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The Effectiveness of Hot Pepper (*Capsicum Frutescens* L.) Extracts in Managing Major Pests of Cabbage (*Brassica Oleracea* L.) Under Rain Fed Conditions

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ABSTRACT: *A field experiment was carried out in Makonde District, Mashonaland West Province of Zimbabwe to evaluate the effectiveness of hot chilli pepper (Capsicum frutescens l.) extracts in managing major pests of cabbage (Brassica oleracea l.) under rain fed conditions during 2017/2018 rainy season. A Randomised Complete Block Design (RCBD) with 4 different concentrations of hot chilli pepper extracts (0.02 m/v, 0.04 m/v, 0.06 m/v and 0.08 m/v), synthetic insecticide (Imidacloprid+ beta cyfluthrin[a]) as the positive control and no insecticide application as the negative control was used in the study. Diamond back moth (DBM), cabbage looper, cross stripped cabbage worm, snails, cabbage webworm, aphids colonies, ladybird beetles, wasps were counted at 2, 4, 6, 8 and 10 weeks after transplanting. The number of damaged leaves were counted at physiological maturity of the cabbages. Marketable yield of cabbages was also accessed at physiological maturity. Data was analyzed using Genstat (version 10.3DE) Discovery 11thEdition (VSN International Ltd., 2015). There were significant differences in the mean counts of diamond back moth, cabbage looper, cross stripped cabbage worm, common snails, cabbage webworm and cabbage aphids due to different application rates of hot chilli pepper extracts, chemical insecticide application and no insecticide application ($p>0.05$). At 2 and 4 weeks after transplanting, there were significant differences in the mean counts of beneficial insects (wasps) due to different application rates of hot chilli pepper extracts, chemical insecticide application and no insecticide application ($p>0.05$). The treatment of hot chilli pepper extracts at 0.08 m/v concentration had the highest marketable yield whilst the treatment of no insecticide application had the lowest marketable yield. The study concluded that effectiveness of hot chilli pepper extracts in controlling major pests of cabbages was 0.08m/v. From the study it was recommended that farmers use hot chilli pepper extracts at 0.08m/v concentration as alternative to synthetic insecticides for effective control of major pests such as diamond back moth, cabbage looper, snails, cabbage webworm, cross stripped cabbage worm and cabbage aphids.*

Keywords: *Hot chilli pepper extracts, Cabbage, Rain-fed conditions.*

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I. INTRODUCTION

Cabbage (*Brassica oleracea*) is a biennial leafy plant that belongs to the Brassicaceae family which consists of crops collectively referred to as crucifers (Richardson, 2012). The crop originated from the Mediterranean region and is closely related to crops like broccoli, cauliflower and Brussels sprouts (Gibson, 2012; Mochiah *et al.,* 2011). It is a vegetable crop that has adventitious roots, grows close to the ground and has leaves that can either be tightly compacted or loose (DAFF, 2011). Cabbage has colours which range from green to purple and these colours are used to classify cabbage into green, red or Savoy types (Gibson, 2012). *Brassica oleracea* forms a head at the center of the plant as the number of leaves increases; the head is as a result of vegetative terminal buds formed by leaves that develop over the stem (Richardson, 2012). The head of cabbage varies in shape from round, pointed to flat but green round-headed cabbages with white interior leaves are more common (Gibson, 2012).

Cabbage grows best in the cool season, under moist weather conditions (Richardson, 2012). The average optimum temperature for growth and development of cabbage is 18^{o}C, with an average maximum of 24^{o}C and an average minimum of 4.5^{o}C (FAO, 2015). It requires well-drained soils, fertile soil that range from light sand to heavy clay soils (Mochiah *et al.,* 2011). The pH that is most suitable for cabbage production in the region of 5.8 – 6.3 (Richardson, 2012). Though they can be grown all year round, the peak production period in the south of the Sahara is from November to March because of conducive climatic conditions particularly temperature and rainfall.

Nutritionally, cabbage is of high importance due to its high contents of vitamin A, B and C, magnesium, potassium and also manganese (Adeniji *et al.,* 2010; Meena et al., 2010; Hasan and Solaiman, 2012). Cabbage is also used in the medical field because it possesses some medicinal properties (Tendaj and Sawicki, 2012). It contains glutamine which has anti-inflammatory properties (Caunii *et al.,* 2010) and anti-oxidative compounds which prevent cancer (Tendaj and Sawicki, 2012).

The economic importance of cabbage is mainly highlighted in its contribution to national income accounting, especially for developing countries (Mochiah *et al.,* 2011). In Zimbabwe, it accounts for approximately 3.5 to 4.5% of Gross Domestic Product (GDP) and it also contributes towards foreign exchange earnings (Zimtrade, 2015). Cabbage is cultivated in both rural and urban settings, where it creates employment both in the commercial and subsistence sector of agriculture (Akter *et al.,* 2011). The crop also creates employment for supporting industries such as seed houses, agro-chemicals manufactures, processing and marketing as well as the distribution industries (Nyagumbo *et al*., 2016).

Despite the various benefits that are associated with cabbage production and consumption, it is prone to insect pests' infestation (Mochiah *et al.,* 2011). It is infested by a variety of pests at different growth stages, resulting in significant crop damage (Timbilla and Nyarko, 2004). The main damage to cabbage by insect pests is the damage to the cabbage head and the growing apexes which reduce both quality and quantity, notwithstanding financial benefits negated (Mochiah *et al.,* 2011). Insect pests' damage in cabbage may cause total yield losses of up to 70% of the total yield (Selvamuthukumaran and Baskaran, 2010). Some of the major pests of *Brassica oleracea* are aphids *(Aphis brassicae)*, diamondback moth *(Plutella xylostella)*, cabbage webworm *(Helula undalis)*, cabbage white butterfly (*Pieris brassicae)* and the cabbage looper *(Trichoplusia Ni* (Hübner). However, insect pests of the order Lepidoptera are the most detrimental on the overall productivity of cabbage (Mochiah *et al.,* 2011).

The most common method of controlling insect pests in cabbage is chemical control; it has wide use globally, regionally and locally. Globally, the use of chemicals to control insect pests in cabbage is wide spread. Reports indicated that more than 80% of cabbage farmers use chemical control though some now use it in conjunction with other control methods (Cooper and Hans, 2007). In West Africa, as shown by a survey of cabbage Production Constraints in Ghana, chemical control is also the most common method of controlling insect pests though it has a number of challenges to small holder farmers (Timbilla and Nyarko, 2004).

In South Africa, emphasis is on chemical control through the use of registered chemicals (FAO, 2015). In Zimbabwe, chemical control is used by both small scale and large scale cabbage producers (Nyagumbo *et al*.,

2016) Chemical control methods are widely preferred because of their effectiveness and ready availability of the chemicals (Mkandla, 2008). Insecticides are widely used in the control of insect pests in cabbage and they are considered to be among the major reasons behind the increase in cabbage productivity (Timbilla and Nyarko, 2004; Cooper and Hans, 2007).

Regardless of their positive effects on cabbage production, intensive use of insecticides is now being discouraged due to toxicity to humans and other animals (Rauh *et al.,* 2011). Insecticides lead to environmental contamination such as water and land pollution as well as insect pest resistance and loss of biodiversity (Angbanyere and Baidoo, 2014). Of major concern is water pollution, whereby toxic compounds introduced into water bodies resulting in negative effect on irrigation, domestic use and recreational use of water (Rauh *et al.,* 2011).

In an attempt to avoid the negative environmental effects of convectional insecticides, attention has been shifted to the use of botanical insecticides (Coulibaly et al., 2007). Botanical insecticides are naturally occurring chemicals with insecticidal properties that are extracted from plants (Regnault-Roger and Philogène, 2008). Generally botanical insecticides have minimal negative environmental effects and they are more sustainable compared to conventional insecticides (Buss and Park-Brown, 2002).

These plants are usually locally available and they reduce costs of production because they are obtained at zero or minimal cost (Devanand and Rani, 2008). In addition, botanical insecticides result in reduced insect pest resistance and also have low phytotoxicity. Examples of plants that can be used as botanical insecticides include hot pepper chilli (*Capsicum frutescens)*, tobacco (*Nicotiana tabacum),* garlic (*Allium sativum),* ginger (*Zingiber officinale),* neem (*Azadirachta indica), lemon bush (Lippia javanica)* and sweetsop (*Annona squamosa) (*Ahmed et al., 2009)

A study carried out in Pakistan showed that neem, tobacco, datura and akk extracts were all effective in controlling diamondback moth in cauliflower (Mari, 2012). Neem extracts were the most effective in controlling diamondback moth at the larval stage (Mari, 2012). Different pesticidal plant extracts were evaluated against major cabbage insect pests in Uganda and the results indicated that *Euphorbia tirucalli, Jatropha curcas* and *Phytolacca dodecandra* extracts all reduced populations of all major cabbage pests (Mwine *et al*., 2013).

In Nigeria, neem (*Azadirachta indica*) and garlic (*Allium sativum)* extracts were used to in the control of storage pests in cereal grains and results showed that they are suitable for the control of storage pests (Onu, 2016). Locally in Zimbabwe, *Lippia javanica* extracts were used against rape aphids and tomato red spider mites in rape and tomatoes respectively (Muzemu *et al*., 2012) Results indicated that *Lippia javanica* had was effective in controlling aphids and red spider mites on rape and tomato respectively but its efficacy varied with the period of treatment application probably due to chemical composition of the plant species used (Muzemu *et al*., 2012; Ngowi *et al.,* 2007).

The use of plant extracts as insecticides is on the increase because they are easily biodegradable and also they are safe to both users and consumers (Singh *et al*., 2001). Extracts of plant origin have different modes of action in the control of insect pests; they can either be antifeedants or toxicants whilst some are repellents (Tohamy *et al*., 2002). Repellant plant extracts protect crops against insect pests with minimal impacts on the ecosystem and non-target pests (Hussein *et al*., 2014). In some studies, different concentrations of garlic juice were used to control the common house fly (*Musca domestica*) and the results revealed that mortality rates caused by the garlic juice were comparable with those obtained with convectional insecticides (Gareth *et al.,* 2006).

The insecticidal properties of hot chilli pepper are attributed to a group of chemicals called capsaicinoids that is found mainly in the fruit (Dastagir *et al*., 2012). Capsaicinoids include chemicals such as dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin, homodihydrocapsaicin and capsaicin (Vinayaka *et al*., 2010). Capsaicin accounts for up to 70% of the total capsaicinoids in hot chilli pepper and it causes irritation when it comes in contact with insect pests and it also gives off a burning sensation (Dastagir *et al*., 2012). It has a pungent smell which also gives anti-fungal, anti-bacterial properties that help to protect plants (Vinayaka *et al*., 2010).

In some studies, carried out in Ghana, extracts of hot chilli pepper (*Capsicum frutescens)* have been used to control pests of different crops such as cucumbers, tomatoes and wheat *(*Fening *et al.,* 2011), in these studies different water extracts of hot chilli pepper were used to control insect. The effectiveness of using different concentrations of hot chilli pepper extracts in the management of major pests of cabbage has not yet been fully explored. Therefore, this study aims to assess the effectiveness of different concentrations of hot chilli pepper extracts in the management of major pests of cabbage under rain fed conditions.

Developing countries are facing problems of environmental pollution and health risks as a result of use and/or misuse of convectional pesticides (Mkindi *et al*., 2015). Farmers in Zimbabwe are also facing the same problems of environmental pollution and health risks due to use and/or misuse of convectional pesticides (Horticultural Promotion Council, 1998). Small holder farmers are also struggling to cope with the high costs and sometimes unavailability of convectional pesticides that are used in cabbage production (Proctor *et al*., 2000). Insect pests are becoming resistant and resilient to convectional insecticides due to their ability to rapidly change their genetic material through mutations and this is negatively affecting cabbage production (Dinham, 2003). Alternative ways of controlling insect pests without inflicting insect pests' resistance and resilience need to be devised. The use of convectional pesticides as a primary method of controlling pests in cabbages is thought to be causing phytotoxicity and it has residual effects (Moyo, 2000). The residual effects of the chemicals are posing health risks to consumers and other animals. Consumers in both local and export market are now advocating for organic vegetables that are grown with minimal use of agro-chemicals in an effort to avoid health risks (Proctor *et al*., 2000).

There is need to evaluate the suitability of extracts of hot chilli pepper as botanical insecticides in the management of major pests in cabbage. The findings of this research will help in reducing the continued use of convectional insecticides which have high risks of causing phytotoxicity and chemical residual effects. It will also assist in coming up with environmentally friendly as well as cost effective methods of controlling insect pests in cabbage, especially for smallholder farmers.

Although it is known that hot chilli pepper has insecticidal properties, the research findings will help in establishing the most effective application rate of hot chilli pepper extracts in the management of major pests of cabbage under rainfed conditions, high temperature and high humidity. Effects of hot chilli pepper on non-target organisms and beneficial insects of cabbage will also be established. The findings of this research will also help in ascertaining the economic benefits of using hot chilli pepper as a botanical pesticide in cabbage production.

II. MATERIALS AND METHODS

Description of the study area

The study was conducted in Ward 11 of Makonde District in the Mashonaland West province of Zimbabwe. The study site is in the agro-ecological region 2a which is characterized by annual rainfall that ranges between 750mm to 1050mm with 15 to 18 pentads per season (Vincent and Thomas, 1960). The experiment site is also characterized by warm summers and cool winters, with temperatures ranging between 20 to 27ºC and 5 to 19ºC respectively (Vincent and Thomas, 1960). Intensive production of crop such as tobacco, wheat, barley and maize is practiced in the agro-ecological region as well as intensive livestock production involving dairy, poultry, beef and pig production (FAO, 2010). The study area has a gentle north-east facing slope and the soils are sandy loams. The pH for the soils is slightly acidic with a value of 6.2 (ZFC soil analysis, 2017).

Preparation of hot chilli pepper extracts

Ripe, disease and blemish free hot chilli pepper fruits were collected and dried in a shade, until they achieved a constant weight. They were kept away from sunlight to prevent photo-oxidation of the active ingredients (Mwine *et al*., 2013). Dried hot chilli pepper fruits were ground into powder using a mortar and pestle. Three different masses of hot chilli pepper i.e 20g; 40g; 60g and 80g were weighed using a kitchen scale. Each of the weighed hot chilli pepper portion was mixed with 1 litre of distilled water and the extracts were set in a muslin cloth and squeezed to avoid blockages of the knapsack during spraying operations. Three drops of liquid soap were added and mixtures were stirred and were then stored in bottle containers. Hot chilli pepper extract concentrations of 0.02, 0.04, 0.06 and 0.08 mass/volume (m/v) were prepared 24 hours before use. The extracts were stored at room temperature (24 ^{o}C), away from sunlight and they were strained right before use by means of a tea strainer.

Experiment management

Description of variety used in the experiment

The variety used for the experiment was Capture from Klein and Karoo (K_2) seed house. It is a hybrid variety which takes between 8-12 days to germinate (Klein and Karoo, 2016). Capture is an all year round variety that takes between 80- 100 days to reach physiological maturity. It takes 18-24 day from germination to transplanting. The variety produces green round-headed cabbages with white interior leaves (Klein and Karoo, 2016).

Field operations

Land preparation was done by digging using a hoe and clods were broken manually to achieve a fine tilth. Plot size measuring 4 X 2m were marked prior to planting and each plot had three rows of seven plants each, using in-row spacing of 0.5m and inter-row spacing of 0.5m. The gross plot area was 8m^2 and the net plot area was 1.5m^2. Pathways of 1m were left between each experimental plot. Basal fertilizer of Compound D (N_7:P_{14}:K_7) at a rate of 15g per planting station (600kg/ha) was applied before transplanting.

Weeds control was by mechanical means, using a hoe and hand pulling starting at 2 weeks after transplanting and then once in every 2 weeks thereafter. Hoeing was done cautiously in an effort to avoid damaging the roots of the crop. Mechanical weed control was preferred over other methods of weed control because it is cheap and environmentally friendly.

Ammonium nitrate (34.5%N) was applied as top dressing fertilizer in split application, firstly at 3 weeks after transplanting and lastly at 6 weeks after transplanting. At 3 weeks after transplanting, it was applied at a rate of 5g (200kg/ha) per planting station, whilst at 6 weeks it was applied at a rate of 3.75g (150kg/ha) per planting station. Application of insecticides was done as per treatments requirements shown in Table 3.1. It was done at 14 days' intervals, starting from 2 weeks after transplanting. Scouting for any signs of diseases was done periodically using the zig-zag scouting technique.

Harvesting was done when the fruit capsule had ripened and the stem had turned from green to yellow. It was done mechanically by bending the head to one side and cutting it with a sharp knife.

Experimental design and treatments

Randomized Complete Block Design (RCBD) was used for the experiment as it allowed for the randomization and replication of treatments. The experiment had six different levels (Table 1). The six treatments that were used for the experiment were randomly assigned to the plots, making one block. The blocks were replicated three times, to give a total of 18 experimental plots.

Measurements

All the measurements were taken starting from 2 weeks after transplanting and at 14 day intervals up to physiological maturity of cabbage. The measurements were taken on a net plot area of three plants that were randomly selected from the middle row. The three plants that were randomly selected from the middle row were marked and they were used for all the measurements that followed. Outer rows and plants on the edges were not considered in taking measurements. This was done to eliminate the border effects. All measurements were done early in the morning, before the insects became active.

Insect pests' counts

Insect pests' counts were done on the three randomly selected plants from the middle row just before spraying and then repeated three days after spraying. The direct counting method was used to determine presence levels of diamond back moth, cabbage looper, cross-stripped cabbage worm, snails and cabbage web worms (Mwine *et al*., 2013). This determined the number of eggs, larvae, pupae and adults of each insect pest on the leaves of the three randomly selected plants from the middle row. When cabbage leaves had started folding, they were opened up to enable direct counting of each of the insect pests (Mwine *et al*., 2013).

The direct counting method was done without removing the insect pests and it was assisted by hand lens to accurately identify small eggs of insect pests. It gave particular emphasis to each stage of insect development i.e eggs, larvae, pupae and adult stage. The direct counting method took into consideration both live insect pests and dead bodies of insect pests. The amount of insect pests' at each stage of development was counted and recorded just before spraying and then repeated three days after spraying at each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage. This procedure was done on the three randomly selected plants from the middle row at each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage.

For cabbage aphid infestation, assessment was done by determining the leaf area covered by aphids' colonies on the three randomly selected plants from the middle row. The assessment was done on three upper leaves of each of the three randomly selected plants from the middle row, just before spraying and then repeated three days after spraying. This procedure was done at each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage.

Beneficial insects count

The direct counting method was used to determine presence levels of ladybird beetle (natural enemy of cabbage aphids) and wasps (natural enemy of cabbage looper). It was done on the three randomly selected plants from the middle row just before spraying and then repeated three days after spraying. Particular emphasis was given to each stage of insect development was i.e eggs, larvae, pupae and adult stage, the amount of insect pests' at each stage of development was counted and recorded. The direct counting method took into consideration both live insect and dead bodies of insects. This procedure was done at each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage

Number of damaged leaves

The number of damaged leaves was measured by physical counting of leaves and heads that showed insect pests damage on the three randomly selected plants from the middle row. The counts were done 24 hours after each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage.

The extent of leaf damage was obtained by estimating the damaged area of cabbage leaves using a squared paper grid (Mwine *et al*., 2013). This was done on the three upper leaves of the three randomly selected plants from the middle row. The estimates were done 24 hours after each fortnightly insecticide application from 2 weeks after transplanting up to physiological maturity of cabbage.

Marketable yield

The mass of marketable cabbages harvested from the three randomly selected plants from the middle row across all treatments was measured using a kitchen scale in kilograms. It was then converted to kg/ha by multiplying by 40 000 which was the plant population per hectare. All unmarketable leaves were removed from the cabbages before the mass was determined.

Data analysis

Data collected from the experiment was analyzed using a statistical package called Genstat (version 10.3DE). Analysis of variance was carried out and mean separation was done using a Least Significant Differences (LSD) at $p<0.05$.

III. RESULTS AND DISCUSSION

Effect of insecticide application rates on mean count of diamond back moth (DBM)

There were no significant statistical differences ($p>0.05$) in the mean count of diamond back moth at 2 and 4 weeks after transplanting (WAT) due to different application rates of hot chilli pepper extracts (Table 2). Although there were no statistically significant differences, the negative control had the highest mean number of diamond back moth compared to the rest of the treatments at 4 WAT. At 6, 8 and 10 WAT the different insecticide application rates had a significant effect on the mean count of diamond back moth (Table 2). The negative control treatments were statistically higher than the rest of the treatments at 6, 8 and 10 WAT.

Effect of insecticide applications rates on mean count of cabbage looper

There were no significant statistical differences (p>0.05) in the mean count of cabbage looper at 2 and 4 WAT due to different insecticide application rates (Table 3). At 6 WAT, different insecticide application rates had a significant effect on the mean count of cabbage looper. Negative control had the highest mean count of 5.33 followed by hot chilli pepper extracts at 0.02 m/v concentration with 3.33 (Table 3). At 8 WAT, different insecticide application rates had a significant effect on the mean count of cabbage looper. The negative control treatment had the highest mean count of 7.33, followed by treatment of hot chilli pepper extracts at 0.02 m/v concentration with 5.67 (Table 4.2). At 10 WAT, insecticide application rates had a significant effect on the mean count of cabbage looper. The negative control treatment had the highest mean count of 8.33, followed by treatment of hot chilli pepper extracts at 0.02 m/v concentration with 6.33 and then treatment of hot chilli pepper extracts at 0.04 m/v concentration with 5.67. However, the mean count of cabbage looper in treatments of hot chilli pepper extracts at 0.04 m/v, 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a] had no significant differences among them. Also the mean count of cabbage looper in treatments of hot chilli pepper extracts at 0.02 m/v and 0.04 m/v concentrations had no significant differences between them (Table 3).

Effect of insecticide application rates on mean count of cross stripped cabbage worm

There were no significant statistical differences (p>0.05) in the mean count of cross stripped cabbage worm at 2 WAT due to different insecticide application rates (figure 1). At 4, 6, 8 and 10 WAT, there were significant differences in the mean count of cross stripped cabbage worm due to insecticide application rates. At 4 WAT, the negative control had a relatively higher mean count compared to treatments of hot chilli pepper extracts at 0.04 m/v, 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a]. At 6 WAT, the negative control a relatively higher mean count compared to treatments of hot chilli pepper extracts at 0.04 m/v, 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a]. Hot chilli pepper extracts at 0.02 m/v concentration had a second relatively higher mean count of cross stripped cabbage worm compared to hot chilli pepper extracts at 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a] (Figure1).

At 8 WAT, the negative control had a significantly higher mean count compared to treatments of hot chilli pepper extracts at 0.04 m/v, 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a] (Figure1). Hot chilli pepper extracts at 0.02 m/v concentration had the second highest mean count, though it was relatively lower than the mean count of the negative control. At 10 WAT, the negative control had a significantly higher mean count compared to treatments of hot chilli pepper extracts at 0.02 m/v, 0.04 m/v, 0.06 m/v, 0.08 m/v concentrations and Imidacloprid+ beta cyfluthrin[a] (Figure1).

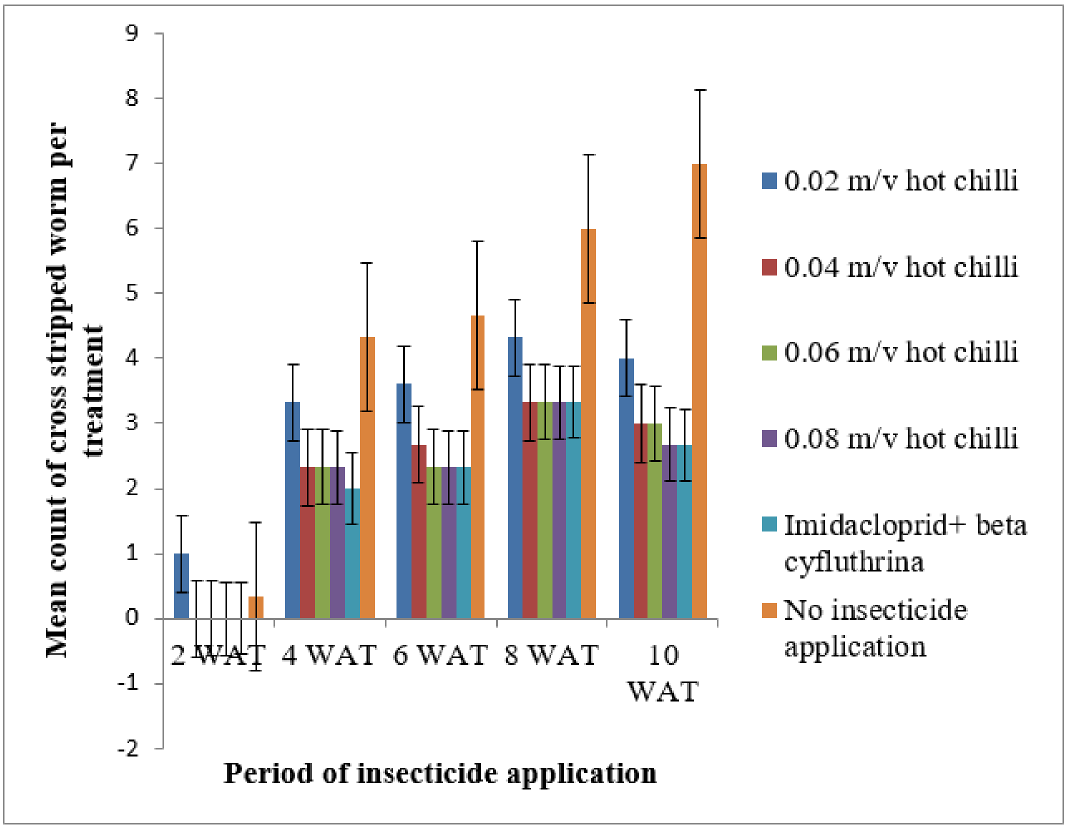

Figure 1: Mean cross stripped cabbage worm count in cabbages

Effect of insecticide application rates on mean count of snails

There were no significant statistical differences (p>0.05) in the mean count of snails at 2 and 4 WAT due to different insecticide application rates (Figure 2). At 6, 8 and 10 WAT, there were significant differences in the mean count of snails due to insecticide application rates. At 6 WAT, the negative control had a significantly higher mean count of snails compared to the rest of the treatments (Figure 2). At 8 WAT, the negative control had a significantly higher mean count of snails compared to the rest of the treatments. At 10 WAT, the negative control had a significantly higher mean count of snails compared to the rest of the treatments (Figure 2).

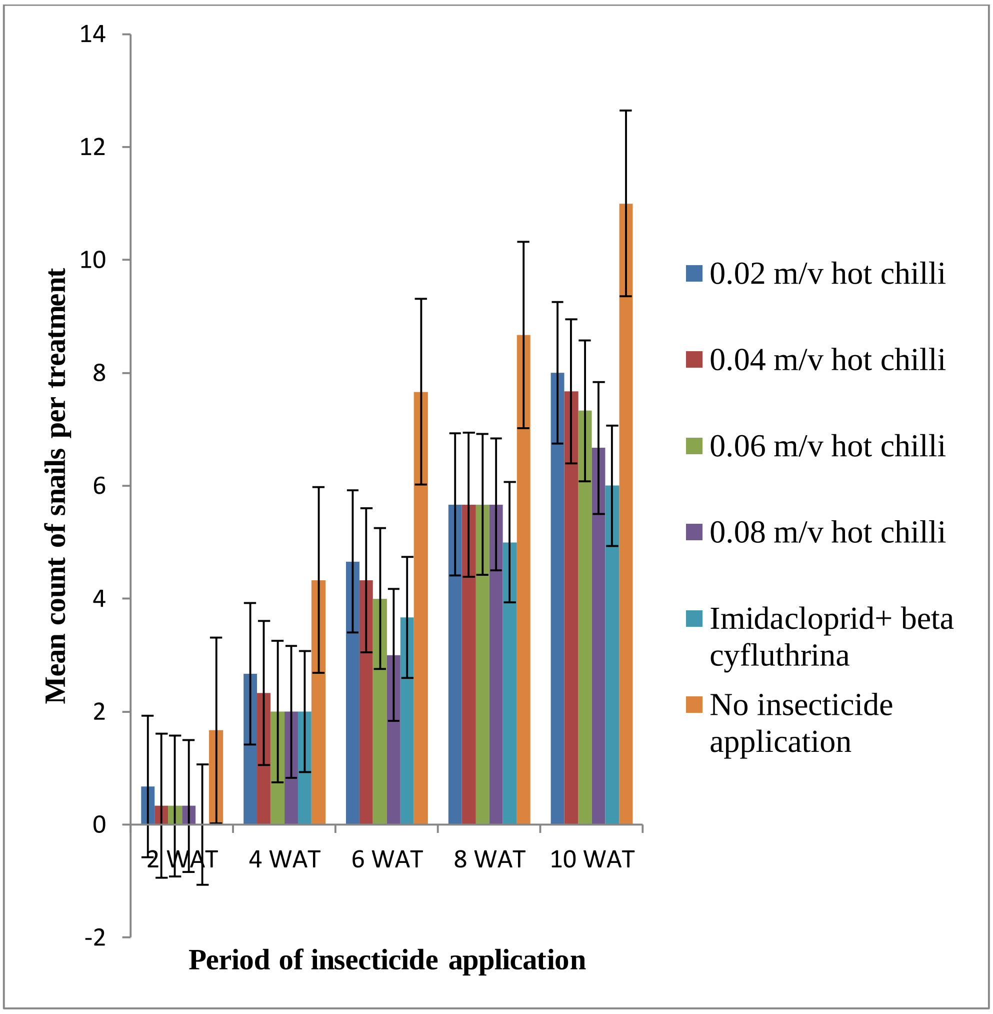

Figure 2: Mean snail count in cabbages

Effect of insecticide applications rates on mean count of cabbage webworm

There were no significant statistical differences (p>0.05) in the mean count of cabbage webworm at 2 WAT due to insecticide application rates (Table 4). At 4, 6, 8 and 10 WAT, there were significant differences in the mean count of cabbage webworm due to insecticide application rates. At 4 WAT, the negative control had the highest mean count of 4.67 followed by hot chilli pepper extracts at 0.02 m/v and 0.04 m/v concentrations, all with 2.67, Imidacloprid+ beta cyfluthrin[a] and hot chilli pepper extracts at 0.08 m/v concentration had the lowest mean count of 1.67 (Table 4). At 6 WAT negative control had the highest mean count of 9 followed by hot chilli pepper extracts at 0.02 m/v concentration with 5.33 (Table 4). At 8 WAT, the negative control had the highest mean count of 9.33 followed by hot chilli pepper extracts at 0.02 m/v concentration with 4. At 10 WAT negative control had the highest mean count of 11 followed by hot chilli pepper extracts at 0.02 m/v concentration with 3.33 (Table 4).

Effect of insecticide application rates on mean count of cabbage aphids colonies

There were no significant statistical differences (p>0.05) in the mean count of cabbage aphid colonies at 2, 4, 8 and 10 WAT due to insecticide application rates (Table 5). At 6 WAT, insecticide application rates had a significant effect on the mean count of cabbage aphid colonies. Negative control had the highest mean count of 7.667 followed by hot chilli pepper extracts at 0.02 m/v concentration with 4.667, hot chilli pepper extracts at 0.04 m/v concentration with 4.33, hot chilli pepper extracts at 0.06 m/v concentration with 4, Imidacloprid+ beta cyfluthrin[a] with 3.667 and then hot chilli pepper extracts at 0.08 m/v concentration with 3 (Table 5).

Effect of insecticide application rates on mean count of wasps

There were significant statistical differences at 2 and 4 WAT due to insecticide application rates (Table 6). At 2 WAT the negative control treatment, hot chilli pepper extracts at 0.02 m/v concentration and positive control treatment had the highest mean counts of wasps and their mean counts were not significantly different from each other. At 4 WAT the negative control treatment had the highest mean count of 4.33 followed by the treatments of hot chilli pepper extracts at 0.02 m/v and 0.04 m/v concentration with 2.67 whilst the treatment of hot chilli pepper extracts at 0.08 m/v had the lowest mean count of 1. There were no significant statistical differences ($p>0.05$) in the mean count of wasps at 6, 8 and 10 WAT due to insecticide application rates (Table 6).

Effect of insecticide applications rates on final yield

There were significant statistical differences in the final yield due to insecticide application rates (Figure 3). Cabbages treated with hot chilli pepper extracts at 0.06 m/v, 0.08 m/v and Imidacloprid+ beta cyfluthrin[a] all had significantly higher marketable yield compared to those of the negative control treatment. However, the final yield in treatments of hot chilli pepper extracts at 0.02 m/v, 0.04 m/v, 0.06 m/v, 0.08 m/v and Imidacloprid+ beta cyfluthrin[a] we're not significantly different. Also there were no significant statistical differences in the final yield of cabbages that were treated with hot chilli pepper extracts at 0.02 m/v, 0.04 m/v concentrations and the negative control. Hot chilli pepper extracts at 0.08 m/v concentration had the highest yield whilst negative control had the lowest yield (Figure 3).

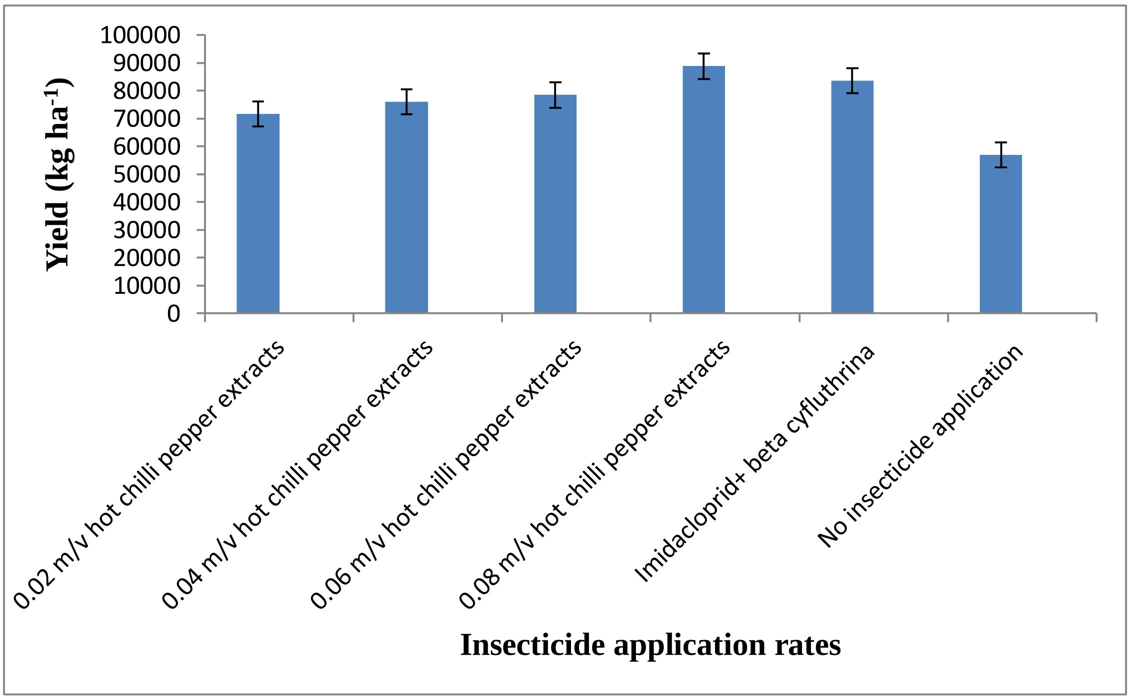

Figure 3: Final yield of cabbages

Effect of insecticide application rates on mean count of diamond back moth

There were no diamond back moth infestations in all the treatments except in the negative control at 2 weeks after transplanting. This could be as a result that the period was coincided with dry spell which had high temperatures and very low humidity. The absence of diamond back moth may have been due to extended overwintering as highlighted by Katsaruware-Chapoto *et al.*, (2017) who showed that diamond back moth is not active in high temperature and low humidity regimes.

At the end of the dry spell, populations of diamond back moth started to increase steadily across all treatments. The steady increase contradicted the study by Mari (2012) who observed a decrease in the numbers of diamond back moth after botanical insecticide applications. In this study, hot chilli pepper extracts at 0.08 m/v concentration had the least number of diamond back moth insect pests, suggesting that it was the most effective in controlling the insect pests. The results of the study showed that it could be a good alternative to synthetic insecticides, which concurs to the findings of Muzemu *et al*., (2012) who found that botanical insecticide at the highest concentration will cause the reduction of insect pests in vegetable production.

Effect of insecticide application rates on mean count of cabbage looper

From 2 to 4 weeks after transplanting, all the insecticide applications rates had no effect on the populations of cabbage looper. The findings of this study contradicted with the findings of Baidoo and Mochiah (2016) where synthetic insecticide application significantly reduced cabbage looper populations. Mkindi *et al*., (2015), also showed that hot chilli pepper extracts at 0.08 m/v concentration were the best alternative because of their non-cytotoxicity, easy of biodegradability and low costs. During the late stages of cabbage development, all hot chilli pepper extracts concentrations were as equally effective as synthetic insecticide in controlling cabbage looper.

Effect of insecticide application rates on mean count of cross stripped cabbage worm

At 2 weeks after transplanting, all the insecticide applications rates had no effect on the populations of cross stripped cabbage worm. The findings of this study contradicted with the findings of Baidoo and Mochiah (2016) where synthetic insecticide application at 2 weeks after transplanting significantly reduced cross stripped cabbage worm. From 4 to 10 after transplanting, insecticide application rates had the effect on the populations of cross stripped cabbage worm. The observed results were in line with the findings of Baidoo and Mochiah (2016), who found that bioinsecticide concentration rates at 0.08m/v control cross stripped cabbage worm. The observation of this study also concurred with Muzemu *et al*., (2012) who observed that botanical pesticides have equivalent effect to synthetic chemicals in controlling insect pests.

Effect of insecticide application rates on mean count of snails

In the early stages of cabbage development, the populations of snails were low across insecticide application rates except for the negative control treatment. According to PANS (2008), snails are most prevalent in cabbages during the wet season. In this study, there was low population of snails, this is probably as a result of 2017/2018 rain season. At 4 to 10 weeks after transplanting, the highest concentration of hot chilli pepper extracts was the most effective in controlling snails. The observations contradicted with the findings of Baidoo and Mochiah (2016), who observed that synthetic chemicals were more effective at 2 to 10 weeks after transplanting than botanical insecticides. During the late stages of cabbage development, synthetic insecticide had similar effects with different concentrations of hot chilli pepper extracts though it had the lowest populations.

Effect of insecticide application rates on mean count of cabbage webworm

At 2 weeks after transplanting, all treatments had no effects on the population of cabbage webworm this is probably as a result of dry spell period which was experienced during 2017/2018 rain season. At 8 and 10 weeks after transplanting, bioinsecticide concentration of hot chilli pepper at 0.08m/v had the lowest populations of cabbage webworm though it was not reducing the populations when compared to other hot chilli pepper extracts concentrations and synthetic insecticide. These findings were in line with findings of Muzemu *et al*., (2012) who finds that botanical insecticides have the same effect as synthetic insecticides in controlling insect pests.

Effect of insecticide application rates on mean count of cabbage aphids colonies

During the first 4 weeks after transplanting, cabbage aphid colonies in the cabbages were very few across all treatments. This could have been attributed to the environmental conditions that were prevailing at the time. The cabbage aphids might have reduced their life cycle in response to temperature increases as suggested by Katsaruware-Chapoto *et al*., (2017) hence they infested cabbages at a later stage.

At 6 weeks after transplanting, the highest concentration of hot chilli pepper gave the lowest population on the cabbage aphids. The observations contradicted with the findings of Baidoo and Mochiah (2016), who observed that a synthetic chemical is more effective than botanical insecticides in controlling insect pests at all stages of cabbage development. At 8 and 10 weeks after transplanting were reduced, this probably due to repellent effect of hot chilli pepper.

Effect of insecticide application rates on mean count of ladybird beetles

All the bioinsectide application rates had no significant effects on the population of ladybird beetle throughout the experiment. The findings of the study contradicted with Baidoo and Mochiah (2016) who stated that synthetic insecticides significantly reduced the populations of beneficial insects as compared to botanical insecticides.

Effect of insecticide application rates on mean count of wasps

During the early stages of cabbage development, the highest concentration of hot chilli pepper extracts reduced wasps populations as compared to synthetic insecticides. This contradicted with Baidoo and Mochiah (2016) who stated that synthetic insecticides significantly reduced the populations of beneficial insects at all stages of cabbage development. At 6 and 10 weeks after transplanting, all insecticide application had similar effects on the populations of wasps this is probably due to anti-feedant effect of hot chilli pepper. This observation was similar to what was observed by Katsaruware-Chapoto *et al*., (2017) who observed that bioinsectide greatly reduce all kinds of micro-organism.

Effect of insecticide application rates on mean number of damaged leaves

All treatments had no effects on the number of leaves in cabbages at all stages of cabbage development. Through observations, the similarities in the mean number of damaged cabbages could have been attributed to the mode of action of the insecticides. All the insecticides that were used had anti-feedant properties which prevented insect pests from damaging the leaves (Mochiah, 2016). Despite the similar effects, cabbages treated with Imidacloprid+ beta cyfluthrin[a] had the least number of damaged leaves at all stages of cabbage development. The observations were similar to what was observed by Baidoo and Mochiah (2016) who observed that synthetic chemicals resulted in the reduction of damaged leaves by not eating the leaves.

Effect of insecticide application rates on final yield

Hot chilli pepper extracts at 0.08 m/v concentration had the highest final yield. This was probably due to high concentration of anti-feedant mode of action against major pests in cabbage production. The observation was similar to that of Muzemu *et al*., (2012) who observed that high concentration of botanical insecticides gives higher yields of vegetables because they do not allow insect pest to eat any part of the crop when they are applied. The lowest yield was recorded in the negative control (untreated); this is probably due insect pest infestation. This study concurs to the findings of Baidoo *et al*., (2012) who observed that uncontrolled insect pest greatly reduce the yield.

IV. Conclusion

The study showed that the effectiveness of hot chilli pepper extracts in controlling major pests of cabbages depended on the concentration and the insect pest species. It also showed that the most effective stage in cabbage development for applying different concentrations of hot chilli pepper extracts was from 6 to 8 weeks after transplanting. The study showed that plots treated with hot chilli pepper extracts at 0.08 m/v concentration had the highest yield than all other treatments. Basing on yield, hot chilli pepper extracts at 0.08 m/v concentration had highest economic benefits in the management of major pests of cabbages under rain feed condition.

Based on research results, it is therefore recommended that farmers should, use hot chilli pepper extracts as alternatives to synthetic insecticides to control major pests such as diamond back moth, cabbage lopper, cross stripped cabbage worm, cabbage aphids and cabbage snails. Hot chilli pepper extracts should be applied from 4 weeks after transplanting or after scouting for effective insect pest control. Apply hot chilli pepper extracts at 0.08 m/v concentration at two weeks intervals from 4 weeks after transplanting up to physiological maturity to control major pests in cabbage production.

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Table 1: Different treatments and their descriptions

Treatment Number	Treatment Description
1	20g of hot chilli pepper mixed with 1 litre of distilled water (0.02 m/v)
2	40g of hot chilli pepper mixed with 1 litre of distilled water (0.04 m/v)
3	60g of hot chilli pepper mixed with 1 litre of distilled water (0.06 m/v)
4	80g of hot chilli pepper mixed with 1 litre of distilled water (0.08 m/v)
5	Imidacloprid+ beta cyfluthrin[a] (positive control) @ 60ml/100 litres of water
6	No insecticide application (negative control)

Table 2: Mean diamond back moth (DBM) count in cabbages

Insecticide application rates	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
0.02 m/v hot chilli pepper extracts	0**NS**	2.69 **NS**	5**a**	3.67**a**	3**a**
0.04 m/v hot chilli pepper extracts	0 **NS**	2.33 **NS**	5**a**	3.67**a**	3**a**
0.06 m/v hot chilli pepper extracts	0 **NS**	2.33 **NS**	4.67**a**	3.33**a**	2.33**a**
0.08 m/v hot chilli pepper extracts	0 **NS**	1.33 **NS**	4**a**	2.67**a**	2**a**
Imidacloprid+ beta cyfluthrin[a]	0 **NS**	1.67 **NS**	4**a**	3.33**a**	2.67**a**
No insecticide application	0.333 **NS**	4.33 **NS**	9**b**	9.33**b**	11**b**
p Value	0.465	0.059	0.001	0.001	0.001
Sed	0.1925	0.839	0.577	0.577	0.683
Lsd	0.2488	1.869	1.747	1.286	1.522

NS -not significant

Means followed by the same letters in a column are not significantly different at (p< 0.05)

Table 3: Mean cabbage looper count in cabbages

Insecticide application rates	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
	0.333**NS**	3 **NS**	3.33**a**	5.67**b**	6.33**b**
0.04 m/v hot chilli pepper extracts	0 **NS**	2.33 **NS**	3**a**	5**a**	5.67**ab**
0.06 m/v hot chilli pepper extracts	0 **NS**	1.67 **NS**	2.67**a**	4**a**	4.67**a**
0.08 m/v hot chilli pepper extracts	0 **NS**	1.67 **NS**	2**a**	4**a**	4.33**a**
Imidacloprid+ beta cyfluthrin[a]	0 **NS**	1.67 **NS**	2**a**	4.33**a**	5.33**a**
No insecticide application	0.667 **NS**	4.67 **NS**	5.33**b**	7.33**c**	8.33**c**
p Value	0.295	0.053	0.029	0.002	0.001

Sed	0.322	0.931	1.084	0.609	0.059
Lsd	0.7175	2.074	2.41	1.356	1.309

NS - not significant

Means followed by the same letters in a column are not significantly different at (p< 0.05)

Table 4: Mean cabbage webworm count in cabbages

Insecticide application rates	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
0.02 m/v hot chilli pepper extracts	0**NS**	2.67**b**	5.33**a**	4**a**	3.33**a**
0.04 m/v hot chilli pepper extracts	0**NS**	2.67**b**	5**a**	3.33**a**	3**a**
0.06 m/v hot chilli pepper extracts	0.33**NS**	2.33**a**	4.67**a**	3.33**a**	3**a**
0.08 m/v hot chilli pepper extracts	0.33**NS**	1.67**a**	4**a**	3**a**	2**a**
Imidacloprid+ beta cyfluthrin[a]	0.33**NS**	1.67**a**	4.33**a**	3.33**a**	2.67**a**
No insecticide application	0.67**NS**	4.67**c**	9**b**	9.33**b**	11**b**
p Value	0.611	0.05	0.002	0.001	0.001
Sed	0.413	0.865	0.865	0.644	0.683
Lsd	0.92	0.927	1.927	1.435	1.522

NS -not significant

Means followed by the same letters in a column are not significantly different at (p< 0.05)

Table 5: Mean cabbage aphid colonies count in cabbages

Insecticide application rates	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
0.02 m/v hot chilli pepper extracts	0**NS**	0**NS**	4.667**c**	1.333**NS**	1.67**NS**
0.04 m/v hot chilli pepper extracts	0**NS**	0**NS**	4.33**c**	1**NS**	1.33**NS**
0.06 m/v hot chilli pepper extracts	0**NS**	0**NS**	4**b**	1**NS**	1.33**NS**
0.08 m/v hot chilli pepper extracts	0**NS**	0**NS**	3**a**	1**NS**	1.33**NS**
Imidacloprid+ beta cyfluthrin[a]	0**NS**	0**NS**	3.667**b**	1**NS**	1**NS**
No insecticide application	0.33**NS**	0.333**NS**	7.667**d**	1.667**NS**	2**NS**
p Value	0.492	0.435	0.001	0.211	0.55
Sed	0.2018	0.1925	0.2854	0.2981	0.531
Lsd	0.4566	0.4288	0.66	0.6643	1.182

NS - not significant

Means followed by the same letters in a column are not significantly different at (p< 0.05)

Table 6: Mean wasps count in cabbages

Insecticide application rates	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
0.02 m/v hot chilli pepper extracts	3.67**b**	2.67**b**	2**NS**	2.33 **NS**	2 **NS**
0.04 m/v hot chilli pepper extracts	2.67**a**	2.67**b**	2 **NS**	2 **NS**	1.67 **NS**
0.06 m/v hot chilli pepper extracts	2.33**a**	2.33**b**	1.33 **NS**	1.33 **NS**	1.67 **NS**
0.08 m/v hot chilli pepper extracts	1.67**a**	1**a**	1.33 **NS**	1.33 **NS**	0.67 **NS**
Imidacloprid+ beta cyfluthrin[a]	3**b**	1.67**a**	1.67 **NS**	1.67 **NS**	1.33 **NS**
No insecticide application	4**b**	4.33**c**	2 **NS**	2.67 **NS**	2 **NS**

p Value	0.025	0.012	0.958	0.55	0.596
Sed	0.59	0.694	1.051	0.839	0.812
Lsd	1.315	1.546	2.341	1.869	1.809

NS- not significant

Means followed by the same letters in a column are not significantly different at (p< 0.05)

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