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Evaluation of Local Plant for Managing Diamondback Moth (DBM) on Head Cabbage in Ethiopia

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Abstract: Cabbage (*Brassica oleracea* var. capitata) is the second most important vegetable crop in Ethiopia. Many insect pest species belonging to 16 families have been recorded on cabbages. Therefore, the objective of this study was to assess the efficacy of botanicals for managing diamondback moth (DBM) on head cabbage. The experiment was conducted using irrigation at Adami Tulu Agricultural Research Center (ATARC) during 2013 September to December. The head cabbage variety Copenhagen Market was used for this experiment. Treatments were arranged in randomized complete block design (RCBD) with four replications. For DBM management four locally available botanicals and diazinon chemical was sprayed continuously for six weeks. Throughout the growing season diazinon significantly reduced the DBM larvae and pupae population followed by garlic cloves. Highly significant differences among the treatments were observed after application of botanicals and chemical on DBM larvae and pupae. All botanical treatments reduced the number of DBM larval population and increased marketable yield. The highest marketable cabbage yield was obtained from plots sprayed with diazinon, followed by garlic treated cabbages.

Key words: Botanicals · Diazinon · Cabbage · Garlic · Ginger · Endod · Papaya

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. *capitata)* is the second most important vegetable crop in Ethiopia with respect to production next to red pepper (*Capsicum* spp) [1]. It is produced by private farmers [2]. The land occupied during 2010 main rainy season (Meher) was 4,802 ha with a production level of 43,483.43 tons [3].

Many insect pest species belonging to 16 families have been recorded in Ethiopia on head cabbage [4]. However, only the diamondback moth (DBM) (*Plutella xylostella* L. Lepidoptera: Plutellidae), cabbage aphid (*Brevicoryne brassicae* L. Hemiptera: Aphididae), flea beetles (*Phylloterta* spp) and cabbage leaf miner (*Chromato myiahorticola* Goureau) (Diptera: Agromyzidae) are of economic importance [4,5].

The DBM is the dominant and most destructive insect pest of crucifer crops worldwide. Yield loss studies at Melkassa Agricultural Research Center (MACR) of the Ethiopian Institute of Agricultural Research (EIAR) showed that losses vary between 36.1-91.2% and complete crop failure is common in seasons of heavy infestations [4].

In Ethiopia, DBM pest status is believed to be strongly influenced by extensive level of insecticide usage and cabbage production methods. According to [6], DBM is problematic in the Central Rift Valley areas where the crop is cultivated all the year-round using irrigation and where insecticide use is heavy.

However, excessive use of insecticides has led to insecticidal resistance development, pest resurgence, residue hazards in foods and overall environmental contaminations. This has prompted the promotion of other DBM management alternatives such as microbial insecticide, insect growth regulators (IGRs) and botanicals. For example, aqueous extract of neem seed powder (50g/l) and Bt (0.5kg/ha) were earlier recommended for use on cabbage under Ethiopian condition [4].

Botanical insecticides are not only effective against crop pests but remain safer to natural enemies [7]. They have been in use for centuries by farmers in developing countries to control insect pests of both field crops and stored produce. Nicotine, rotenon and pyrethrum were popular among the botanical insecticides. Some of these plant species possess one or more

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useful properties such as repellency, anti feeding, fast knock down, flushing action, biodegradability, broad-spectrum of activity and ability to reduce insect resistance [8]. Therefore, this study was mainly conducted to determine the influence of botanical insecticides against DBM on head cabbage. The specific objective was:

- To assess the efficacy of some botanicals for managing DBM on head cabbage.

MATERIALS AND METHODS

Description of the Experimental Sites: The experiment was conducted using irrigation at Adami Tulu Agricultural Research Center (ATARC) during 2013 from September to December. ATARC is located in the mid Rift Valley of Ethiopia about 167km south from Addis Ababa. It lies at a latitude of 7° 9'N and longitude of 38° 7'E. It has an altitude of 1650 m.a.s.l. and it receives a bimodal unevenly distributed average annual rainfall of 760.9 mm per annum. The long-term mean minimum and the mean maximum temperature are 12.6 and 27°C respectively. The pH of the soil is 7.88. The soil is fine sandy loam in texture with sand, clay and silt in proportion of 34, 48 and 18% respectively [9].

Experimental Design and Management: The head cabbage (*B. oleracea* var. *capitata*) variety, Copenhagen Market, was used for the present experiment. Seedlings were grown on raised seed bed of 10 m^2 and transplanted on October 7, 2013 when seedling reached third to fourth true leaf stage. Each plot had three ridges of four meter long and each ridges with one row of cabbage on each side. Ridges were spaced 60 cm apart. The spacing between plants was 30 cm. Treatments were arranged in randomized complete block design (RCBD) with four replications. Spacing between plots and blocks was 1 and 1.5 m, respectively. All data were collected only from the central four rows. The crop was irrigated twice per week for the first four weeks after transplanting and once weekly thereafter. Plots were fertilized with diammonium phosphate (DAP) and urea @ 200 and 100 kg ha^{-1}, respectively. The whole amount of DAP was applied just before transplanting, while urea was applied by splitting the total amount in two. Half of the 100 kg was applied one month after transplanting and the remaining half at the beginning of head formation stage. Other field management practices like weeding, cultivation and maintenance of ridges were carried out as needed.

Experimental Materials: The experimental treatments were four botanicals and an insecticide diazinon (Table 1). Applications of treatments started three weeks after transplanting. Treatments were applied weekly until about fifteen days before harvest. Spray was made using manually operated knapsack sprayer of 15L capacity using hollow cane nozzle. Botanical extracts were prepared one day before treatment application following the respective procedure described below.

Preparation and Application of Botanicals

Ginger Rhizome Extraction: Fresh ginger rhizomes were bought from market and ground using manual grinder. Ground ginger of 250 g was added into 500 ml of distilled water and allowed to stand for 24 hours. The infusion was later filtered using a 40 mm muslin cloth the aqueous extract was labeled and kept in room temperature until it was used. At the time of application the extract was diluted in 3 L of water and stirred well before spraying [10].

Garlic Bulb Extraction: The scale of matured garlic bulb was peeled off and 200 g of peeled clove was put in 1 L of water and ground with a blender to obtain garlic juice. The juice was thoroughly mixed with additional 1 L of water. The mixture was then sieved to obtain a uniform extract and kept in the room temperature until used [10].

Papaya Leaves Extraction: A 92 g of papaya young leaves was collected and dried under shade. The dried leaf was ground using mortar and pestle. The finely ground papaya leaf was mixed with 1 L of water and left to stay for 24 h. After filtering the mixture through muslin cloth 1 L of water was added and sieved to obtain a uniform extract [10].

Table 1: Details of plant species used for the experiment.

Treatment code	Common name	Scientific name	Variety	Part used	Rate
1	Garlic	*Allium sativum (L)*	Bisheftu netch	clove	100 g/L
2	Endod	*Phytolacca dodecandra (L)*	Local	berry	50 g/L
3	Papaya	*Carica papaya(L)*	Poyo	leaves	46 g/L
4	Ginger	*Zingiber officinale roscoe (L)*	Boziab	rhizome	70 g/L
5	Diazinon				2 L/ha

Endod Berry Extraction: The matured berries were washed with tab water and cut into small pieces. These pieces were dried under shade at room temperature (25°C) till they were completely dry. The dried berries were ground with mortar and pestle. The powders were dissolved in distilled water @ 50 g/L water. The solutions were allowed to stand for 24 hours and then the mixture was filtered through cheese cloth and filter paper for spraying on field.

Data Collection

Canopy Spread: Canopy spread was measured with a ruler at the time of harvest. The spread of canopy was measured as the horizontal distance from one end of the plant to the other i.e. the two most outspread and directly opposite leaves of the plant.

Plant Height: Plant height was measured from the soil surface to the apex of the plant using ruler at the time of harvest. The highest point reached by the plant was recorded as the height of the plant [11].

Yield: Marketable and unmarketable yield data were taken from the central four rows of each plot, by removing the outer damaged leaves and discarding heads with less than 4 cm in diameter. Yield losses were estimated by comparing the yield of treated cabbage with the untreated control [12].

$$Yield\ loss\ (\%) = \frac{(\overline{X}-\overline{Y})}{\overline{X}} * 100$$

DBM Leaf Damage: All plants and plant parts were examined for leaf damage by DBM before treatment application and at weekly interval thereafter. DBM leaf damage score on each leaf of a plant was taken based on a scale of 0 to 5 (0= no leaf damage; 1= up to 20% of the total leaf area damaged; 2= 21-40% of the total leaf area damaged; 3= 41-60% of the total leaf area damaged; 4= 61-80% of the total leaf area damaged; and 5= more than 80% leaf area damaged) [13].

Estimation of DBM Population: The number of DBM larvae and pupae were recorded before and after 24hr application of botanical extracts or chemicals at weekly interval thereafter. Totally ten plants were selected randomly and examined for the presence of the different life stage of DBM. The number of larvae and pupae from each tagged leaves was counted with the help of hand lens and mean number per plant was calculated.

Stand Count: Stand count after crop establishment and at harvest was taken by counting the number of plants in each plot. Number reduction in plant stand was calculated as a difference between stand counted at establishment of seedlings and harvest.

Estimation of Cabbage Head Formation: Cabbage head formation in each treated plot was recorded during harvesting. Total number of cabbage plants with head and without head was recorded separately.

Data Analysis: Data analysis was carried out using the SAS version 9.2. To stabilize the variance count and percentage data were transformed either to logarithmic or square root scale. The mean value of the recorded data's was subjected to analysis of variance (ANOVA). If there was significant difference among the treatments, mean separation was carried out using tukey's significance difference at P 0.05.

RESULTS AND DISCUSSIONS

Leaf Damage Visual Scores across Weeks: In the first week there were non-significant differences ($P<0.05$) among all treatments, because it was before the applications of any treatments (Table 2). The extent of damage caused by DBM on head cabbage was almost similar, though there were leaf damage scale variations among treatments. In the 2nd week, however, there were significant differences ($P<0.05$) among treatments in the extended of leaf damaged score. The highest leaf damage was recorded on ginger sprayed cabbages, whereas the least leaf damage was recorded on garlic treated cabbages. Similarly in the 3rd, 4th, 5th and 6th weeks there were significant differences ($P<0.05$) among treatments in leaf damaged score. In all the cases the ginger cabbage had the highest leaf damage score whereas cabbages treated with diazinon had the lowest leaf damage due to DBM. Cabbages treated with botanicals had intermediate leaf damage. In general the level of leaf damage on endod treated plots increased at the heading stage because the population of larvae was higher at the heading stages.

The present observation is in line with finding of [14] who stated that, all crop growth stages are subjected to severe DBM infestation, so insecticide applications are required to control DBM, especially during the peak population period. When DBM is not managed the scale of leaf damage increased in untreated cabbage, but decreased generally in treated cabbages throughout the growing season. In studies made by [15] the leaf damage

Table 2: Mean leaf damage due to DBM on cabbage treated with different botanicals in six weeks period.

	Weeks					
Treatments	1	2	3	4	5	6
Ginger	3.20±.04a	3.45±.045a	2.86±0.30a-c	3.00±.0a-c	3.25±.06b	3.25±.06bc
Diazinon	3.16±.00a	2.50±.02ab	1.50±.18d	0.50±.15d	0.75±.12e	0.37±.12f
Garlic	3.00±.02a	2.0±.15b	2.58±.27a-d	2.30±.07a-c	1.50±.01d	1.75±.15e
Endod	3.00±.00a	2.06±.14b	3.04±.08ab	2.60±.18ab	3.50±.08ab	3.50±.07ba
Papaya	2.83±.02a	2.43±.01ab	1.83±.05b-d	2.00±.12b-d	2.25±.07cd	2.50±.08de
CV	17.94	11.76	22.03	10.93	7.54	9.89

Note: Means followed by the same letter within a column are not significantly different (tukey's) at P =0.05.

Table 3: Mean number of DBM Larvae per plant sprayed with botanicals and chemical in 24h post applications

	Week					
Treatment	1	2	3	4	5	6
Ginger	2.33±.00ab	0.50±.11cd	1.25±.09cb	0.91±.14a-c	3.00±.18b	3.75±.11b
Diazinon	0.33±.10d	0.00±.07d	0.25±.13c	0.00±.00c	0.00±.00c	0.00±.00c
Garlic	0.50±.00d	1.16±.13a-c	0.62±.12c	0.50±.08a-c	2.00±.18bc	2.00±.18cb
Endod	1.00±.15cd	1.00±.15bc	1.50±.22bc	0.79±.10a-c	2.75±.29b	3.00±.33b
Papaya	1.75±.07bc	1.66±.11ab	1.62±.12c	1.25±.05a-c	2.50±.08b	3.00±.00cb
CV	26.51	17.44	27.10	14.24	21.92	24.93

Means followed by the same letter within a column are not significantly different (tukey's) at P = 0.05

was significantly lower in fields treated with insecticides than in fields not treated with insecticides. Sakai [16] shows all crucifers suffer depredation by this pest practically throughout the growing season. [11] reported the mean leaf damage for unprotected plants were higher than those which were treated in various ways.

DBM Larval Population 24h after Treatment Application: Across all the weeks significant differences ($P < 0.05$) were observed on population of DBM larvae per plant among treatments following foliar applications (Table 3). The highest number of DBM larvae per plant was recorded from papaya cabbages. Whereas the least number of DBM larvae were recorded from head cabbage treated with diazinon followed by garlic treated cabbages. Although there was a reduction of DBM larval population in all treated plots 24h after applications, the degree of DBM larval population reduction was not as expected, which might be partly attributed to the difference in pre-spray larval density and to the shortest evaluation time. Between the fourth and sixth week there was non-significant difference among ginger and endod treated cabbage. Within the same time span, however, the effectiveness of other botanicals was relatively variable.

In all weekly applications, diazinon significantly reduced DBM larvae population; this was followed by garlic. In Japan [17] reported that diazinon proved more toxic to a susceptible strain of DBM than dichlorvos, profenofos, acephate and chlorpyriphos. [18] also reported that insecticides are generally considered the most effective means of protecting crops against insect damage as they provide rapid papaya of wide pest complex of major crucifer's pests and growers concerned about leaf damage, even of a few holes, tend to spray insecticides. Nakagome and Kato [14] believed that repeated insecticide applications are required to papaya DBM, especially during the peak population period. However, Motoyama *et al*. [19] warned that effective insecticidal control of DBM might not be achieved for longer period as the insect can develop resistance to a new insecticide very quickly because of its unique feature of insecticide resistance.

In this study, botanicals gave acceptable level of DBM larvae reduction. Nayem and Rokib [10] found vigorous okra growth by treating with garlic bulb extracts. These plant extracts are applicable to cabbage pest management through reduction in use of synthetic insecticides spray as an important component of integrated pest management (IPM) programme. Botanical insecticides can influence the behavior and development of the herbivorous insect, which uses the plant for their reproduction as they have antifeedent, non-neuro toxic modes of action and low environmental persistence [20].

Table 4:

	Week					
Treatment	1	2	3	4	5	6
Ginger	0.66±.18c	1.50±.08ab	1.00±.25ab	1.50±.10ab	1.25±.08bc	1.50±.16b
Diazinon	0.00±.00d	0.00±.00e	0.00±.00b	0.00±.00d	0.00±.00d	0.25±.12b
Garlic	1.00±.00bc	1.25±.21a-c	0.50±.15ab	0.83±.09a-d	1.00±.00c	0.75±.10b
Endod	1.00±.15bc	2.00±.15a	1.50±.28a	1.00±.12a-d	2.00±.18ab	1.00±.17b
Papaya	1.00±.00bc	1.37±.10a-c	0.67±.21ab	0.41±.08a-d	1.00±.00c	1.00±.00b
CV	16.64	16.65	22.03	11.54	14.91	24.99

Means followed by the same letter within a column are not significantly different (tukey's) at P =0.05

DBM Pupae Population 24h after Treatment Application: Similar to the larval population, there was significant differences (P<0.05) were observed among treatments across weeks in number of DBM pupae per plant after foliar applications (Table 4). The pupal population intensity followed more or less the larval population intensity. Thus, the highest number of DBM pupa per plant was recorded from endod cabbages, except at the 2nd week while the highest number of DBM pupa per plant was recorded from endod sprayed cabbages. The least number of DBM pupae were recorded from head cabbage treated with diazinon. Similarly, in the third and fourth weeks the least number of DBM pupae were recorded from head cabbage treated with garlic and papaya treated cabbages. In the fifth week, relatively more number of pupae was recorded on all botanical treated cabbages. The numbers of DBM pupae might not be reduced across the weeks, because it is likely that more pupae survive if there were more number of pupae in a particular treatment cabbage before treatment application. Botanicals can have effect on developmental stages of exposed pupae, which can produce morphological abnormalities in different developmental stages. Phytochemicals have considerable capacity to reduce adult emergence at low dosage, which reduce the recruitment over time and the desired characteristic of botanical insecticides. The adult emergence is affected by phytochemicals, which often cause acute and chronic toxicity in pupal stages, dead larvae-pupal intermediate stage having the head of pupa and the abdomen of a larva. Dead adults with folded wings in pupal exuvium and emerged adults were unable to escape the pupal exoskeleton, half ecdysed adults etc. [21]. According to [22] plots treated with Dipel and Xen Tari chemicals showed the least DBM number throughout the sampling weeks. Also Gashawbeza [6] observed low number of DBM ranging from zero to 4 per plant in an insecticide endod trial. He reported significant differences in DBM number between the untreated plot and plots treated weekly throughout the growing period.

Effect of Botanicals on Some Agronomic Characteristics

Plant Height at Harvest: There was significant difference (P<0.05) among treatments in affecting plant height (Table 5). Cabbage sprayed with either diaznon or garlic produced the tallest plants. Medium plant height was measured from cabbages treated with other botanicals. However, head cabbage sprayed with ginger cabbage had the shortest plants height. This is consistent with the finding of [11] who indicated that treating cabbage with insecticide reduced the insect population on cabbage and hence better growth of the crop. Nayem and Rokib [10] also reported that okra grows vigorously when treated with botanical insecticides.

Plants Stand Count: There were significant differences (p<0.05) among treatments in plant stand count per plot (Table 5). Large number of plant was recorded on diaznon sprayed plots, while the least number of plant stands per

Table 5: Effect of botanicals on agronomic characteristics of cabbage at Adami Tullu

Treatment	Canopy spread(cm)	Plant height(cm)	% tage cabbage with head	Plant stand count(number)
Ginger	44.56±1.00a	18.5±0.53c	86.61e	44.50±0.64ab
Papaya	47.37±0.91a	21.2±1.46a-c	87.37e	48.25±2.50ab
Endod	46.05±1.84a	20.81±1.30a-c	89.00d	49.0±2.04ab
Garlic	47.96±1.80a	22.53±0.39ab	90.35c	49.50±1.93ab
Diaznon	45.93±1.00a	22.71±0.70a	93.17a	51.25±0.85a
CV	6.6	8.01	2.75	8.6

Means followed by the same letter within a column are not significantly different (tukey's) at P =0.05.

Table 6: Effect of botanical application on yield of cabbage.

Treatment	Marketable yield ton/ha	Unmarketable yield ton/ha	Yield loss (%)
Ginger	61.00b	10.50b	54b
Papaya	67.00ab	6.50bc	58b
Endod	66.55ab	7.00bc	58b
Garlic	71.00a	4.25bc	60a
Diaznon	92.50a	3.250c	0
CV (%)	13.57	47.61	32

Note: Means followed by the same letter within a column are not significantly different at p= 0.05; Yield loss is computed as the difference between treated and untreated plots.

plot was observed from ginger plots. Botanicals did not differ statistically from each other in affecting plant stand, although there were more number of plants on endod and garlic treated plots than plots sprayed with other botanicals. The loss of plant stand is attributed to damage by DMB and managing DBM population will reduce the death of cabbage plants [6].

Cabbage with Heads: Significant differences ($p<0.05$) were observed among treatments in the percentage of plants that formed head (Table 5). Cabbages treated with diazinon and garlic, in decreasing order respectively formed greater percentage of heads than those cabbages treated with other botanicals. The least number of plants with head was recorded from ginger plots. The DBM feed mostly on young part of the plant which is the major part for head formation. As plant losses this part they fail to form head or die under severe infestation. Paul *et al*. [23] reported that destruction of the main buds of seedlings by DBM larvae may result in plants with multiple undersized heads. Moreover, according to Asare *et al*. [11] heavy head per plant was recorded for cabbages that received treatments against DBM attack when compared with the control.

Plant Canopy Spread: There were non-significant differences ($p>0.05$) among treatments in plant canopy spread (Table 5). Even though statistically non significant, cabbages treated with papaya and endod had larger diameter than cabbages treated with diazinon, which had relatively more number of plants per plot. Moreover, although statistically non-significant plant canopy spread was negatively correlated with leaf damage and DBM larvae population except in 3rd and 4th week owing to less number of larvae recorded during those weeks. DBM larvae adversely affected the formation of head by destroying the tip of the head cabbage [24].

Effect of Botanicals on Cabbage Yield and Yield Components

Effect on Marketable and Unmarketable Yield: There were significant differences ($P< 0.05$) among treatments in marketable yield of cabbages (Table 6). Marketable yield of cabbage ranged from 27 to 92 ton/ha. The highest level of marketable cabbage yield was obtained from plots sprayed with diazinon, followed by garlic treated cabbages. Moreover, cabbages treated with chili, ginger, turmeric and lantana gave comparable yield with the aforementioned botanicals. The ginger had the lowest marketable yields. This indicates that controlling DBM populations with botanicals can double the yield of head cabbage production, even though botanicals were not equally as effective as the chemical insecticide in reducing DBM larval population and reducing associated losses.

There were significant differences ($P<0.05$) among treatments on unmarketable yield of the head cabbages. Highest levels of unmarketable yield per plot were obtained from untreated checks. However, non significant differences were recorded among plot of chili, ginger, turmeric and lantana. Diazinon treated plot had the lowest unmarketable yields, which was followed by cabbage treated with neem and garlic (Table 6).

Hasheela *et al*. [17] obtain the highest number of marketable cabbage heads from sprayed cabbage while the highest number of unmarketable cabbage heads on unsprayed one. DBM larvae feeds on the marketable portions of the crop, therefore, synthetic insecticides will remain essential for the management of this pest (Hill & Foster, 2000). The plant extracts compared favorably with the synthetic insecticide in the control of DBM. This could be due to the pungent smell given out by the soaked plant extract [25].

Yield Loss: There were significant differences ($P<0.05$) among treatments in reducing yield losses caused by

DBM in cabbages (Table 6). The amount of marketable cabbage yield loss ranged from 53 to 70%. Gauging the effectiveness of control measures is one of the purposes of estimating yield losses due to pests. Thus the lowest level of yield loss relative to the ginger was obtained from cabbages sprayed with diazinon, followed by cabbages treated with garlic. Moreover, on chili, ginger, turmeric and lantana treated cabbage the yield losses ranged from 52.5, 54, 56 and 58%, respectively. By using diazinon the population of DBM was dramatically reduced resulting in more yield save.

Yield loss studies carried out at Melkassa research center of the Ethiopian Institute of Agricultural Research (EIAR) for two seasons between November 2001 and June 2002 showed that losses can vary between 36.1 and 91.2%, which corresponds to 12 and 48.7 tons/ha [6]. Similarly Lidet [22] reported that yield losses ranged between 62.8 and 74.7% which equates to 44.8 to 52.9 tons per ha at Melkassa and Wonji, respectively.

CONCLUSION

Leaf damage was non- significant for pre-application in 1st week. In the 2nd week, however, there were significant differences ($P<0.05$). The highest leaf damage score was recorded on ginger, whereas the least leaf damage was recorded on garlic treated plots. Similarly the leaf damage of the various treatments was significantly different on 3 to 6 weeks of observations. During these periods the highest leaf damage was on ginger cabbage and the least plots treated with diazinon. Ginger cabbage, the extent of leaf damage increased across the growing season. The leaf damage on botanical treated cabbages was intermediate.

Across the weeks there were significant differences ($P<0.05$) among treatments in affecting population of DBM larvae following foliar applications. The highest number of DBMs larvae (7 per plant) was recorded from ginger plots, except 2nd week in which the highest number of larvae per plant was recorded from chili treated plots. On the other hand, the least number of DBM larvae were recorded from head cabbage treated with diazinon and garlic. Within the same time span, however, the effectiveness of other botanicals was relatively variable. This shows both botanical and chemical insecticide can reduce the number of DBM larvae, even though application of diazinon effectively controlled DBM larvae. Similar to the larval population, across weeks there were significant differences ($P<0.05$) among treatments in number of DBM pupae per plant after foliar applications. The highest number DBM of pupa (5 per plant) was recorded from ginger plots, except at the 2nd week in which the highest number DBM pupae per plant were recorded from endod sprayed plots. The least number of DBM pupae were recorded from head cabbage treated with diaznon. Both botanical and chemical insecticides minimized pupal population of DBM, but the population increased after the fifth week except in diazinon treated cabbage. In most case all agronomic characters, marketable yields and cabbage with head were negatively correlated with cabbage leaf damages across the week.

Significant differences were observed among treatments in some agronomic characteristics of head cabbage. Cabbages sprayed with diaznon produced the tallest plants, followed by garlic and neem. Cabbages treated with other botanicals had medium plant height. However, cabbages sprayed with ginger and unsprayed (control) cabbages had the shortest plants height. There were also differences among treatments in plant stand count and plants with head per plot. Large number of plant and plants with head were recorded on diaznon sprayed cabbages, while the least number of plant stands and plants with head per plot was observed from untreated (ginger) plots.

On the yield data significant differences ($P< 0.05$) among treatments was observed in marketable yield of the cabbages. The highest levels of cabbage marketable yield per plot were obtained from plots sprayed with diazinon foliar applications. This was followed by cabbage treated with neem and garlic. Untreated plot (ginger) had the lowest marketable yields. These indicate that controlling DBM populations with botanicals will increase the yield of head cabbage. The lowest level of yield loss relative to the control was obtained from cabbages sprayed with diazinon followed by cabbage treated with neem and garlic. The economic returns of botanical applications were relatively less than the economic return from diazinone treated cabbage. However, it was much greater than the economic return from untreated cabbages.

The highest DBM larvae and pupae per plant and leaf destroyed per plant were recorded in untreated cabbages across the growing season, whereas the least level DBM larvae and pupae infestation per plant and leaf damage per plant were recorded in diazinon sprayed plots within the growing season. The medium levels of reduction were observed in all botanical treated plots. However, botanicals have additional intangible advantage in that they are environmentally friendly, available locally and reduce the chance of insecticide resistance development.

Recommendations: Finally, from this study the following recommendations have been developed

- To boost head cabbage production in the Central Rift Valley area, DBM and aphid that occur concurrently on head cabbage should be controlled by using diazinon as alternative to the currently used insecticides especially lamda cyhalothrin.
- Botanical insecticide can be used to manage the population of DBM, however further studying the dose, extraction procedure and mode of action is required.
- If botanicals are used to manage DBM, they must be integrated with cabbage aphid control methods.
- Botanical preparation, identification and collection are not well known by the producers in the Central Rift Valley area, so training is important for those producers.

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