown experimentally to lower the population of fall armyworm larvae in maize, only *Bacillus thuringiensis* currently is feasible, and success depends on having the product on the foliage when the larvae first appear (Maiga and Ndiaye, 2017). Natural strains of *Bacillus thuringiensis* tend not to be very potent, and genetically modified strains improve performance on controlling lepidopteran pests including fall armyworm (Hardke *et al*., 2017).

2.4.2 Host-plant resistance

Programs to improve resistance to *Spodoptera* species have developed crop varieties with better resistance, as in maize (Vilella *et al.*, 2002). Partial resistance is present in some sweet corn varieties, but it is inadequate for complete protection since the resistance mechanism appears to function through increased toughness of the leaves with a thicker epidermis (Venter, 2017).

2.4.3 Pheromone use for control

The word pheromone comes from the Greek 'pherein', meaning to transfer, and 'hormon', meaning to stimulate. Pheromones are a class of semiochemicals that insects and other animals release to communicate with individuals of the same species (Hailu, 2018). The key to all of these behavioral chemicals is that they leave the body of the first organism, pass through the air or water and reach the second organism, where they are detected by the receiver. The main methods for utilizing an understanding of pheromones to control pests are monitoring, mating disruption, 'lure and kill' or mass trapping and other manipulations of pest behavior (Kieser *et al* (2016).They have also been used to monitor, forecast and control population of pests. Pheromones are used to control insects by two main techniques; mass eradication and mating disruption (Kumela *et al*., 2019). Even if large numbers of male individuals can be caught by coupling pheromone releasers with use of insect trapping devices, the success of pheromone-based control strategies is usually low (Reid and Stiller, 2010).

2.4.4 Integrated Pest Management Programs

Integrated control of *Spodoptera frugiperda* can be facilitated by cultivation practices aimed at destroying wintering sites, improved varieties with resistance to defoliation by conventional mechanisms or the introduction of *Bacillus thuringiensis* crops (Hardke *et al*. 2014)

2.4.5 Chemical control

Several chemicals have been applied for control of fall armyworm. Recommended insecticides for *Spodoptera* species include esfenvalerate, carbaryl, chlorpyrifos, malathion, permethrin, and lamba-cyhalothrin (Maiga, 2017). FAW insecticidal control should be done when egg masses are found on more than 5% of the plants, 50% of the plants have severe leaf damage or when 25% of the plants have leaf damage with live larvae still present (Pitre, 2018). FAW larvae has developed resistance to some insecticides and it varies regionally (Reynolds and Merchant, 2015). However, the effects of chemicals to the environment and escalating prices has been a challenge to many farmers particularly smallholder farmers.

2.4.6 Cultural control

In Zimbabwe some smallholder farmers rely on handpicking and physically crushing the caterpillars and the application of wood ashes and soils to leaf whorls as a way of controlling the pest. Despite the potential of ashes to be a cheap method of controlling FAW, most farmers lack information on the right quantity of ashes to be applied to a plant in order to kill the pest without damaging the crop. Therefore the information from this study is going to equip farmers with adequate information on the defined quantity of ashes effective in controlling FAW.

However, the most important cultural practice is early planting and/or early maturing varieties (Flanders *et al*., 2016). Early harvest allows many maize ears to escape the higher armyworm densities that develop later in the season (Maiga, 2017) Reduced tillage seems to have little effect on fall armyworm populations (Witt, 2016), although delayed invasion by moths of fields with extensive crop residue has been observed (Hardke *et al*., 2014). A clean crop and weeding are always recommended (William, 2016). Scouting is an important factor in determining fall armyworm infestation before it causes economic damage (Flanders *et al.*, 2016).

CHAPTER 3: METHODOLOGY

3.1 Site description

The research was carried out in Ward13 of Karoi district under chief Mudzimu. The area is located about 105 km West of Karoi town. The area falls under agro-ecological region three which normally receives annual rainfall of between 600-750 mm per annum. The rainy season usually starts in the month of November and ends in the month of April, although sometimes it extends into May. The area receives mean annual temperature of 25 degrees. Predominantly, the area has well-drained red-loam soils with pH ranging from 5 to 5.5.

3.2 Experimental Design and Treatment

The randomized complete block design (RCBD) design was used in the experiment with four treatments replicated three times. There was one factor under consideration which was ash dosage. The following treatment were evaluated: 2g of ash, 5g, 10g of ash and a control treatment which was untreated. Slope and soil fertility were used as blocking factor.

Table 3. 1Summarizes the field layout of the experiment.

BLOCK 1
BLOCK 2
BLOCK 3
Border

3.3 Agronomic practices

3.3.1 Land preparation

Land preparation was done using an ox-drawn plough. Harrowing then followed to break clods in order to produce fine tilth. Planting stations were marked with a hoe three days after the effective rains on the 22nd of November 2019.

3.3.2 Planting

The crop was sown with the first rains which were received on the 22nd of November 2019. Planting was done manually and 2 maize seeds were placed on each station. A 90 cm by 30cm inter row by intra-row spacing was used for planting the maize to give a population of 40 000 plants per hectare. Each plot had 4 rows and 15 stations giving a total of 60 plants per plot.

3.3.3 Fertilizer management

Compound D (7 N: 14 P: 7 K) was applied at a rate of 250kg per hectare, thus 6g per planting station and Ammonium nitrate (34.5% N) was used as a top dressing at a rate of 200kg per hectare, which gives us 5g per station. AN was split applied to reduce leaching, so the first 2.5g was applied at 4 weeks after planting and the remaining 2.5g was applied at 10 weeks.

3.3.4 Water management

The research was done during the rainy season and it was a rain fed trial plot. Potholes were put in the inter row so as to conserve some moisture.

3.3.5 Weed management

Weeds were under strict control throughout the growing period. The predominant weeds in the field were the black jack, upright starbar and amaranthus hybridas. Soon after planting the maize, pre-emergence herbicides Metalachlor was applied as a pre-emergence herbicide and Atrazine applied as both pre and post emergence herbicides.

3.3.6 Pests and diseases management

Two weeks after the crop emerged, the researcher scouted for the pest and observed that FAW was found in the whorl of the plants scouted. Each experimental units received treatment on the 14th of January 2020. The ashes were prinked into the whorl of the plant with a FAW larvae.

3.4 Data collection

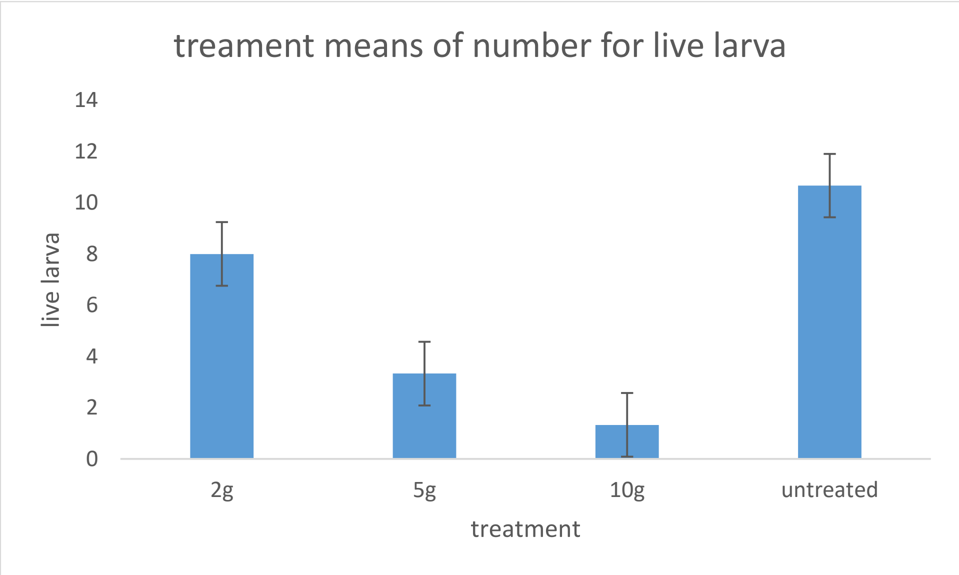
Data was collected at 2 weeks after crop emergence. Larvae on 10 selected plants per each plot were counted and recorded. Then after 6 hours of receiving treatments the plants were examine for all the larvae in the plant whorls.

3.5 Data analysis

Analyses of variance (ANOVA) was done in Genstat software 2014 version. Means were compared using 5% Fisher's Protected LSD.

CHAPTER 4: RESULTS

4.1 Effects of different doses of ash on number of FAW in maize production.



4.2 Effects of different doses of ash on number of FAW

The treatment mean of dead FAW larva varied significantly between treatments (Fig 4.2). Number of dead FAW larva increased progressively with an increase in dosage of ashes. At dosage of 10 g, the highest mortality rate (89.33%) was recorded whereas untreated control recorded zero mortality rate.

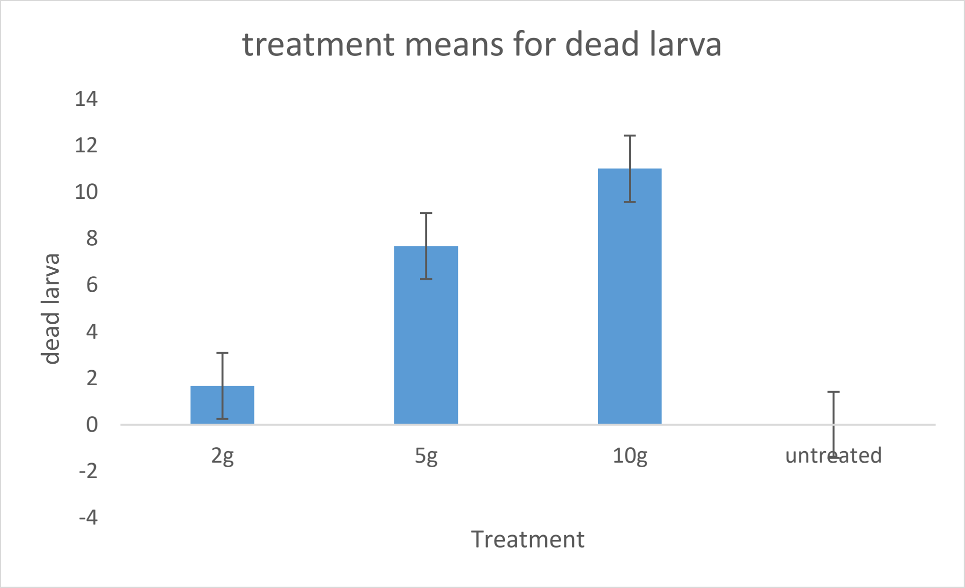


Fig 4.2 Effects of different doses of ash on FAW larva death

CHAPTER 5: DISCUSSION

Amongst the wood ash dosages which were used to control FAW, 10g was most effective as compared to lower dosages and untreated control. Highest number of dead larva was recorded from 10g treated plots whereas highest number of live larva was recorded on untreated control. The results supported the work of Abate *et al.,* (2015) who reported that in the wood ash kill bothersome pests like snails, slugs and some kinds of soft bodied invertebrates. Abate *et al*., 2000 further support the use of wood ash for pest control, where he emphasized on the sprinkling of ashes around the base of the growing plants so that the pest will not climb and get into the plant. Martínez *et al.,* (2017) confirmed the efficacy of applying wood ashes and soils to maize plant whorls in order to control FAW.

The results are linked to the findings of Birhanu (2018) who reported that sprinkling ash on and around plants has a deterrence effect to pests. Lower dosages was less effective in killing the larvae since few salts to kill the pest were produced whereas at higher dosages more salts are produced enough to dehydrate the larva. The results can be linked to the work of Blanco *et al.,* (2010) who clarified that the ash tends to suck the water out of the insect therefore putting a ring of ash around or on plants can keep slugs away. Blanco *et al.,* (2016) added that ashes work on slugs, worms and snails because it is so basic that crawling through it will burn their moist skin whilst ants or anything with an exoskeleton with likely be un-affected thus justifying its selectivity. Forim *et al* (2010) reported the efficacy of spreading wood ash around and then soaking the area with water can control maggots, cutworms, cucumber beetles, squash bugs and slugs and described the effects of ashes as dehydration of soft-bodied insects. Clark *et al*., (2007) added that if the ash gets wet, there is need to refresh the wood ashes as the water will leach away the salt that makes wood ashes an effective pest control.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1Conclusions

Basing on the results from this study, number of dead larva of FAW increased with an increase in dosage rate. On the other hand, the number of live FAW larva was higher in untreated control with mortality rate of zero. The results therefore concludes that high dosages had a greater effect on the FAW larva.

6.2 Recommendations

From the results, farmers are recommended to use 10g of ash as a way to controlling FAW in maize production. The application should be done on the 2nd week after emergence. To researchers further investigations on the side effects of ashes such as damaging the crop should be done. There is need for further investigations on the exact exposure time which can effectively control more FAW larva. The fall armyworm can best be controlled at early stages of growth before much crop damage is done. It also recommended for researchers to explore on other organic amendments that will repel the moth after killing the larvae, so as to prevent the moth from laying more eggs on the crop. The researcher should incorporate this amendments so as to improve the efficiency of ash in controlling FAW. Use of ash is therefore recommended to be considered as a tool for Integrated Pest Management to ensure little harm to the environment.

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APPENDICES

Summary of analysis of variance

Appendix 1: Variate: number of live FAW larva

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	18.167	9.083	3.94	
Replication.*Units* stratum					
Treatment	3	163.667	54.556	23.66	0.001
Residual	6	13.833	2.306		
Total	11	195.667			

Appendix 2: Variate number of dead FAW larva

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	3.167	1.583	0.52	
Replication.*Units* stratum					
Treatment	3	237.583	79.194	26.16	<.001
Residual	6	18.167	3.028		
Total	11	258.917			

Appendix 3: Variate FAW larva mortality rate_%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	71.167	35.583	4.20	
Replication.*Units* stratum					
Treatment	3	16294.917	5431.639	641.11	<.001
Residual	6	50.833	8.472		
Total	11	16416.917			