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The Effect of Plant Extract for Managing Diamondback Moth, Plutella Xylostella L. (Lepidoptera: Plutellidae) on Head Cabbage in Ethiopia

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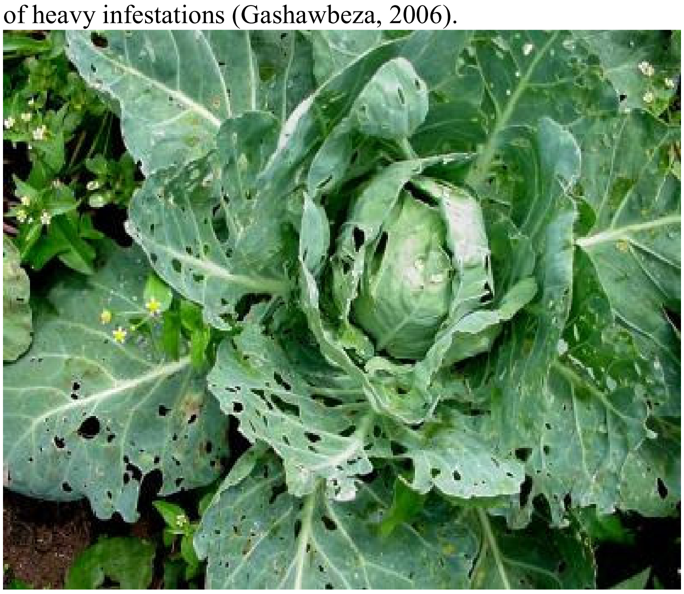
Abstract
Cabbage (Brassica oleracea var. capitata) is the second most important vegetable crop in Ethiopia. Many insect pest species belonging to 16 families have been recorded on cabbages. Therefore the objective of this study was to assess the efficacy of botanicals for managing diamondback moth on 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 was sprayed continuously for six weeks. Throughout the growing season neem significantly reduced the DBM larvae and pupae population. 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 neem.
Keywords: botanicals, neem, cabbage, turmeric, control, lantana, DBM.

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 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, 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 (Tsedeke and Gashawbeza, 1994; 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 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 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 (Gashawbeza *et al.,* 2009).

Botanical insecticides are not only effective against crop pests but remain safer to natural enemies (Patel *et al*., 2003). 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 (Schmutterer, 1981). Some of these plant species possess one or more useful properties such as repellency, anti feeding, fast knock down, flushing action, biodegradability, broad-spectrum of activity and ability to reduce insect resistance (Mochiah *et al.*, 2011).

Therefore this study was 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 diamondback moth on head cabbage.

2. Materials and Methods

2.1. 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 ºC 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 (ATARC, 1998).

2.2. 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 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 at the beginning of head formation stage. Other field management practices like weeding, cultivation and maintenance of ridges were carried out as needed.

2.3. Experimental Materials

The experimental treatments were four botanicals and an untreated check (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. For comparison untreated check was included.

Table 6.Details of plant species used for the experiment

Treatment code	Common name	Scientific name	Variety	Part used	Rate
3	Neem	*Azadirachta indica*	Local	kernel	50 g/L
6	Lantana	*Lantana camara*	Local	leaf	100 g/L
7	Chili	*Capsicum annuum (*L)	Marecofana	fruit	100 g/L
8	Turmeric	*Curcuma longa (*L)	Local haldi	rhizome	50 g/L

2.4.4. Chili preparation

A 200 g of red chili pepper was mixed in two liters of water and the solution was allowed to stand for 24 hours, and then the solutions was strained and added 50 g of concentrate to a 3.75 L of water. The extract was later sprayed on the leaves.

2.4.5. *Lantana camara* leaf extraction

One kg of young fresh lantana leaf was collected and crushed into small pieces using knife, then the chopped leaf was ground using grinder with 250 ml of water to make paste. The paste was strained through muslin cloth and kept for 24 hours. At the time of application the aqueous extract was diluted in 9.75 L water.

2.4.7. Turmeric extraction

One kg of turmeric rhizome was chopped and soaked overnight in 2 L of water. The next day the extract was filtered and filled up to 15 L and sprayed on the field.

2.4.8. Neem kernel extraction

Neem kernel was collected from Dire Dawa, Eastern Ethiopia. Kernels were crushed in to fine powder using mortar and pestle, and sieved using wire mesh. The extract was made by mixing the powder with water in plastic container at the rate of 50 g powder per liter of water. After mixing, the solution was stirred carefully until all the powder wasmixed 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.

2.5. Data collected

2.5.1. 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 (P. K. Baidoo, 2012).

2.5.2. 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 (Asare *et al.,* 2010).

2.5.3. 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 (Judenko, 1973).

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

Where, $\bar{x}$ = mean seed cotton yield of treated plots

$\bar{y}$ = mean seed cotton yield of untreated plots

2.5.4. Diamondback Moth leaf damage

All plants and plant parts were examined for leaf damage by DBM before treatment application and at weekly interval 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).

2.5.5. 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 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.

2.5.6. 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.

2.5.8. 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.

2.6. 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.

3. Results and Discussion

3.1. Leaf damage visual scores across weeks

Leaf damage scores over six weeks period is given in table (2). 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 control cabbages, whereas the least leaf damage was recorded on neem 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 control cabbage had the highest leaf damage score whereas cabbages treated with neem had the lowest leaf damage due to DBM. Cabbages treated with botanicals had intermediate leaf damage. Level of leaf damages were positively correlated with the larvae population, except in 2nd and 3rd weeks.

The present observation is in line with finding of Nakagome and Kato (1981) 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 Freddy (2011) the leaf damage was significantly lower in fields treated with insecticides than in fields not treated with insecticides. Sakai (1984) shows all crucifers suffer depredation by this pest practically throughout the growing season. Asare *et al* (2010) reported the mean leaf damage for unprotected plants were higher than those which were treated in various ways.

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

Treatment	**Week**					
	1	2	3	4	5	6
Control	3.37±.12a	3.16±.09 ab	3.50±.028a	4.0±.00a	4.12±.25a	4.25±.25a
Turmeric	3.12±.12a	2.95±.37ab	2.10±0.4b-d	3.50±0.00ab	2.50±.28c	3.00±.41cd
Chili	3.10±.19a	2.91± .33ab	2.27±.14b-d	2.60±.12dc	3.25±.25b	3.25±.25bc
Lantana	3.01±.19a	2.18± .27ab	2.50±.21a-d	2.70±.75a-c	2.00±.00c	2.00±.00e
Neem	3.00±.00a	2.50± .14ab	2.25±.39b-d	2.40±.16a-c	2.25±.25cd	2.25±.25d-e

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

3.2. DBM larval population24h 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 were recorded from control cabbages, except during second week when the highest number of larvae per plant was recorded from chili treated cabbages. Whereas the least number of DBM larvae were recorded from head cabbage treated with neem. Although there was 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. Within the same time span, however, the effectiveness of other botanicals was relatively variable.

In all weekly application, neem significantly reduced DBM larvae population; this was followed by lantana and turmeric. Magallona (1985) also reported that insecticides are generally considered the most effective means of protecting crops against insect damage as they provide rapid control 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 (1981) believed that repeated insecticide applications are required to control DBM, especially during the peak population period. However, Motoyama *et al (*1990) 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, botanicalsgave acceptable level of DBM larvae reduction. Nayem and Rokib (2013) found vigorous okragrowth by treating with garlic bulb extracts, but not so effective than the neem extracts to control DBM. Shivanand*et al*., (2009) reported botanical insecticides as effective against *P. xylostella.* 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 (Arnason *et al.,* 1992).Gaby (1988) also indicated that botanicals like neem extracts play an important role in altering the attractive properties of crucifer plants to *P. xylostella*.

Table 3. Mean number of DBM Larvae per plant sprayed with botanicals and chemical in 24h postapplications

Treatment	Week					
	1	2	3	4	5	6
Control	3.16± .48a	1.50±.28ab	2.87±.51a	1.91±.41a	8.00±.57a	8.00±.57a
Turmeric	2.33± .33ab	1.79±.00ab	1.00±.57cb	1.50±.25ab	2.25±.75b	2.50±.64b
Chili	1.75±.63bc	2.00±.00a	2.00±.4ab	0.91±.4a-c	3.90±1.2b	3.92±1.2b
Lantana	2.00± .00a-c	1.25± .47a-c	1.25±.47bc	1.20±.45a-c	2.00±.57bc	2.25±.75b
Neem	0.00±.00d	1.00±.27bc	0.25±.25c	0.29±.04bc	2.00±.00b	2.25±.25b

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

3.3. DBM pupae population 24h after treatment application

Similar to the larval population, there was significant differences (P< 0.05) 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 control cabbages. The least number of DBM pupae were recorded from head cabbage treated with neem. In the 2nd week there were less than one DBM pupa per plant on lantana and neem treated cabbages. Similarly, in the third and fourth weeks the least number of DBM pupae were recorded from head cabbage treated with neem, turmeric and lantana 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 would 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.(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 low number of DBM ranging from zero to 4 per plant in an insecticide control trial. He reported significant differences in DBM number between the untreated plot and plots treated weekly throughout the growing period.

Table 4.Mean number of DBM Pupae per plant sprayed with botanicals and chemical in 24 hr applications

Treatment	Week					
	1	2	3	4	5	6
Control	2.75± .14a	1.62±.21ab	1.70±.29a	1.83±.16a	2.50±.28a	5.00±1.58a
Turmeric	1.33± .19ab	1.00±.00 b-d	1.30±.33a	1.30±.00a-c	1.50±.28bc	1.50±.28b
Chili	1.25± .14a-c	1.00± .00b-d	1.00±.4ab	1.00±.00a-d	1.00±.00c	1.0±.00b
Lantana	1.50±.00ab	0.25±.14de	1.30±.44a	1.33±.66a-c	1.00±.40c	0.50±.28b
Neem	1.25± .14a-b	0.50±.28c-e	0.00±.00b	0.25±.00cd	0.75±.25a-c	0.50±.28b

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

3.8. 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 neenm produced the tallest plants. Medium plant height was measured from cabbages treated with other botanicals. However, head cabbage sprayed with the control cabbage had the shortest plants 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.

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 neem, lantana and turmeric, 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 untreated (control) 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*. (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 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 turmeric, neem and lantana had larger diameter than cabbages treated with chilli, 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 (Talekar and Shelton, 1993).

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)
Control	46.68±1.56a	18.50±0.89c	83.14f	42.75±1.43b
Chili	47.65±1.77a	19.85±0.37bc	88.47d	46.25±3.70ab
Turmeric	48.18±1.11a	19.91±0.37bc	88.75d	46.0±1.58ab
Lantana	48.05±1.20a	20.05±0.79a-c	88.42d	46.25±0.94ab
Neem	48.86±2.32a	21.77±0.64ab	91.70b	49.00±2.67ab
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

3.10. 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 neem. Moreover, cabbages treated with chili, turmeric and lantana gave comparable yield with the aforementioned botanicals. The untreated plot (control) 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 (Table 6). Highest levels of unmarketable yield per plot were obtained from untreated checks. However, non significant differences were recorded among plot of chili, turmeric and lantana. Neem treated plot had the lowest unmarketable yields.

Hasheela *et al*. (2010) reported that as compared to unsprayed cabbage, highest number of marketable cabbage heads was obtained from sprayed cabbage while the highest number of unmarketable cabbage heads was noted 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 which deter animals from eating the plant Sivapragasam and Aziz (1990).

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 control was obtained from cabbages sprayed with neem. Moreover, on chili, turmeric and lantana treated cabbage the yield losses ranged from 52.5, 56 and 58% respectively.

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 Gashawbeza (2006). Complete crop failure is reported to be common on farmers' field in seasons of heavy infestation in the Central Rift Valley areas when there is no DBM management. Similarly Lidet (2007) 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.

Economic return

Results of the economic analysis are presented in (Table 6). Spraying cabbage with neem gave the highest net benefit per hectare with the highest marginal return rate, but the marginal return rate of from these treatments was less than the return from lantana treatment because the application and preparation costs of lantana were less than the cost of all botanicals. Untreated plot (control) resulted in the lowest economic return with lowest marginal return rate. The economic evaluation indicated that controlling DBM population using botanicals increased net benefit and marginal return rate at least twice when compared to untreated check.

Table 6. Effect of botanical application on yield of cabbage and economic return

Treatment	Marketable ton/ha	Unmarketable ton/ha	Yield loss (%)	Farm gate Price birr	Gross return birr/kg	Variable cost birr/ha	Net benefit birr/ha	Marginal return rate
Control	27.75c	20.0a	-	3	83250	21096	62,154	3.92
Chili	58.50b	8.75bc	52.52c	3	175500	28776	146,724	6.09
Turmeric	63.50b	9.50bc	56b	3	190500	25296	165,204	7.52
Lantana	63.25b	8.25bc	56b	3	189750	22776	166,974	8.31
Endod	66.55ab	7.00bc	58b	3	199650	29016	170,634	6.88
Neem	77.25a	5.50bc	64a	3	231750	30276	201,474	7.65
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

4. Summary and 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 differences on 3 to 6 weeks of observations. During these periods the highest leaf damage was on ginger cabbage and the least plots treated with neem. Control 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 control 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 neem. Within the same time span, however, the effectiveness of other botanicals was relatively variable. This shows botanical insecticide can reduce the number of DBM larvae, even though application of neem 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 control plots, except at the 2nd week in which the highest number DBM pupae per plant were recorded from chilli sprayed plots. The least number of DBM pupae were recorded from head cabbage treated with neem. Both botanical and chemical insecticides minimized pupal population of DBM. 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 neem produced the tallest plants and cabbages treated with other botanicals had medium plant height. However, 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 neem sprayed cabbages, while the least number of plant stands and plants with head per plot was observed from untreated (conrol) 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 neem foliar applications.

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 neem 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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