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Bioactive leaf extracts of thorn apple (*Datura stramonium* l.) as an alternative to synthetic pesticides for fall armyworm (*Spodoptera frugiperda* (J.E Smith) management in maize (*Zea mays* L.)

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ABSTRACT

Maize productivity is still far below its potential as one of the major cereals since 2016 cropping season. Fall armyworm (FAW) (Spodoptera frugiperda J.E Smith) has confirmed to be an invasive, voracious and polyphagous insect pest of economic importance worldwide which has emerged from one season to the next. It requires adoption of low cost alternatives such as the use of botanical pesticides. A laboratory experiment was carried out to assess the potency of bioactive leaf extracts of thorn apple (Datura stramonium l.) as an alternative to synthetic pesticides for fall armyworm (Spodoptera frugiperda (J.E Smith) management in maize (Zea mays L.). Maize foliage diets were used in this study. A Complete Randomised Design (CRD) was used with five treatments replicated three times. Treatments included; negative control (Distilled water), 30% (30grams D. stramonium per 100ml distilled water), 60% (60grams D. stramonium per 100ml distilled water), 100% (100grams D. stramonium per 100ml distilled water) and a positive control (Demise) at label dose. D. stramonium extract was toxic to FAW. Results indicated that there were no significant differences (p>0.05) amongst the D. stramonium dosages (60% and 100%) and the positive control at 6, 8 and 10 hrs. Significant differences (p<0.05) were realized amongst the three treatments (60%, 100% and positive control (Demise)) and the negative control (distilled water). The optimum dose for effective fall armyworm control is 60% D. stramonium concentration. The study recommends the use of D. stramonium as an insecticide at lower dosages of 30% for the control of fall armyworm as it showed efficacy.
Keywords: *Spodoptera frugiperda*; D. *stramonium*; invasive; polyphagous

1. INTRODUCTION

Maize (Zea mays L. is a staple food in Zimbabwe and Southern Africa. It is the major source of carbohydrate in most meals in Zimbabwe (FAO, 2015). In the 2016/2017 season, maize production went down to 35%, which was one third lower than the previous season (FAO, 2017). In Zimbabwe, the maize crop has suffered severe attack as from 2016 agricultural season from the problem pest, fall armyworm (FAW) S. frugiperda (Prasanna et al., 2018). According to FAO (2017) and Muturiki et al. (2019), invasive fall armyworm presents significant threats to maize production and food and nutrition security in Zimbabwe, including maize production areas in the region.

Several authors have indicated that Spodoptera frugiperda is a Lepidopteran pest that feeds in large numbers of leaves and stems of more than 100 plant species, causing major damage to economically important cultivated grasses such as maize, rice, sorghum, sugarcane as well as some vegetable crops and cotton (Capinera, 2000; CABI, 2018a) but has a strong preference for maize. S. frugiperda can destroy 40–70% of maize yield (Day et al., 2017). One adult can lay between 1000 and 1500 eggs (Capinera, 2000) which hatch into feeding larva. According to Rose et al. (1975), the moth of S. frugiperda can travel up to 2000 km each year in search of warmer climates.

FAO (2017) highlighted that the fall army worm (S. frugiperda) originated from Central and South America and found itself into Southern Africa in 2016 and then reached Zimbabwe that same year; 2016). (Maes, 2018) postulated that infestation by fall armyworm could potentially reduce crop yields by 21% to 53% over a three-year period across African countries where the pest has been found. Reports by FAO (2017) postulated that fall armyworm will cause an estimated $3 billion losses in maize yield. The FAW (S. frugiperda) has costed Africa over $13 billion as experts warn the pest has come to stay on the continent (Kebede, 2018).

In the face of potentially devastating losses due to FAW, many stakeholders have turned to chemical pesticides for control. Day et al. (2017) suggested that the preferred management option for FAW is integrated pest management (IPM)), based on utilizing a combination of control methods that is sustainable, cost-effective and causes minimal risks to humans and the environment. FAO (2018b) stated some pesticides which are reported as being used for FAW management which include methomyl, methyl parathion, endosulfan and lindane, all of which are classified as highly hazardous pesticides (HHPs). They have high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems and pesticides that cause severe or irreversible harm to health or the environment under conditions of use in a country" (FAO, 2016).

Evidence from different African countries illustrates that improper use of chemicals is causing loss of life and negative repercussions on human health, and other problems associated with their use are loss of efficacy, regulatory restrictions as a result of adverse effect on non-targeted organisms and eco-toxicity (FAO, 2003; Lorini et al., 2007). Farmers are putting themselves at risk using toxic products about which they know little and/or do not have the suitable personal protective equipment to adequately manage risks (Bateman et al., 2018). Given the concerns posed by pesticides, the development of low-risk management approaches using biopesticides for FAW based on biochemical, microbial or microbial pest management products is high on the list of near-term activities identified in action plans for affected countries in Africa, at both national and regional level.

Numerous plant species have pesticide properties and some offer an effective alternate to synthetic chemicals for pest management for poor farmers. Stevenson et al. (2017) highlighted that the promotion of these botanical plants especially those with optimized applications are based on knowledge of the active plant chemical greatly benefit such resource poor farmer. Botanical pesticides have long been publicised as smart alternatives to synthetic chemical pesticides for pest management because botanicals reputedly pose little threat to the environment or to human health. The body of scientific literature documenting bioactivity of plant derivatives to pests continues to expand, yet only a handful of botanicals are currently used in agriculture (El-Wakeil, 2013).

Several plant extracts have insecticidal properties against stem borers infesting cereals in Africa. These include Neem (Azadirachta indica), Acacia (Acacia sp.), Fish-poison bean (Tephrosia vogelii), Wild marigold (Tagetes minuta), Wild sage (Lantana camara), Jatropha (Jatropha curcas), Chillies (Capsicum sp.), Onion (Allium cepa), and Tobacco (Nicotiana tabacum) (Shazzadul, et al., 2017; Sakadzo et al., 2020). Among many other botanicals, extracts of plants such as Azadirachta indica, Milletia ferruginea, Croton macrostachyus, Phytolacea docendra, Jatropha curcas, Nicotina tabacum and Chrysanthemum cinerariifollium have been used successfully to control insect pests (Jirnmci, 2013; Schmutterer, 1985). Silva et al. (2015) reported high larval mortality of FAW using seed cake extract of A. indica. In recent studies, ethanolic extracts of Argemone ochroleuca (Papaveraceae) caused FAW larval mortality due to a reduction in feeding and slowed larval growth (Martínez et al., 2017).

Datura stramonium L. is a member of solanaceae family, is widely distributed all over the world and easily accessible. Gaire and Subedi (2013) have reported that the plant height is between 90-125cm or greater than that, with smooth, light weight, thin, stem. Ovate, furcated, spiny leaves 6-18cm with light green in colour has dark veins, leaves has repulsive and pungent taste and eggs shaped capsular immature green fruit contains spines and after maturation fruit splits into four chamber obtain numerous black seeds. Gaire and Subedi (2013) highlighted that Datura stramonium plant generates a characteristic odour that acts as repellent for various insects and pests. Kurnal et al. (2010) have reported that the ethanol extracts of Datura stramonium leaf and seed showed potent acaricidal, repellent, and oviposition deterrent activity against insect pests.

There is partial or no documented information on the efficacy of Datura stramonium on fall armyworm. Therefore, this research sought to assess the potency of bioactive leaf extracts of thorn apple (Datura stramonium L.) as an alternative to synthetic pesticides for fall armyworm (Spodoptera frugiperda (J.E Smith) management in maize (Zea mays L.).

2. MATERIALS AND METHODS

2.1 Study Site

The experiment was carried out in the chemistry laboratory located at 20°6.137'S and longitude 30°51.688'E at the Great Zimbabwe University (GZU) main campus in Masvingo, Zimbabwe. Figure 1 shows the site map of Great Zimbabwe University. Rainfall is erratic, characterized by frequent dry spells. The area receives an average of 450-650 mm rainfall per annum. Mean annual temperatures range from 15^0C to 25^0C (Meteorological Service Department, 2017).

2.2 Experimental design

The experiment was arranged as a complete randomised design (CRD) with five treatments replicated 3 times as shown in Table 1.

2.3 Experimental procedure

D. stramonium leaves were harvested in the wild. Leaves of fully grown plants were washed to remove soil particles. The material was then cut into pieces and shed dried for one month. After drying, the material was crushed into powder form manually using a traditional mortar and pistil. Further grinding was done by using an electric mortar. Three concentrations of D. stramonium were made on the basis of weight and volume (extract powder: distilled water) ie 10 grams of extract powder was added to 100ml of distilled water to give 10 % concentration of aqueous following the protocol used by Sakadzo et al. (2018). Distilled water was used as the control. Demise was diluted as per label recommended instructions.

2.4 Collection and preparation of maize leaf foliage

Protocols by Birhanu et al. (2019) and Sakadzo et al. (2020) were followed.

2.5 Data collection

Confirmation of death of the FAW caterpillars was done by pricking the insect body with a needle. FAW caterpillar was considered dead if it could not right itself after being placed on its dorsal surface (Sakadzo et al., 2020).

2.6 Data analysis

Square root transformation was used to transform the collected data. Data was analyzed by using GenStat Version 2013. Means were separated using Fisher's Protected Least Significant Differences (LSD) at 5% significance level.

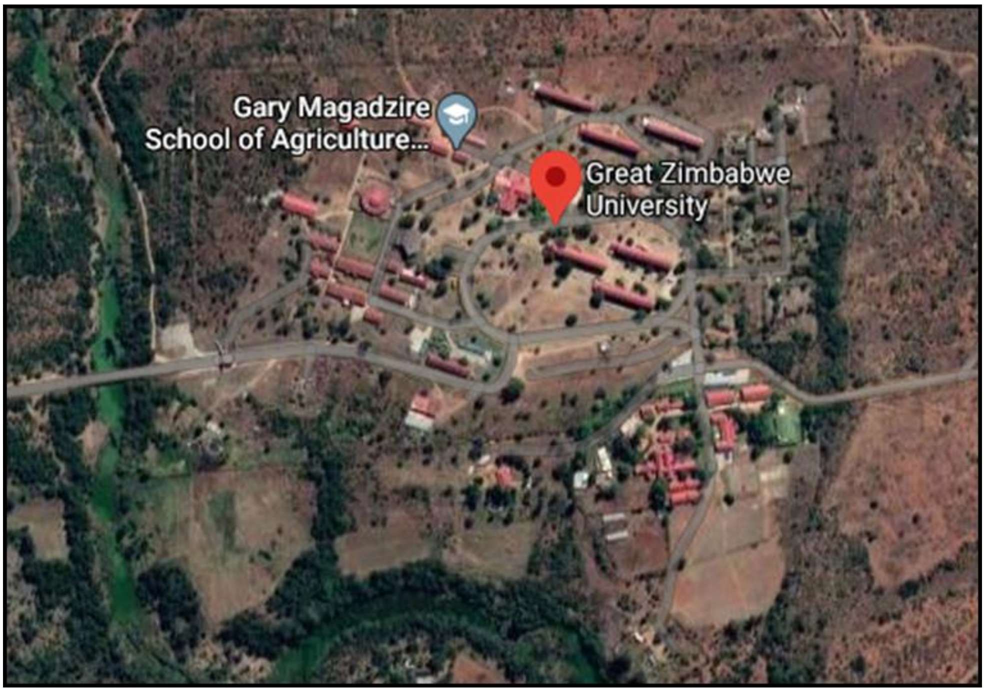

Figure 1: Site map of Great Zimbabwe University. Source: Google map (2020)

Table 1: Treatment description

Treatment	Pesticide	Rate of pesticide
1	*Datura stramonium*	30g/100ml wv (10%)
2	Demise (Positive control)	0,002ml/100ml
3	*Datura stramonium*	60g/100ml wv (90%)
4	*Datura stramonium*	100g/100ml wv (100%)
5	Negative control (Distilled water)	0g/100ml (0%)

3. RESULTS

3.1 Effect of D. stramonium crude leaf extracts on mean FAW mortality at 2 and 4 hours after treatment

Results of the effect of crude leaf extracts of D. stramonium on the mortality of FAW after 2 and 4 hours are summarized in table 2 and Fig 2. There were no significant deaths (zero deaths) among the different extract concentrations and the negative control in the first four hours of treatment. However, the positive control recorded one death which was significantly higher (p= 0.003) than the rest of the treatments (Fig 2).

3.2 Efficacy of thorn apple (D. stramonium) against FAW larva

During the initial stages of the experiment, zero fall army worm mortality was recorded on 10% D. stramonium, Negative control and 60% D. stramonium concentrations. Results obtained showed that there were significant differences (p<0.05) amongst the four treatments when compared to the positive control (Demise) in terms of fall armyworm mortality. Positive control and 100 % D. stramonium concentrations scored the highest fall armyworm mortality as from 4hrs to 10hrs whilst 10% D. stramonium and negative control scored the least

3.3 Effect of D. stramonium crude leaf extracts on mean FAW mortality 6 hours after treatment

After six hours, results showed that the 60% and 100% leaf extract doses recorded significantly higher FAW mortalities (p=0.003) than lower doses. The 60% and 100% leaf extract dose FAW mortalities were however not significantly different from the mortality caused by the positive control where a synthetic insecticide Demise was used (Figure 3).

3.4 Effect of D. stramonium crude leaf extracts on mean FAW mortality 8 hours after treatment

There were no significant differences (p>0.05) amongst the D. stramonium leaf extract treatments but significantly different from the negative control and positive control. However, the positive control (Demise) scored the highest (2.57) fall mortality which was significantly higher (p=0.046) than the negative control which recorded no mortality as shown in figure 4.

3.5 Effect of D. stramonium crude leaf extracts on mean FAW mortality 10 hours after treatment

Obtained results showed that there were no significant differences amongst the four treatments (30%, 60%, 100% D. stramonium leaf extract concentrations and Positive control (Demise). However, the mentioned treatments were significantly different (p<0.05) from the negative control (distilled water). Positive control (Demise) recorded the highest mortality (1.3) whilst negative control (Distilled water) recorded the least (0) (Figure 5).

3.6 Discussion

3.6.1 Efficacy of thorn apple (D. stramonium) against FAW larva

Results realized showed that D. stramonium was efficacious against fall armyworm larvae at all tested doses. However, the lower dose of 30% took longer to begin to cause FAW mortality (8 hrs) as compared to higher doses which started to cause FAW mortality earlier after 6 hours. For the 30% D. stramonium leaf extract concentration there was no hourly mortality of fall armyworm larvae until the 8th hour. Once the lowest concentration began to be efficacious, the mean FAW mortalities it caused were not significantly different from higher leaf extract doses. Results concurs to findings by Jawalkar et al. (2016) who indicated that D. stramonium was efficacious to rice weevil (Sitophilus oryzae L.) even at lower dosages, an increase in mortality was observed with dosage increase. This observation of toxic effects at low concentration of botanical insecticides is corroborated by Aniszewski (2007) who reported that botanical insecticides are efficacious even at low concentrations. This might be due to the interaction of phytochemicals and the FAW larvae at early stages. Fatma et al. (2013) postulated that these phytochemicals are important for mediating interactions between plants and their biotic environment and do not have apparent function in physical or biochemical processes.

It has been reported that all Datura species contain atropine alkaloids such as scopolamine, hyoscyamine and atropine, primarily in their seeds and flowers (Oseni et al., 2011) which might have caused mortality of the fall armyworm larvae. Gaire and Subedi (2013) highlighted that Datura stramonium plant generates a characteristic odour that acts as repellent for various insect pests due to the presence of alkaloids. Fatma and Bahia (2013) reported that alkaloids interfere with neuroendocrine control by inactivating the acetylcholinesterase in treated larvae. Some authors have declared that tropane alkaloids effects range from being stimulatory, narcotic, toxic and can cause death even on low doses (Hassine et al., 2013; Diaz, 2015). Kurnal et al. (2010) have reported that the ethanol extracts of Datura stramonium leaf and seed showed potent acaricidal, repellent, and oviposition deterrent activity against insect pests.

Phytochemicals have been shown to have insecticidal and feeding deterrent activities against various insects (Adeniyi et al., 2010; Gurib-Fakim et al., 2006). Alkaloids are cyclic organic compounds containing nitrogen in a negative oxidation state; they are widely distributed in plant kingdom (Bruneton, 1999) and constitute an interesting family synthesized and accumulated by several plants (Hartmann, 1996). Alkaloids have previously been reported as the most important group of natural substances playing an important role in the ecology of organisms which synthesize them. For example, it has been suggested that they constitute part of the plant defenses against phytophagous animals along with terpenoids, phenols, flavonoids and steroids (Kubo, 2006; Cox, 2004; Rattan, 2010). These compounds are insecticidal at low concentrations, their mechanism of action differ, but many affect acetylcholine receptors in the nervous system (for instance nicotine) or membrane sodium channels of nerves (for instance veratrin) (Aniszewski, 2007).

The insecticidal activity of crude leaf extract of D. stramonium may also be attributed to the presence of scopolamine, hyoscyamine and atropine which are associated with the alterations in the feeding behaviour, interaction with hormones that regulate the growth and causing death at different stages of development (De Geyter et al., 2007; Ikbai, 2010).

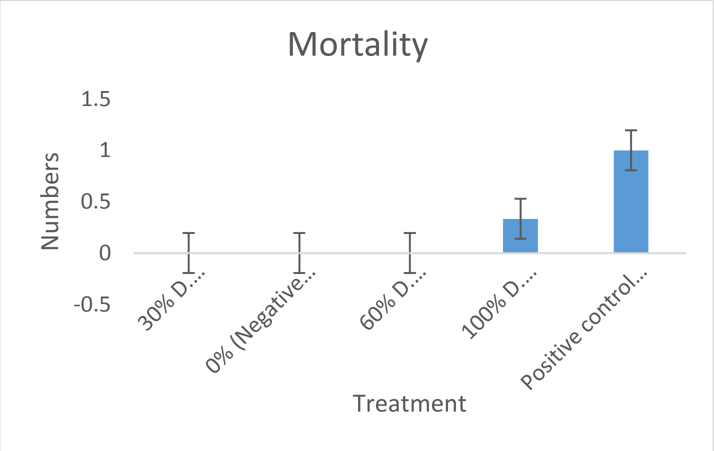

Figure 2: FAW mortalities after exposure to *D. stramonium* concentrations at 2 ad 4hrs

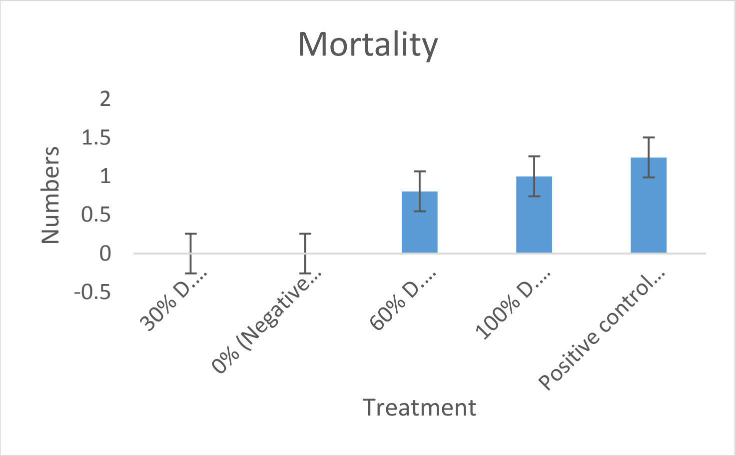

Figure 3: FAW mortalities after exposure to *D. stramonium* concentrations at 6hrs

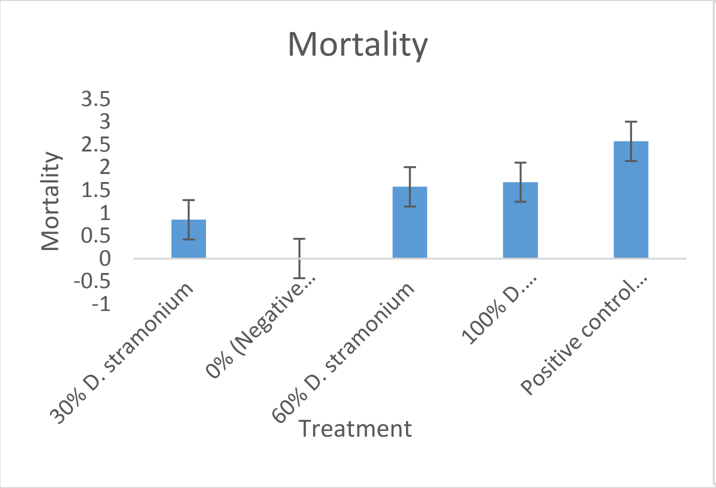

Figure 4: FAW mortalities after exposure to *D. stramonium* concentrations at 8hrs

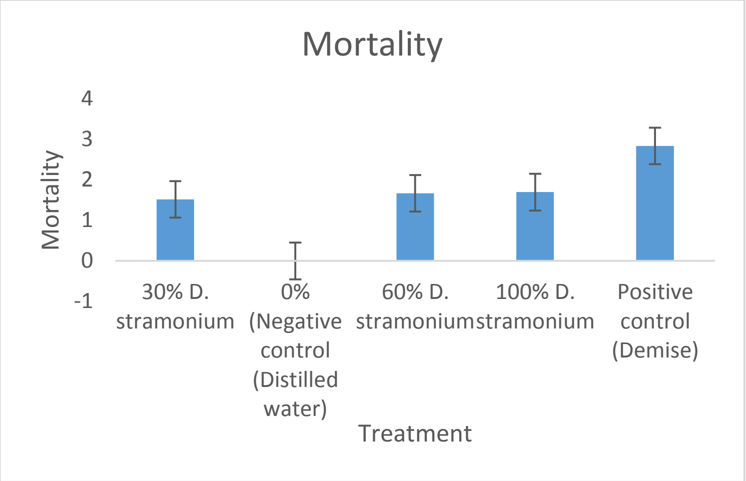

Figure 5: FAW mortalities after exposure to *D. stramonium* concentrations at 10hrs

4. CONCLUSIONS

D. stramonium was efficacious against fall armyworm larvae at all the tested dosages. According to this study, the optimum dose for effective fall armyworm control is 60% D. stramonium since it was not significantly different from 100% D. stramonium concentration, but significantly different from positive control (Demise) in terms of FAW mortalities after 10 hours of exposure to treatments..

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