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Evaluation of head cabbage varieties and botanicals for diamondback moth management in east Shewa

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Abstract

Cabbage is the second most important vegetable crop in Ethiopia. Many insect pest species belonging to 16 families have been recorded on cabbages. The objective of this study was to determine the influence of head cabbage varieties and botanicals against DBM on head cabbage. The experiment was conducted using irrigation at Adami Tulu Agricultural Research Center (ATARC) during the 2020 cropping season. The head cabbage Glorai, Victoria, K500, Bandug F1and ThomaF1 varieties were used for this experiment. Treatments were arranged in a randomized complete block design (RCBD) with three replications. For DBM management two locally available botanicals and fastac chemicals were sprayed continuously for four weeks and an untreated plot was included for comparison. Throughout the growing season fastac significantly reduced the DBM larvae and pupae population, followed by neem seed and garlic cloves. Highly significant differences among the treatments were observed after the application of botanicals and chemicals on DBM larvae and pupae mortality rate in all of the treatments, but non-significant differences were observed among the head cabbage varieties.

Keywords: Botanical; garlic; fastac; head cabbage; neem; Plutella xylostella.

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1. 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) (MOA, 2002). It is produced by private farmers (Lemma *et al*., 1994). The land occupied during the 2010 main rainy season (Meher) was 4,802 ha with a production level of 43,483.43 tons (CSA, 2012).

Many insect pest species belonging to 16 families have been recorded in Ethiopia on head cabbage (Gashawbeza*et al.*, 2009). However, diamondback moth (DBM) (*Plutellaxylostella* L. Lepidoptera: Plutellidae), cabbage aphid (*Brevicory nebrassicae* L. Hemiptera: Aphididae), flea beetles (*Phylloterta* spp.) and cabbage leaf miner (*Chromatomyi ahorticola* Goureau) (Diptera: Agromyzidae) are of economic importance (Gashawbeza *et al.*, 2009).

The diamondback moth 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 and 91.2% and complete crop failure is common in seasons of heavy infestations (Gashawbeza, 2006).

In Ethiopia, DBM pest status is believed to be strongly influenced by an extensive level of insecticide usage and cabbage production methods. According to Gashawbeza and Ogol (2006), DBM is problematic in the Central Rift Valley areas where the crop is cultivated all 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. There is a need, therefore, to diversify the control options for DBM on cabbage and minimize dependency on pesticide usage. The use of host plant resistance to reduce DBM development has an interesting potential for cabbage, broccoli (B. oleracea var. Italica), and cauliflower (B. oleracea var. botrytis) Hamilton, J.A., *et. al.*(2005). Some evidence suggests that larval feeding or survival may be reduced in normal-bloom varieties through anti xenosis (Verkerk, & Wright, 2008).

Resistant cabbage varieties have been effective in controlling some serious pests of cabbage (Sastrosiswojo *et al*. 1987). Some species and cultivars of brassicas have been more resistant to cabbage DBM infestations than others (Singh & Ellis 1993; Ellis *et al.* 1998). However, Collier & Finch (2008) found that the level of resistance to DBMs was not sufficient to ensure that the partially resistant cultivars remained DBM-free. Van Emden (2007) showed that partial host plant resistance allows a lower dose of insecticide to be effective when DBM populations exceed a threshold. Although several cabbage cultivars are recommended for use in Botswana (Munthali *et al*., 2004; Boket *et al*. 2006), their relative resistance to the cabbage DBM has not been determined.

1.1. Purpose of study

Some plant species possess one or more useful properties such as repellence, anti-feeding, fast knockdown, flushing action, biodegradability, broad-spectrum of activity, and the ability to reduce insect resistance (Mochiah *et al.*, 2011). Therefore this study was conducted to determine the influence of head cabbage varieties and botanicals against DBM on head cabbage in mid rift valley, Ethiopia.

2. Materials and methods

2.1. Data collection instrument

The study collected data using an experiment.

2.1.1. Description of the experimental sites

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC). ATARC is located in the mid-Rift Valley of Ethiopia about 167km south of Addis Ababa. It lies at a latitude of 7° 9'N and a 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 ^{o}C respectively. The pH of the soil is 7.88. The soil is fine sandy loam in texture with sand, clay, and silt in the proportion of 34, 48, and 18% respectively.

2.1.2. Experimental design and management

The experiment was done using 4x5 factorial combinations of head cabbage varieties and plant extract treatments. Head cabbage varieties Glorai, Victoria, K500, Bandug F1, and Thoma F1 and the plant extract Neem, Garlic, and Fastac chemical were used for the present experiment.

Each plot has four-meter long and each ridge 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 a randomized complete block design (RCBD) with three replications. Spacing between plots and blocks was 1 and 1.5 m, respectively. All data were collected only from the central four rows. Plots were fertilized with NPS and urea at the rate of 200 and 100 kg/ha, 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 was at the beginning of the head formation stage. Other field management practices like weeding, cultivation, and maintenance of ridges were carried out as needed.

2.2. Preparation and application of botanicals

2.2.1. 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 an additional 1 L of water. The mixture was then sieved to obtain a uniform extract and kept at room temperature until used (Nayem & Rokib, 2013).

2.2.2. Neem seed extraction

Neem seed was collected from Matahara town Eastern Ethiopia. Kernels were crushed into a fine powder using mortar and pestle and sieved using wire mesh. The extract was made by mixing the powder with water in a plastic container at the rate of 50 g of powder per liter of water. After mixing, the solution was stirred carefully until all the powder was mixed completely with the water. This solution was left overnight. The following morning the extract was filtered into the sprayer using plastic mesh for field use (Lidet, 2007).

2.3. Data collected

2.3.1. 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 the establishment of seedlings and harvest

2.3.2. Canopy spread

Measurement of canopy spread was done with a ruler at the time of harvest. The spread of the 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.

2.3.3. Plant height

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

2.3.4. Diamondback Moth leaf damage

All plants and plant parts were examined for leaf damage by DBM before treatment application and at weekly intervals thereafter. Diamondback moth 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) (Iman *et al*, 1990).

2.3.5. Estimation of Diamondback Moth population

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

2.3.6. 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.

2.4. Analysis

2.4.1. Financial analysis

To assess the benefits derived from the application of each treatment, the simple partial budget technique was employed as described by (CIMMYT, 1988).

$$\mathrm{MRR\%} = \frac{\text{Change NI}}{\text{Change TVC}}$$

Where: NI= change in net income, TVC= change in total variable cost, MRR= Marginal rate of return.

Gross field benefit: it was computed by multiplying the farm gate price that farmers receive for the crop when they sell it.

Total cost: It includes the material and the application costs. The cost of neem was wage paid for collecting ripened kernel 50birr/kg, respectively. The cost of garlic was 80birr/kg. The cost of Fastac chemical was 400birr/L. These prices were based on the 2018 offseason market. A single preparation and application cost for each treatment was also 400birr/ha. The cost of inputs and production practices such as labor costs for land preparation, weeding, hoeing, watering, and harvesting were assumed to remain the same among all the treatments. On the untreated plot, there were only inputs and production cost which was the same for all treatments.

Net benefit: was calculated by subtracting the total costs from the gross field benefit for each treatment.

2.4.2. Estimation of cabbage head formation

Cabbage head formation in each treated plot was recorded during harvesting. The total number of cabbage plants with heads and without heads was recorded separately

2.4.3. Data analysis

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

3. Results

3.1. Leaf damage scores across the weeks

Leaf damage scores over four weeks period are given in table (1). In the first week, there were non-significant differences (P<0.05) among all treatments, because it was before the application of any treatments. 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 leaf damaged score. The highest leaf damage was recorded on untreated and all cabbages varieties, whereas the least leaf damage was recorded on fastac chemicals and botanical-treated cabbages varieties. Similarly in the 3rd and 4th weeks, there were significant differences (P< 0.05) among treatments in leaf damaged score. In all the cases the untreated cabbage had the highest leaf damage score whereas cabbages treated with Fastac had the lowest leaf damage due to DBM. Cabbages treated with botanicals had intermediate leaf damage. In general, the level of leaf damage on the control-treated plots increased at the heading stage because the population of larvae was higher at the heading stages.

Table 1

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

treatments	Weeks			
	1	2	3	4
Untreated bandung	3.2a	3.9a	4.00a	3.62a
Untreated k500	2.66a	3.61a	2.66ab	4.62a
Untreated thomas	3.00a	2.96ab	3.33a	3.90a
Untreated gloria	2.66a	3.22a	3.22a	4.22a
Untreated victoria	2.77a	2.67ab	3.33ab	3.55a
Fastac treated gloria	2.00a	1.67bc	0.66c	1.66bc
Fastac treated k500	2.20a	1.43c	2.33bc	1.43bc
Fastac treated thomas	2.00a	2.08bc	1.77bc	2.08bc
Fastac treated c victoria	2.45a	2.31b	1.74bc	2.33bc
Fastac treated bandung	2.33a	2.42b	2.33bc	2.77bc
Garlic treated bandung	2.5a	1.33bc	3.00abc	2.00bc
Garlic treated gloria	2.43a	2.70abc	3.20abc	2.69bc
Garlic treated k500	2.33a	2.05bc	2.30bc	2.06bc
Garlic treated thomas	2.66a	2.70bc	2.86bc	2.97ab
Garlic treated victoria	2.33a	2.66abc	2.52bc	2.69bc
Neem treated gloria	2.45a	2.5abc	2.16bc	2.50bc
Neem treated K500	2.33a	1.81bc	2.22bc	1.8bc
Neem treated thomas	2.5a	1.67bc	2.67bc	1.67bc
Neem treated victoria	2.44a	2.33bc	2.27bc	1.8bc
Neem treated bandung	2.33a	2.41abc	2.16bc	2.4bc
LSD	ns	4.02	3	3.11
Mean	2.47	2.42	2.56	2.64
CV	25.69	27.68	30.33	31.45

3.2. DBM larval population24h after treatment application

Across all the weeks' significant differences (P< 0.05) were observed in the population of DBM larvae per plant among treatments following foliar applications (table 2). The highest numbers of DBM larvae per plant were recorded from untreated cabbage varieties. Whereas the least number of DBM larvae were recorded from head cabbage varieties treated with Fastac, followed by garlic and neem treated cabbage varieties. 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 pres pray larval density and to the shortest evaluation time.

Table2

Mean number of DBM Larvae per plant sprayed with botanicals and chemicals in 24h post applications

treatments	Weeks			
	1	2	3	4
Untreated bandung	2.67ab	2.33ab	5.67a	6.33a
Untreated k500	2.87ab	5.04a	6.88a	5.08a

Untreated thomas	2.83ab	3.33ab	5.00ab	3.33ab
Untreate gloria	3.88a	3.22ab	5.22ab	3.03ab
Untreated victoria	3.66a	2.67ab	6.67a	2.67ab
Fastac treated gloria	0.5de	1.67b	0.00b	1.16b
Fastac treated k500	0.67de	1.00b	1.33b	1.00b
Fastac treated thomas	0.00e	0.88b	0.88b	0.76b
Fastac treated victoria	0.00e	1.33b	0.75b	1.75b
Fastac treated bandung	0.32de	1.67b	2.00b	1.67b
Garlic treated bandung	1.25cde	1.33b	3.33b	2.00ab
Garlic treated gloria	1.27cde	1.4b	2.67b	1.4b
Garlic treated k500	1.33cde	1.22b	1.32b	1.32ab
Garlic treated thomas	1.87cd	1.00b	3.5ab	1.00b
Garlic treated victoria	1.78cd	1.66b	2.33ab	1.33b
Neem treated gloria	1.22cde	0.83b	0.33b	0.83b
Neem treated K500	0.83de	1.35b	2.67b	1.44b
Neem treated thomas	1.23cde	1.33b	2.33b	1.33b
Neem treated victoria	1.2cde	1.22b	2.5b	1.00b
Neem treated bandung	1.33cde	0.46b	1.22ab	0.87b
LSD	0.45	1.23	1.41	2.33
Mean	1.53	1.74	2.83	1.96
CV	29	26.58	19.88	21.33

3.3. DBM pupae population 24h after treatment application

Similar to the larval population, there were significant differences (P< 0.05) among treatments across weeks in the number of DBM pupae per plant after foliar applications (table 3). The pupal population intensity followed more or less the larval population intensity. Thus, the highest number of DBM pupa per plant was recorded from untreated cabbage varieties. The least number of DBM pupae were recorded from head cabbage varieties treated with Fastac.

Table 3

Mean number of DBM Pupae per plant sprayed with botanicals and chemicals in 24 hr applications

Treatments	**Weeks**			
	1	2	3	4
Untreated bandung	5.22ab	1.78a	4.30a	3.35ab
Untreated k500	6.45a	1.67a	5.67a	4.77a
Untreated thomas	7.11a	1.33ab	5.00a	2.87ab
Untreated gloria	4.66b	1.86a	4.86a	3.86a
Untreated victoria	4.22b	1.66ab	5.66a	4.66a
Fastac treated gloria	0.00c	0.4ab	0.45b	1.00b
Fastac treated k500	0.67c	1.33ab	0.67b	1.45b
Fastac treated thomas	0.33c	0.66ab	1.00b	0.75b
Fastac treated victoria	0.33c	1.16ab	0.33b	1.08b
Fastac treated bandung	0.45c	1.00ab	1.00b	1.00b
Garlic treated bandung	1.33c	0.45ab	1.67b	1.16b

Garlic treated gloria	1.67c	1.33ab	2.83ab	1.33b
Garlic treated k500	1.2c	0.22ab	1.33b	1.78b
Garlic treated thomas	1.33c	0.66ab	1.67b	0.5b
Garlic treated victoria	1.67	0.66ab	2.76ab	2.83ab
Neem treated gloria	0.67c	1.22ab	0.00b	0.33b
Neem treated K500	1.00c	0.68ab	1.33b	0.67b
Neem treated thomas	1.22c	1.00ab	0.67b	1.00b
neem treated victoria	1.00c	1.33ab	0.42b	2.67b
Neem treated bandung	1.33c	0.67ab	1.00b	0.83b
LSD	0.61	1.74	1.56	2.47
Mean	2.75	0.43	2.42	1.84
CV	31	23.47	26.55	28.33

3.4. Effect of varieties and botanicals and chemical application on Some Agronomic Characteristics

Plant height at harvest:

There was a significant difference (P<0.05) among treatments in affecting plant height (Table 4). Cabbage varieties sprayed with either fastac or garlic produced the tallest plants. Medium plant height was measured from cabbage varieties treated neem. However, head cabbage varieties sprayed with ginger and untreated cabbage had the shortest plant height. This is consistent with the finding of Asare *et al.* (2010) who indicated that treating cabbage with insecticide reduced the insect population on cabbage and hence better growth of the crop. Nayem and Rokib (2013) also reported that okra grows vigorously when treated with botanical insecticides.

3.4.1. Plants stand count:

There were significant differences (p<0.05) among treatments in plant stand count per plot (Table 4). A large number of the plant was recorded on fastac sprayed plots, while the least number of plant stands per plot was observed from untreated (control) plots. Botanicals did not differ statistically from each other in affecting plant stand. The loss of plant stand is attributed to damage by DMB and managing the DBM population will reduce the death of cabbage plants (Gashawbeza, 2006).

3.4.2. Cabbage with heads:

Significant differences (p < 0.05) were observed among treatments in the percentage of plants that formed heads (Table 4). Cabbage varieties treated with Fastac, garlic, and neem, in decreasing order respectively formed a greater percentage of heads of cabbage varieties. The least number of plants with the head was recorded from untreated (control) plots. The DBM feeds mostly on the young part of the plant which is the major part of the head formation. As plants lose this part they fail to form a head or die under severe infestation.

Van Mele *et al*. (2001) 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* (2010) heavy head per plant was recorded for cabbages that received treatments against DBM attack when compared with the untreated.

3.4.3. Plant canopy spread

Similar to others there were also significant differences (p > 0.05) among treatments in plant canopy spread (table 4). Cabbage varieties treated with Fastac, Neem and garlic had larger diameters, which had relatively area coverage of plants per plot. The least canopy spread of plants with less area coverage was recorded from untreated (control) plots. DBM larvae adversely affected the formation of the head by destroying the tip of the head cabbage.

Table 4

Effect of botanicals on agronomic characteristics of cabbage varieties at Adami Tullu

treatments	Stand counts(number)	Plant canopy(cm)	Plant height(cm)	Cabbage with head (%)
Untreated bandung	26.00bc	35.33cd	27.67bcd	83.14d
Untreated k500	26.00bc	43.00cbd	24.33bc	85.47cd
Untreated thomas	27.68bc	32.33d	24.67bcd	79.61d
Untreated gloria	28.05bc	35.67cd	26.33bcd	86.75c
Untreated victoria	23.00c	44.33bcd	23.00d	84.37c
Fastac treated gloria	35.66ab	69.67a	29.00bcd	92.42a
Fastac treated k500	36.00ab	51.67abc	36.33ab	90.00ab
Fastac treated thomas	31.33abc	52.00abc	33.00abc	90.35ab
Fastac treated victoria	36.00a	60.33ab	33.00abc	91.70a
Fastac treated bandung	38.00a	45.00bcd	41.67a	93.17a
Garlic treated bandung	34.67ab	44.00bcd	30.67bc	86.14c
Garlic treated gloria	35.00ab	54.00abc	36.67ab	88.47b
Garlic treated k500	32.33abc	52.00abc	31.67bcd	86.61c
Garlic treated thomas	33.33ab	55.67ab	34.00abc	88.75b
Garlic treated victoria	34.67ab	51.33abcd	35.33abc	87.37b
Neem treated gloria	30.67abc	46.67 bc	32.00abc	88.42b
Neem treated K500	36.00a	60.00ab	27.00bcd	89.00ab
Neem treated thomas	26.00bc	56.67ab	26.00bcd	84.35c
Neem treated victoria	36.33a	53.67acb	30.67abc	91.70ab
Neem treated bandung	37.00a	53.33abc	30.33bcd	90.17ab
LSD	7.8	11.22	4.35	5.6
Mean	28.66	47.36	33	86.51
CV	22	19	24	26

3.5. Effect of chemical and botanicals on cabbage varieties yield and yield components

Effect on Marketable and unmarketable Yield

There were significant differences ($P< 0.05$) among treatments in the marketable yield of cabbage varieties (Table 5). The marketable yield of cabbage varieties ranged from 269 to 480 qu/ha. The highest level of marketable cabbage varieties yield was obtained from plots sprayed with Fastac, followed by neem and garlic-treated cabbage varieties. The untreated plot (control) had the lowest marketable yields. This indicates that controlling DBM populations with botanicals can double the yield of head cabbage varieties 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 the unmarketable yield of the head cabbage varieties (Table 5). The highest levels of unmarketable yield per plot were obtained from untreated checks. However, no significant differences were recorded between fastac and botanicals.

Hasheela *et al*. (2010) reported that as compared to unsprayed cabbage varieties, the highest numbers of marketable head cabbage varieties were obtained from sprayed cabbage varieties while the highest number of unmarketable cabbage varieties heads was noted on unsprayed ones. DBM larvae feed 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 were 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 which deters animals from eating the plant.

3.6. Financial analysis

Results of the economic analysis are presented in (Table 5) spraying cabbage varieties with Fastac gave the highest net benefit per hectare with the highest marginal return rate. This was followed by cabbage varieties treated with neem and garlic. The untreated plot (control) resulted in the lowest economic return with the lowest marginal return rate. The economic evaluation indicated that the untreated DBM population using botanicals increased net benefit and marginal return rate at least twice when compared to the untreated check.

Table 5

Effect of botanical application on yield of cabbage varieties and economic return

treatments	Marketable yields (qu)	Unmarket able yield (qu)	Farm get price(birr)	Gross return rate	Variable cost birr/ha	Net income	Marginal rate return
Untreated bandung	269.30c	36.70a	8	215,440	48200	167,240	3.4
Untreated k500	296.70bc	29.67ab	8	237360	48200	189,160	3.6
Untreated thomas	286.70c	32.33ab	8	229360	47600	181760	3.8
Untreated gloria	272.30c	28.67b	8	217840	50300	16540	3.2
Untreated victoria	269.30c	27.33bc	8	215440	48200	167240	3.2
Fastac treated gloria	447.70a	23.00bc	8	358160	53800	304360	5.6
Fastac treated k500	343.30ab	22.30bc	8	274640	54000	220640	4
Fastac treated thomas	339.70abc	24.33bc	8	271760	54000	217760	4
Fastac treated victoria	379.70ab	19.33cd	8	303760	55200	248560	4.5
Fastac treated bandung	434.00a	28.00b	8	347200	54000	293,200	5.4
Garlic treated bandung	414.30ab	17.33d	8	331440	51000	280440	5.5
Garlic treated gloria	346.30ab	23.00bc	8	277040	51800	225,240	4.4
Garlic treated k500	359.00abc	22.30bc	8	287200	51000	236200	4.6
Garlic treated thomas	337.00abc	23.22bc	8	269600	52600	217,000	4.2
Garlic treated victoria	381.70ab	27.33bc	8	305360	52600	252760	4.8
Neem treated gloria	367.00ab	19.33cd	8	293600	50200	243,400	4.8
Neem treated K500	427.30a	27.67bc	8	360240	50500	306740	6
Neem treated thomas	425.30a	27.67bc	8	340240	50500	289,740	5.4
Neem treated victoria	358.67ab	17.22d	8	286936	50500	236,436	4.6
Neem treated bandung	417.00ab	25.33bc	8	333600	50500	283,100	5.2
CV	27	18					

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

4. Discussion

The population growth of DBM larvae and pupae showed a similar trend during the growing season except before the application of any treatments. 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 fastac, followed by neem and garlic treated cabbages and untreated plots (control) had the lowest marketable yields The present observation is in line with the findings of Gautam et al., (2018) 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.

In all weekly applications, Fastac significantly reduced the DBM larvae population; this was followed by garlic and neem. Oberholzer, (2019) reported that chemicals proved more toxic to a susceptible strain of DBM than dichlorvos, profenofos, acephate, and chlorpyriphos. Other researchers also reported that insecticides are generally considered the most effective means of protecting crops against insect damage as they provide rapid untreated of wide pest complex of major crucifer's pests, and growers concerned about leaf damage, even of a few holes, tend to spray insecticides. Soth et al., (2022) believed that repeated insecticide applications are required to control DBM, especially during the peak population period. However, Navik *et al (*2019) warned that effective insecticidal control of DBM might not be achieved for a 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 an acceptable level of DBM larvae reduction. Nayem and Rokib (2013) found vigorous okra growth by treating with garlic bulb extracts, but not as effective as the neem extracts to control DBM. Gautam *et al*., (2018) reported botanical insecticides as effective against *P. xylostella.* These plant extracts apply to cabbage varieties' pest management through a reduction in the use of synthetic insecticide spray as an important component of the 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 antifeedant, non-neuro toxic modes of action, and low environmental persistence. Gautam et al., (2018) also indicated that botanicals like neem extracts play an important role in altering the attractive properties of crucifer plants to *P. xylostella*.

Botanicals can have an effect on the 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 reduces 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, the dead larvae-pupal intermediate stage having the head of the pupa and the abdomen of a larva. Dead adults with folded wings in pupal exuvium and emerging adults were unable to escape the pupal exoskeleton, half ecdysed adults, etc.(Facknath and Kawol, 1996). According to Lidet (2007) plots treated with Neem 50, Dipel and Xen Tari chemicals showed the least DBM number throughout the sampling weeks. Also, Gashawbeza (2006) observed a low number of DBM ranging from zero to 4 per plant in an insecticide untreated trial. He reported significant differences in DBM number between the untreated plot and plots treated weekly throughout the growing period.

5. Conclusion

Leaf damage 1st week was non-significant differences (P> 0.05) across all treatments. In the 2nd week, however, there were significant differences (P<0.05) among treatments in leaf damaged score. The highest leaf damage score was recorded on untreated (control) cabbage varieties, whereas the least leaf damage score was recorded on Fastac treated plots. Similarly, in the 3rd and 4th weeks, there were significant differences (P< 0.05) among treatments in leaf damaged score. During these periods the highest leaf damage score was recorded on control cabbage but the least leaf damage was recorded on plots treated with fastac chemical.

Across all the weeks there were significant differences (P< 0.05) among treatments in affecting the population of DBM larvae following foliar applications. The highest number of DBMs larvae (6.88 per plant) was recorded from control plots. On the other hand, the least number of DBM larvae were recorded from head cabbage treated with Fastac, Garlic, and Neem. This shows both botanical and chemical insecticides can reduce the number of DBM larvae, even though the application of chemicals effectively controlled DBM larvae.

Similar to the larval population, across weeks there were significant differences (P< 0.05) among treatments in several DBM pupae per plant after foliar applications. The highest number of DBM of pupa was recorded from control plots. The least number of DBM pupae were recorded from head cabbage treated with fastac. Both botanical and chemical insecticides minimized the pupal population of DBM. On the yield data, significant differences (P< 0.05) among treatments were observed in the marketable yield of the cabbages. The highest levels of cabbage marketable yield per plot were obtained from plots sprayed with fastac foliar applications. This was followed by cabbage treated with neem and garlic. The untreated plot (control) had the lowest marketable yields. These indicate that controlling DBM populations with botanicals can increase the yield of head cabbage.

Based on the above results, it can be concluded that the highest plant height at harvest, a large number of stand count, and a large number of cabbage with heads were recorded in fastac treated plot, whereas the shortest plant height, least stand count and least number of cabbage with head were recorded in the untreated plot. However, botanicals have additional intangible advantages in that they are environmentally friendly, available locally, and reduce the chance of insecticide resistance development.

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

- Across all the weeks there were significant differences (P< 0.05) among treatments in affecting the population of DBM larvae and pupae.
- The highest marketable cabbage yield was obtained from plots sprayed with fastac, followed by neem and garlic treated cabbages and untreated plots (control) had the lowest marketable yields.
- Those plant species possess useful properties such as repellency, anti-feeding, fast knockdown, flushing action, biodegradability, a broad spectrum of activity, and the ability to reduce insect resistance all botanical treatments reduced the number of DBM larval population.
- Head cabbage varieties listed in this study have no significance for DBM management.
- To boost head cabbage production, DBM on head cabbage should be controlled by using fastac and also neem seed, and garlic cloves as alternatives to the currently used insecticides.
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APPENDIXES

Appendix Table1. ANOVA table of DBM population at 1st Week

DBM leaf damage

Source	DF	S. square	M.square	F value	Pr < F
Replication	3	0.46	0.15	1.07	0.0001
Treatment	19	0.79	0.08	0.61	0.001
Error	38	3.89	0.14		
Total	59	5.14			

Larvae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	1.09	0.36	0.83	0.01
Treatment	19	33.79	3.75	8.54	<0.0001
Error	38	8.79	0.43		

Total	59	5.14

Pupae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.89	0.29	3.01	0.053
Treatment	19	4.55	0.50	5.1261	0.001
Error	38	2.07	0.09		
Total	59	8.6			

Appendix Table 2. ANOVA table of DBM population at 2nd Week

DBM leaf damage

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	12	0.54	0.84	0.008
Treatment	19	9.51	1.05	1.65	0.00004
Error	38	17.33	0.64		
Total	59	28.46			

Larvae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.66	0.22	0.85	0.0047
Treatment	19	10.50	1,16	4,50	0.0014
Error	38	6.48	0.25		
Total	59	18.31			

Pupae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	2.66	0.88	2.96	0.04
Treatment	19	14.52	1.61	5.39	0.0003
Error	38	8.08	0.29		
Total	59	25.27			

Appendix Table 3. ANOVA table of DBM population at 3rd Week

DBM leaf damage

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.83	0.27	0.62	0.001
Treatment	19	13.48	1.49	3.35	0.0092
Error	38	10.28	0.44		
Total	59	24.29			

Larvae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	1.16	0.38	0.60	0.0003
Treatment	19	24.13	2.68	4.16	0.0019
Error	38	42.69			
Total	59				

Pupae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.27	0.09	0.16	0.002
Treatment	19	11.54	1.28	2.31	0.05
Error	38	12.74	0.55		
Total	59	24.74			

Appendix Table 4. ANOVA table of DBM population at 4th Week

DBM leaf damage

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.64	0.64	1.18	0.0003
Treatment	19	17.43	1.93	3.57	0.03
Error	38	4.88	1.54		
Total	59	22.95			

Larvae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.11	0.12	0.35	0.56
Treatment	19	5.77	0.64	2.04	0.16
Error	38	2.52	0.31		
Total	59	8.35			

Pupae after spray

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	0.73	0.73	3.84	0.0008
Treatment	19	6.14	0.68	3.56	0.03
Error	38	1.72	0.19		
Total	59	8.60			

Appendix Table 10. ANOVA Table of Agronomic characters

Cabbage Canopy spread

Source	**DF**	**S. square**	**M.square**	**F value**	**Pr < F**
Replication	2	40.85	13.61	1.49	0.003
Treatment	19	61.46	6.82	0.75	0.006
Error	38	247.30	9.15		
Total	59	349.61			

Cabbage With heads

Source	**DF**	**S. square**	**M.square**	**F value**	**Pr < F**
Replication	2	131.70	43.90	5.60	0.0041
Treatment	19	212.00	23.55	3.00	0.012
Error	38	211.80	7.84		
Total	59	555.50			

Stand count

Source	**DF**	**S. square**	**M.square**	**F value**	**Pr < F**
Replication	2	169.27	56.42	4.58	0.01
Treatment	19	238.22	26.46	2.15	0.06
Error	38	332.47	12.31		

Total	59	739.97			

Appendix Table 11. ANOVA table of yields components

Marketable yields

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	363.30	121.10	1.18	0.33
Treatment	19	5355.00	595,00	5.79	0.0002
Error	38	2775.97	102.81		
Total	59	8494.28			

Unmarketable yields

Source	DF	S. square	M.square	F value	Pr < F
Replication	2	115.50	38.50	2.64	0.06
Treatment	19	756.10	84.01	5.76	0.0002
Error	38	393.50	14.57		
Total	59	1265.10			