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Efficacy of Botanicals to manage Cabbage Aphid (*Brevicoryne brassicae*) on Cabbage (*Brassicae oleraceae*), Ethiopia

Wubayehu Ayenew Kassie[1], Abaynew Jemal Jenber[2*]

[1]Department of Biology, College of Natural and Computational Sciences, Kabridahar University, Kabridahar, Ethiopia.
[2]Department of plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia.

ABSTRACT

An important vegetable in Ethiopia is cabbage (Brassica oleracea L. var. capitata), but the cabbage aphid severely limits its production, resulting in yield losses of up to 80%. Reliance on synthetic insecticides has created environmental and health risks, suggesting that there must be underscoring sustainable pest control alternatives. This study assessed the efficacy of botanicals (Endod, Tobacco, Tinju, and Kitkita) against cabbage aphids in the Koga Irrigation Scheme during the 2023 irrigation season. The experiment used a randomized full block design with three replications and fourteen treatments, including three concentration levels for each botanical, a chemical check (Dimethoate 40% EC), and a control. SAS 9.4 software examined data on aphid infestation, efficacy, plant growth, yield, and economic return. All botanical treatments significantly suppressed aphid populations compared with the control. The highest efficacy was recorded in Endod 7.5% (87.17%) and Tobacco 7.5% (82.12%), comparable to Dimethoate 40% EC (92.76%). Moreover, Endod 7.5% yielded the largest net benefit (762,138 ETB ha^{-1}) with a benefit–cost ratio of 6.69, the lowest yield loss (3.49%), and the highest marketable yield (49.78 t ha^{-1}). Increasing concentration and repeated applications enhanced performance. Therefore, Endod extract at 5–7.5% concentration is recommended as an effective, economical, and eco-friendly botanical option for sustainable cabbage aphid management in Ethiopia.

Keywords: *Brevicoryne brassicae, Botanical insecticides, Cabbage, Eco-friendly pest management, Phytolacca dodecandra, Yield*

Corresponding author: Abaynew Jemal Jenber
e-mail ✉ abujemal900@gmail.com
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INTRODUCTION

Cabbage (*Brassica oleracea* L. var. capitata) is one of the most popular food crops cultivated throughout the world. Brassica leafy vegetables are widely cultivated in Africa, including Ethiopia. In Ethiopia, head cabbage is mostly produced for consumption and as a source of income (Tekle & Tesfu, 2023).

In contrast to other major cabbage-producing nations, Ethiopia in general and Amhara Regional State in particular have very low levels of cabbage production and productivity (Habtamu & Mnuyelet, 2022). In 2018, Ethiopia produces only 6 tons of cabbage per hectare, which is much less than the 16 tons produced in East Africa and the 28.8 tons produced worldwide (CSA, 2021).

The quantity and quality of cabbage are influenced by various factors. Aphids are, the most economically important insect pests of cabbage. Aphids spread 50% of all insect-borne plant viruses in addition to their feeding influence (Gebreyohans, 2021). Cabbage aphid had the potential to lower cabbage yields, quality, and nutritional value (Opfer & McGrath, 2013). According to Lidet *et al*. (2008), entire crop failures were common during seasons with significant infestations, and losses varied from 36.1 to 91.2%. The production of cabbage has become risky, which may have an impact on the quality and market value in Ethiopia (Shiberu & Mulugeta, 2016). As Kassahun (2018) reported, the cabbage aphid is a significant pest that causes a 50–80% production reduction in the Amhara Region, Ethiopia (Abdelmuhsin *et al*., 2022; Fiodorova *et al*., 2022; Zakinyan *et al*., 2023; Negreiros *et al*., 2024).

The use of synthetic insecticides is critical for controlling cabbage aphids and increasing crop productivity (Iqbal *et al*., 2011). Chemical pesticides are still employed by cabbage-grower farmers to control aphids (Mengistie *et al*., 2017). Persistent use of chemical pesticides creates a multitude of negative results, including resistance, residues in harvested product, injury to farmers, beneficial insects, and non-target creatures, contamination of the environment, and financial loss (Shiberu & Mulugeta, 2016). Knowing the negative effects of synthetic chemicals allows for the implementation of alternate control strategies, including using botanicals to reduce synthetic chemical-related problems (Mahmood *et al*., 2022). It is well known that botanicals, or plant-based pesticides, have insecticidal and repellent qualities as well as reduced environmental toxicity (Zahid *et al*., 2016). Therefore, the purpose of this study was to assess the effectiveness of botanical aqueous extracts in controlling cabbage aphids in field settings.

MATERIALS AND METHODS

Description of the study area

The study was conducted at the Koga Irrigation Scheme in North Mecha District during the irrigation season of 2023. It is located at11° 23' 62'' N latitude and 37° 07' 87'' E longitude with an average elevation of 1850 meters above sea level. The mean annual rainfall is 1480 mm. The monthly mean temperature is 25.8°C. The soil at the experiment site is categorized as clay in its textural classification, with a pH value of 5.32. The major crops grown in the study area are Wheat, Barely, Maize, Beans, Cabbage, Potatoes, Tomatoes, Onions, Shallots, and peppers.

Collection and extraction of botanicals

The matured Endod, Kitkita, and fresh and mature Tinjut leaves were harvested in the North Mecha District, whilst tobacco leaves were taken in the Dengur District near Metekel. The leaves were washed, sanitized, and dried in the shade for 15 days to reduce chemical volatility and provide enough air supply (Sarwar, 2015). The dried leaves were cut into small bits to make them easier to grind. The dried leaves are pulverized using a mortar and pestle. Ground leaves of each measured Endod, Tobacco, and Tinjut leaf powder at 2.5%, 5%, and 7.5%, and Kitkita powder at 7.5%, 10%, and 12.5% were diluted with one liter of distilled water. The combinations were thoroughly mixed with frequent agitation at 3-hour intervals for one day to release their toxicity. After one day, the mixed mixture was filtered with cheesecloth for field spraying, and the leaves' aqueous extract stock solutions were diluted and treated at a rate of 150 liters per hectare (Alula & Tesfaye, 2021), with 0.09 liters per plot administered using a hand sprayer. Five superiors were performed at weekly intervals when the plants were at the 6-8 true leaf stage.

Description of experimental materials, treatment, and design

The cabbage variety "Copenhagen Market" was used to raise seedlings of the test crop. This variety grows well at altitudes from 500 to 3000 meters above sea level with a rainfall requirement of 380-550 mm. It can reach maturity in 90-110 days and provides 3-4 t/ha (MoA, 2019). The experiment consisted of 14 treatments. It includes four botanicals, namely, tobacco (*Nicotiana tabacum* L.) leaves, endod (*Phytolacca dodecandra*) leaves, tinjut (*Otostegia integrifolia* (Benth)) leaves with a concentration of 2.5%, 5%, and 7.5%, and kitikita (*Dodonaea angustifolia*) leaves with a concentration of 7.5%, 10%, and 12.5%. A standard check of dimethoate 40% EC (1.5 L/ha) (FAO & WHO, 2022) and an untreated check were used. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly assigned to the unit plot of 2.50 m x 2.40 m = 6 m^2. The experimental area was divided into three blocks. The total area of the experimental plot was 428.4 m^2. The net size of the main plot was 252 m^2. The blocks and plots were spaced at 1.5 m^2 and 0.5 m^2, respectively. Seedlings were planted 30 cm between plants and 50 cm between rows (Aklilu, 2019). There were five rows per plot and eight plants per row, with a total of 40 plants per plot planted.

Experimental procedures and management

Cabbage seeds were sown on a 5 m^2 raised seedbed in 10 cm rows, covered with mulch and soil. Mulch was removed upon germination. Seedlings were irrigated twice daily initially, then reduced after a week, and watering was stopped a week before transplanting to harden the seedlings (MoA, 2019). After five weeks, healthy seedlings with 3–4 true leaves were transplanted. DAP (100 kg/ha) and urea (200 kg/ha) were applied, with DAP at transplanting and urea split equally—half applied one month after transplanting and the remainder at the start of head formation (MoA, 2019).

Data collection

Data were collected before and after three days of treatment application. Data collection was carried out from two weeks after seedling transplantation up to harvest. The experimental plot contains five rows, and the data is obtained from the three central rows. Six plants were sampled randomly, and information on the parameters of the cabbage aphid infestation was gathered. The cabbage yield production was finally calculated and reported in tons per hectare.

Infestation percentage

Before each interval between treatments, the number of afflicted plants was counted, noted, and converted to a percentage using the Abbott (1925) methodology:

$$Infestation\% = \frac{Total\ number\ of\ cabbage\ aphid\ in\ the\ plot}{Total\ number\ of\ plants\ in\ the\ plot\ obserbed} * 100 \quad (1)$$

- *Efficacy percentage*

The numbers were recorded randomly at the middle of three central rows. Six plants per plot were sampled. The numbers of aphids were recorded before the spray and 72 hours after the application of botanicals or chemicals at weekly intervals. The numbers of aphids tagged on leaves were counted with the help of a hand lens. The number of aphids per plant was recorded. The efficacy of each treatment was calculated using the efficacy percentage formula (Abbott, 1925).

$$\text{Efficacy\%} = \frac{\text{PreSpray Count} - \text{Post Spray Count}}{\text{PreSpray Count}} * 100 \quad (2)$$

- *Stand count*
  This is the number of the plant stand at crop establishment. The number of plants in each plot was counted to determine the stand count both at harvest and during crop setup. Plant stand reduction was determined by subtracting the stand count during seedling establishment from the stand count at harvest.
- *Cabbage head formation*- calculations were made to determine the proportion of cabbage plants with head formation.
- *Canopy spread*- the distance measured horizontally between the two ends of the plant was used to calculate the canopy spread. Centimeters were used to measure the plant's two nearest opposing and most widely spaced leaves (Pratiksha, 2022).
- *Plant height*- at the time of harvest, using centimeters, the height of the plant was measured from the soil's surface to

its peak (Tilahun *et al*., 2019).

- *Yield and yield components-* At harvest, data on marketable and unmarketable yields were collected from every plot. To obtain marketable yield, the damaged outer leaves were removed, and the head was discarded. Aphid colonies and the growth of mold that causes sooty cabbage render it unsellable (Hines & Hutchison, 2013). One ton per hectare was used to measure the marketable cabbage.
- *Yield loss estimation-* calculated by applying the formula developed by Tilahun *et al*. (2019) to compare the yield of treated and untreated cabbage.

$$\text{Yield loss} = \frac{Yp - Yt}{Yp} * 100 \quad (3)$$

Where Yp = the yield of maximum protected plot
Yt= yield from plots of other treatments

Data and partial budget analysis

SAS version 9.4 was utilized to analyze the results of the experiment. To determine the average impacts of botanicals and chemicals on aphid fatalities, effectiveness % was computed and then subjected to an analysis of variance (ANOVA). DMRT (Duncan's Multiple Range Tests) was used to calculate means separation utilizing statistical software (P < 0.05). Additionally, analysis of variance (ANOVA) was performed on the mean value of the recorded agronomic information. The significant distinction technique was used to determine mean separation if there were significant differences between the treatments.

The cost-benefit analysis of each treatment application was conducted using the basic partial budget approach described by CIMMYT (1988). A measure of the impact of new capital invested on net returns under new management as opposed to the previous one is the marginal rate of return, expressed as tons per hectare, which was calculated (AlHussain *et al*., 2022; Kumar *et al*., 2022; Spirito *et al*., 2022; Hackenberg *et al*., 2023; Prada *et al*., 2024).

$$\text{Marginal rate of returns (MRR)} = \frac{\text{change in net income compared with control}}{\text{hange in total cost compared with control}} \quad (4)$$

Gross benefit was computed by multiplying Adjusted yield with the current market prices

$$\text{Gross Benefit=Adjusted Yield*Market price} \quad (5)$$

For each therapy, the net benefit was determined by deducting the total expenditures from the gross field benefit.

$$\text{ETB/ha net profit = Gross Benefit - Total variable Cost} \quad (6)$$

Total cost: The price of materials, applications, labor, and chemicals are all included.

The benefit-cost ratio (BCR) was also determined as:

$$\text{BCR} = \frac{\text{Gross return}}{\text{Total variable cost}} * 100 \quad (7)$$

RESULTS AND DISCUSSION

Effect of botanical extracts application on cabbage aphid infestation

The effect of botanical extract concentration on cabbage aphid infestation was highly significant (P<0.001) **(Table 1)**. One week after transplanting, aphid infestation declined in all botanical treated plots but increased in the control. The lowest infestations were recorded with Endod 7.5% (17.56%) and tobacco 7.5% (18.44%), following the standard check, Dimethoate 40% EC (15.11%), while the control showed 33.22%. By the third week, infestation further decreased in Endod 7.5% (9.11%), Endod 5% (9.89%), and tobacco 7.5% (9.94%) treatments, next to Dimethoate (5.17%), but rose in the control (68.8%). In the fourth week, infestation peaked in the untreated plot (83.67%) and was lowest in Dimethoate (4.61%) and Endod 7.5% (6.06%). By the fifth week, infestation dropped significantly in Endod 7.5% (5.44%) and 5% (5.89%) compared to Dimethoate (3.89%), while the control reached 99.88%. Overall, higher botanical concentrations consistently reduced aphid infestation, while untreated plots showed continuous increases. Endod 7.5% performed comparably to the standard chemical check, Dimethoate 40 EC.

These findings agree with earlier studies (Begna, 2014; Desale & Getnet, 2018; Kassahun, 2018; Mulu *et al*., 2023), confirming that increasing botanical concentration enhances aphid control. Desale and Getnet (2018) found that Tinjut leaves at different concentrations decreased the infestation level of cabbage aphids as the Tinjut concentration increased. Kassahun (2018) studied the management of cabbage aphids by using tobacco leaf extract in different concentrations and indicated that the infestation level of cabbage aphids decreased when tobacco concentration increased. Begna (2014) also found that cabbage aphids treated with botanicals such as *Phytolacca dodecandra* L'Herit, garlic, neem, and, chili recorded a higher infestation level than the conventional pesticides. The onion cultivars treated with botanical neem had the highest death rate and the fewest onion thrips (Mulu *et al*., 2023).

Table 1. Effect of different concentrations of botanicals on aphid infestation on Cabbage

Treatment	Concentration%	BT infestation	2nd week infestation	3rd week infestation	4th week infestation	5th week infestation
Endod	2.5	26.22	19.11^{efd}	10.11^{e}	7.56^{fe}	6.83^{gf}
Endod	5	26.33	18.44^{gf}	9.89^{fe}	6.78^{fg}	5.89^{gh}
Endod	7.5	26.22	17.56^{g}	9.11^{f}	6.06^{g}	5.44^{h}
Kitkita	7.5	26.39	21.11^{b}	14.94^{b}	14.06^{a}	10.88^{b}
Kitkita	10	25.89	20.89^{cb}	14.78^{cb}	13.44^{cb}	9.89^{cb}

Kitkita	12.5	26.33	20.78cb	14.67cb	13.28cb	9.22cd
Tobacco	2.5	26.16	20.00f	11.44d	8.11e	7.61ef
Tobacco	5	26.33	19.00efd	10.06e	7.11f	6.94gf
Tobacco	7.5	26.22	18.78ef	9.94fe	6.94f	6.83gf
Tinjut	2.5	25.29	20.56cb	14.50cb	12.89cb	9.06cd
Tinjut	5	26.33	20.22cbd	14.00c	12.44d	8.67ed
Tinjut	7.5	26.22	19.78ced	13.89c	12.11d	7.28f
Dimethoate40EC	1.5l/ha	23.67	15.11h	5.17g	4.61h	3.89i
Untreated		26.06	33.22a	68.72a	83.67a	99.83a
SE (±)		1.09	0.69	0.49	0.45	0.63
Mean		25.94	20.34	15.80	14.93	14.16
CV (%)		4.23	3.37	3.13	3.01	4.46
P>F		0.46	*	*	*	*

BT= Before treatment; Means in the same letter within a column are not significantly different

Efficacy of botanicals on the management of cabbage aphids

The number of cabbage aphids per plot was significantly influenced by botanical extract concentrations (P < 0.001) **(Table 2)**. Aphid populations declined progressively in all botanical treatments after each spray, while they continued to rise in the untreated control plots.

After the first treatment (72 hours post-application), all botanicals reduced aphid numbers, whereas the control showed an increase. Endod extract at 7.5% and 5%, and tobacco extract at 7.5%, were most effective, reducing infestations by 46.51%, 44.83%, and 43.29%, respectively, next to the standard Dimethoate 40% EC. Kitkita 7.5% showed the lowest efficacy (16.59%) **(Table 2)**.

Following the second treatment, Endod 7.5% achieved the highest reduction (76.32%), followed by Dimethoate (58.73%), while Kitkita 7.5% again showed minimal effect (18.33%). After the third application, Endod 7.5%, Endod 5%, and tobacco 7.5% recorded 66.49%, 63.32%, and 61.12% reductions, respectively, compared with Dimethoate (85.6%). Similar trends were observed after the fourth spray, and by the fifth week, Endod 7.5% reached 87.17% reduction, close to Dimethoate (92.76%), whereas Kitkita 7.5% had only 21.71%.

Across all intervals, botanical treatments substantially suppressed aphid populations, confirming that their efficacy was concentration-dependent. Aphid density increased only in the control plots. These results agree with Isman (2000), who noted reduced aphid feeding with higher botanical concentrations, and Kapoor and Sharma (2020), who attributed this to bioactive insecticidal compounds.

Comparable studies support these findings. Gonfa and Shiberu (2022) reported that tobacco extracts effectively killed *Brevicoryne brassicae* nymphs and adults. Alula and Tesfaye (2021) observed that Endod 5% and Kitkita 10% reduced aphids by 84% and 22.33%, respectively, consistent with the present results (81.72% and 22.41%). Kitkita generally performed poorly under field conditions, as also reported by Shiberu and Mulugeta (2016). Endod efficacy increased with concentration, achieving 87.17% reduction at 7.5%, aligning with Megersa (2016), who recorded 100% mortality at 10%.

In the current study, botanicals reduced aphid populations below the economic threshold by the third application and nearly eradicated them after the fifth spray. This strong suppression likely resulted from both toxic and repellent effects and the dispersal of winged aphids from treated plots, similar to observations by Megersa (2016).

Other studies also confirm concentration-dependent performance: Desale and Getnet (2018) for Tinjut extract, Kassahun (2018) and Patel *et al*. (2024) for tobacco (62.73% mortality at 5%), and Kumar and Tayde (2019), who observed a 69.68% reduction. Lanjar *et al*. (2017) also reported that tobacco varieties effectively suppressed cabbage aphids. Tesfaye *et al*. (2021) demonstrated neem's strong efficacy, while Chane and Jenber (2025) found Endod seed extract comparable to Malathion 5% dust in insect mortality. Overall, Endod and tobacco leaf extracts, particularly at 7.5%, were the most effective botanicals for managing cabbage aphids under field conditions, showing strong potential as eco-friendly alternatives to synthetic insecticides.

Table 2. Efficacy of botanicals for the management of cabbage aphids on Cabbage

Treatment	Concentration%	1st week efficacy	2nd week efficacy	3rd week efficacy	4th week efficacy	5th week efficacy
Endod	2.5	42.61d	50.87e	58.31e	70.19f	71.33f
Endod	5	44.83c	55.99c	63.32c	81.72c	85.24c
Endod	7.5	46.51b	58.73b	66.49b	86.26b	87.17b
Kitkita	7.5	16.59i	18.33j	19.59j	21.52l	21.71m
Kitkita	10	18.06h	19.23ji	20.62ji	22.41l	23.32l
Kitkita	12.5	18.98h	20.05i	21.47i	24.89k	26.19k
Tobacco	2.5	40.68e	46.70f	56.04f	68.35g	69.22g
Tobacco	5	42.90d	52.34d	59.50e	72.19e	74.68e
Tobacco	7.5	43.29d	53.53d	61.12d	74.45d	77.31d
Tinjut	2.5	34.24g	40.45h	49.44h	60.64j	63.65j

Tinjut	5	35.43^{g}	43.17^{g}	51.86^{g}	64.18^{i}	65.19^{i}
Tinjut	7.5	37.88^{f}	44.57^{g}	53.05^{g}	66.18^{h}	66.93^{h}
Dimethoate40EC	1.5l/ha	80.41^{a}	76.32^{a}	85.61^{a}	89.27^{a}	92.77^{a}
Control		0.0000^{j}	0.0000^{k}	0.0000^{k}	0.0000^{m}	0.0000^{n}
SE (±)		0.82	0.84	0.88	0.85	0.67
Mean		35.89	41.45	47.60	57.29	58.91
CV (%)		2.28	2.04	2.04	1.85	1.14
P>F		*	*	*	*	*

Means in the same letter within a column are not significantly different ($p<0.05$)

Effect of botanicals on stand count and cabbage head formation

Endod with concentrations of 5% and 7.5% (41.00 and 41.33) had the highest plant stand count when compared to the standard check Dimethoate 40EC (41.67) and control plots (31.67). The largest cabbage head production was found in Endod-treated plots with concentrations of 5% and 7.5%, which were 39.33 and 40.0, respectively, adjacent to the standard check Dimethoate 40EC (41.33) in comparison to the control plots (26.33). The medium stand count and cabbage head development were determined from cabbages treated with the remaining treatments. Relatively lower mean stand counts (35.00 and 35.33) and head formations (30.33 and 31.33) were recorded in Kitkita leaves with concentrations of 7.5% and 10% treated plots among botanicals close to the control. The highest stand count and head formation were seen in Endod at 5% and 7.5% doses **(Table 3)**. It could have happened because it limits the number and potential of parasitic insects that feed on head cabbage plants. These findings corroborate Desale and Getnet's (2018) claim that the efficiency of a treatment that reduces the effects of cabbage aphids is the key factor of cabbage head development. This could mean that botanicals have a deterrent effect or are harmful antifeedants.

Table 3. Effect of botanicals on stand count, head formation, Plant height and Canopy Spread

Treatment	Concentration%	Stand count	Head formation	Plant height	Canopy spread
Endod	2.5	39.33 ^{bdc}	37.00^{de}	25.78^{bcd}	36.22^{d}
Endod	5	41.00^{bac}	39.33^{bc}	27.39^{ba}	37.56^{c}
Endod	7.5	41.33^{ba}	40.00^{ba}	27.89^{ba}	38.22^{b}
Kitkita	7.5	35.00^{g}	30.33^{g}	22.28^{ef}	32.78^{h}
Kitikita	10	35.33^{g}	31.33^{g}	22.67^{ef}	33.50^{g}
Kitikita	12.5	36.00 ^{fg}	32.00^{g}	22.89^{ef}	33.94^{g}
Tobacco	2.5	39.00^{dc}	36.33^{def}	24.50^{ecd}	35.44^{e}
Tobacco	5	39.67^{bdac}	37.33^{de}	26.00^{bcd}	36.33^{d}
Tobacco	7.5	40.00^{bdac}	38.00^{dc}	26.44^{bc}	36.67^{d}
Tinjut	2.5	36.67^{feg}	34.67^{f}	23.33^{e}	34.61^{f}
Tinjut	5	38.00^{fde}	35.67^{ef}	23.500^{e}	35.06^{fe}
Tinjut	7.5	38.67^{de}	36.00^{ef}	24.00^{ed}	35.33^{e}
Dimethoate40EC		41.67^{a}	41.33^{a}	29.28^{a}	39.67^{a}
Control		31.67^{h}	26.33^{h}	21.00^{f}	29.67^{i}
SE (±)		1.18	1.04	1.17	0.27
Mean		38.09	35.40	24.79	35.36
CV (%)		3.11	2.94	4.72	1.77
P>F		*	*	*	*

Means in the same letter within a column are not significantly different

Effect of botanicals on plant height and canopy spread

The effect of botanical extracts on the height and canopy spread of cabbage plants varied depending on the treatment **(Table 3)**. Plots treated with Endod leaf extract at a 7.5% concentration showed the highest plant height and canopy spread, with mean values of 27.89 cm and 36.22 cm, respectively. These results were compared to the standard check, Dimethoate 40% EC, which showed 29.28 cm plant height and 38.17 cm canopy spread. Medium plant height and canopy spread were produced by cabbages treated with different botanical extracts at lower dosages.

Among the botanicals, relatively lower plant height and canopy spread were recorded in Kitkita leaf extract at 7.5% concentration (22.28 cm and 32.78 cm, respectively), followed by the untreated control, which showed the lowest plant height (21.00 cm) and canopy spread (29.67 cm).

This finding is consistent with those reported by Alula and Tesfaye (2021), who found no significant difference among treatments in cabbage plant height and canopy spread when treated with Endod leaf extract (5%) and Kitkita leaf extract (10%), recording 25.67 ± 4.73 cm and 38.67 ± 3.06 cm for Endod, and 26.67 ± 3.51 cm and 37.00 ± 10.58 cm for Kitkita, respectively. In the present study, the tallest plants and widest canopy spread were obtained from Endod-treated plots (5% and 7.5%), while the shortest plants and narrowest canopies were observed in the untreated control plots.

This outcome is consistent with Begna and Tebkew (2015), who found that plants treated with synthetic or botanical insecticides grew taller than untreated (control) plots. Similarly, Alula and Tesfaye (2021) reported comparable trends in plant growth performance, confirming that botanical insecticide applications particularly Endod, can promote healthier plant growth by effectively reducing pest pressure.

Cabbage total yield, marketable yield and unmarketable yield

The botanical concentration differential had a substantial effect on cabbage yield. The maximum yield was found in Endod berry treated plots with a 7.5% concentration compared to the standard control Dimethoate 40EC. The remaining treatments had medium yields. Lower cabbage yields were seen in plots treated with Kitikita. The highest unmarketable yield was seen on untreated plots **(Table 4)**. These results are consistent with prior studies. According to Desale and Getnet (2018), the total marketable yield of Tinjut at concentrations of 2.5%, 5%, and 7.5% was 35.43, 36.87, and 49.64 tons per hectare, respectively. At a 10% concentration, Kitikita had a total marketable output of 31.09 tons per hectare, while Endod had a total marketable yield of 48.02 tons per hectare. These results are consistent with recent findings (Alula & Tesfaye, 2021), which show that the total marketable yield of kitikita at a 10% concentration was 31.59 ton/ha and Endod 5% was 50.07 ton/ha. Tobacco's total marketable yield at 2.5, 5, and 7.5% concentrations was 44.39, 45.27, and 46.89 tons per hectare.

In this study, the highest level of yield was obtained in Endod within the concentration of 7.5% which was 49.78 ton/ha compared with Dimethoate 40EC (51.58 ton/ha). Plots treated with endod showed higher yields; this could be because it reduced the parasite bug that feeds on head cabbage plants, thereby reaching its maximum potential. In line with this, Sarwar (2015) determined that the extract from endod leaves performed better than the control and that sucking pests were eliminated. Thus, the crop's growth and yield were improved. In this study, the greatest Endod concentration produced the highest commercial yield. The control plots produced the lowest commercial yield. Bhat and Dhoj (2005), found that the control plots' marketable yield is significantly lower than that of the treated plots.

The difference in marketable yield was due to the aphicidal effect and concentration of botanical treatments. Cabbage aphids reduce yield directly by sucking sap and indirectly by producing honeydew that hinders photosynthesis, spreads viral diseases, and deforms heads. Higher botanical concentrations increased marketable yield, supporting Desale and Getnet (2018). Repeated application of concentrated extracts enhanced cabbage yield and quality by improving traits such as plant height, canopy spread, and head formation.

Table 4. Effect of botanicals on Cabbage yield, yield components and yield loss

Treatment	Concentration	Total Yield	Marketable yield	Unmartketable yield	Yield loss
Endod	2.5	46.83^{fe}	45.11^{de}	1.72^{c}	12.55^{h}
Endod	5	50.27^{bc}	48.02^{bc}	2.25^{cb}	6.91^{j}
Endod	7.5	51.94^{ba}	49.78^{ba}	2.155^{cb}	3.49^{k}
Kitkita	7.5	32.52^{i}	30.03^{i}	2.49^{cb}	41.78^{b}
Kitkita	10	33.55^{i}	31.09^{ih}	2.46^{cb}	39.73^{c}
Kitkita	12.5	37.12^{h}	34.34^{h}	2.78^{b}	35.64^{d}
Tobacco	2.5	46.36^{fe}	44.39^{fe}	1.97^{cb}	13.95^{h}
Tobacco	5	47.89^{de}	45.28^{de}	2.61^{cb}	12.22^{h}
Tobacco	7.5	49.07^{dc}	46.89^{dc}	2.18^{cb}	9.09^{i}
Tinjut	2.5	39.46^{g}	37.21^{g}	2.25^{cb}	27.87^{e}
Tinjut	5	41.09^{g}	38.49^{g}	2.59^{cb}	25.38^{f}
Tinjut	7.5	44.79^{f}	42.54^{f}	2.25^{cb}	17.52^{g}
Dimethoate40EC	1.5l/ha	53.09^{a}	51.58^{a}	1.51^{cb}	-
Control		20.91^{j}	16.17^{j}	4.74^{a}	68.65^{a}
SE (±)		1.06	1.22	0.44	1.97
Mean		42.49	40.07	2.43	22.48
CV (%)		2.49	3.03	18.33	8.79
P>F		*	*	*	*

Means in the same letter within a column are not significantly different

Yield loss

The biggest yield loss was found in Kitikita treated plots with a concentration of 7.5% (41.78%), followed by untreated check plots (68.65%). The medium yield reduction was observed in the remaining botanical concentrations. Lower cabbage yield losses were seen in Endod treated plots with a concentration of 7.5% (3.49%) compared to the standard check, Dimethoate 40% EC. According to this study, cabbage aphid produces a 68.65% yield reduction in the untreated check **(Table 4)**. Botanicals reduce yield loss by disrupting aphid feeding behavior. This finding is consistent with Shonga and Emana's (2021) finding that cabbage aphid caused an 80% yield loss without treatment.

Partial budget analysis for the management of cabbage aphid using botanicals

The management cost of cabbage aphid control was calculated based on material, labor, and chemical expenses at current market prices. Cabbage yield (kg/ha) and revenue were estimated using a market price of 20 ETB/kg. Endod extract at 5% and 7.5% concentrations produced the highest net benefits (730,350.4 and 762,138.4 ETB/ha) **(Table 5)**, benefit–cost ratios (6.45 and 6.69), and marginal rates of return (32.9 and 34.84) **(Table 6)**. Tobacco extract at 7.5% yielded the second-highest net benefit (701,247.6 ETB/ha) with a benefit–cost ratio of 5.9 and a marginal rate of return of 20.5. Kitikita at 7.5% recorded the lowest economic return (403,305.1 ETB/ha; BCR 3.94; MRR 11.3). The lowest marginal return (9.6) was observed in Dimethoate 40EC due to its high cost. These findings agree with Alula and Tesfaye (2021), who reported higher profitability of Endod over chemical insecticides, and with Begna and Tebkew (2015), Jenber *et al*. (2024), Abaynew *et al*. (2020), and Yechale *et al*. (2021), who also confirmed that botanical treatments enhance net benefit and marginal return through cost-effective pest management.

Table 5. Partial budget analysis for the management of cabbage aphid using botanicals

Treatment	Concentration%	Adjusted yield (kg/ha)	Total variable cost	Growth benefit	Net benefit
Endod	2.5	40599.9	161455.6	811998	650542.4
Endod	5	43215.3	133955.6	864306	730350.4
Endod	7.5	44804.7	133955.6	896094	762138.4
Kitkita	7.5	27029.7	137288.9	540594	403305.1
Kitikita	10	27980.1	137288.9	559602	422313.1
Kitikita	12.5	29880	137288.9	597600	460311.1
Tobacco	2.5	39954.6	140900	799092	658192.0
Tobacco	5	40750.2	142011.1	815004	672992.9
Tobacco	7.5	42204.6	142844.4	844092	701247.6
Tinjut	2.5	33485.4	135622.2	669708	534085.8
Tinjut	5	34640.1	137566.7	692802	555235.3
Tinjut	7.5	38289.6	139511.1	765792	626280.9
Dimethoate40EC	-	46424.7	177011.1	928494	751482.9
Control	-	14554.8	117077.8	291096	174018.2

Table 6. Dominance analysis, benefit cost ratio and marginal rate of return for the management of cabbage aphid using botanicals

Treatment	Concentr	AY	TVC/HA	GB	NB	DA	BCR	MRR
Control	*	14554.8	117077.8	291096	174018.2	~	2.49	*
Endod	5	43215.3	133955.6	864306	730350.4		6.45	32.9
Endod	7.5	44804.7	133955.6	896094	762138.4		6.69	34.8
Tinjut	2.5	33485.4	135622.2	669708	534085.8	D	4.94	18.6
Kitkita	7.5	27029.7	137288.9	540594	403305.1	D	3.94	11.3
Kitikita	10	27980.1	137288.9	559602	422313.1	D	4.08	12.3
Kitikita	12.5	29880	137288.9	597600	460311.1	D	4.35	14.2
Tinjut	5	34640.1	137566.7	692802	555235.3	D	5.04	19.4
Tinjut	7.5	38289.6	139511.1	765792	626280.9	D	5.49	20.2
Tobacco	2.5	39954.6	140900	799092	658192	D	5.67	20.3
Tobacco	5	40750.2	142011.1	815004	672992.9	D	5.73	20.0
Tobacco	7.5	42204.6	142844.4	844092	701247.6	D	5.91	20.5
Endod	2.5	40599.9	161455.6	811998	650542.4	D	5.02	29.8
Dimethoate40EC		46424.7	177011.1	928494	751482.9	D	5.25	9.6

AY=Adjusted yield, TC/ha=Total variable cost per hectare, GB= Growth benefit, NB/ha= Net benefit per hectare, BCR= benefit cost ratio, MRR= marginal rate of return

CONCLUSION

In varying doses, all plant extracts work well to control cabbage aphids. In all experimental treatments, the impact of botanicals at varying concentrations on the degree of cabbage aphid infestation over a one-week period was encouraging. Within a week of the treatments being applied, the degree of cabbage aphid infection dropped. With the exception of the untreated plots, the effectiveness of botanicals improved and the level of cabbage aphid infestation reduced with repeated spraying.

The greater concentration of Endod leaves compared to the usual check. Dimethoate 40EC was associated with reduced aphid infestation levels, higher efficacy, higher head formation, higher stand counts, higher plant heights, higher canopy spreads, higher marketable yields, and lower cabbage yield loss percentages. When compared to control plots, Endod with 5% and 7.5% constriction can be indicated as the most economical and effective botanical in creating a substantial high rate of reduction for cabbage aphid management. This enables farmers to use locally available botanical treatments instead of chemical insecticides, increasing protection for non-target creatures and improving environmental safety (Mubayrik *et al*., 2022; Ayari *et al*., 2023; Chauhan & Angadi, 2024).

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