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Efficacy of aqueous extracts from three plants in controlling cabbage aphid [*Brevicoryne brassicae* L. (Hemiptera: Aphididae)] on field-grown cabbage (*Brassica oleraceae* L.)

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Abstract

Cabbage (*Brassica oleracea* var. capitata L.) crops are frequently attacked by aphids (*Brevicoryne brassicae* L.) which severely damage cabbage production. This research was conducted at an experimental cabbage field of the Institute of Environmental Science, University of Rajshahi, Bangladesh, from 15 November 2020 to 14 February 2021. This study assessed the dose-dependent efficacy of aqueous extracts from the seed of jute (*Corchorus capsularis* L.), leaves of bottle gourd (*Lagenaria siceraria* Molina Standl.), and fruit peel of lemon (*Citrus limon* L. Osbeck), compared with the chemical insecticide Malathion. The experiment design was laid out in a randomized complete block design (RCBD) with three replications. One-way (ANOVA) analysis was performed on the acquired data and significant differences among treatments were detected using Duncan's Multiple Range Test ($p < 0.05$). This study revealed that bottle gourd leaf extract at 10% and 20% (w/v) concentrations resulted in high biopesticide activity against aphids and increased cabbage yield by 12%–13%, compared with the control. The application of 30% (w/v) bottle gourd leaf extract significantly decreased aphid infestation by 28.26% and 46.83% at 45 and 60 DAT, respectively in field-grown cabbage and led to a 30.95% increase in cabbage yield compared with the Malathion. Thirteen potential chemical components of the bottle gourd leaf extract were identified using gas chromatography–mass spectrometry analysis that may possess the insecticidal ability. Results indicated that bottle gourd leaf extract has great potential as an alternative to synthetic chemical pesticides in controlling aphids in cabbage in an environmentally friendly way.

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Introduction

The leafy green biennial cabbage (*Brassica oleracea* var. capitata L.), which is grown as an annual vegetable crop with a tight leafy head, is a member of the Brassicaceae family[1]. Cabbage originated in the Mediterranean region but is now one of the most popular vegetable crops worldwide and grows well in many countries[2]. It is widely cultivated in the northern part of Bangladesh and throughout India, and it has become a staple vegetable in Japan along with the spread of Western food after World War II. Cabbage can be used in a wide range of dishes, as it can be eaten raw, boiled, or stir-fried.

Cereals, oilseed, legumes, and other crops are damaged by aphids either by direct feeding or through pathogen transmission. Fungal growth on aphid honeydew and the transfer of adenoviruses are examples of secondary pathogen infection[3–6]. The measurable economic losses caused by aphids are due to their diverse feeding behavior. They invade and multiply rapidly, and quickly damage field-grown plants, particularly the foliage[7]. In addition, they transmit many viruses that cause diseases. Their salivary secretions cause galls to form on the stem, roots, and leaves. Leaves curl and crumple as a result of the removal of plant sap. The primary growth of young shoots and leaves is inhibited, and fungal growth is promoted by the secretion of honeydew from aphids[8]. The first line of action against aphids under outbreak conditions is pesticide use, but the aphid population can soon recover because of its high proliferation rate. For example, application of pesticide to control aphids on *Brassica juncea* caused 92% mortality of the aphid population, but the population recovered to a similar size as that in the untreated field within 3 to 4 weeks after application[9].

Aphid damage to cabbage plants from the seedling stage to the final growth stage (head formation) is a major problem in cabbage cultivation. The cabbage aphid (*Brevicoryne brassicae* L.), a common plant sap-sucking insect with a global distribution, is a member of the family Aphididae in the order Hemiptera[10]. These aphids cluster in great numbers on the underside of leaves and on the developing parts of affected plants[11]. Because of their waxy layer (honeydew), they appear grayish-white to powder-blue, but their natural color is grayish-green. They reduce the quality and yield of cabbage, lowering its commercial and nutritional value[12].

Biopesticides are certain types of pesticides derived from natural materials such as animals, plants, bacteria, and certain minerals. The US Environmental Protection Agency has categorized biopesticides into three major classes based on the type of bioactive ingredients or agents used for pest control: (i) biochemical pesticides; (ii) microbial pesticides; and (iii) plant-incorporated protectants[13]. Ecofriendly biopesticides do not contain any synthetic chemicals or toxic substances. Botanicals are plant-derived substances that work in a variety of ways[14]. They are derived from either fresh or dried plant materials, such as leaves, bark, flowers, roots, rhizomes, bulbs, seeds, cloves, or fruits. Compared with fresh materials, dried materials yield more active substances, because they are more concentrated after losing water[15].

In this study, plant parts were selected according to phytochemical properties such as aromatic odor and bitterness, and on the pharmacological properties of the plants. Jute seeds are very bitter, bottle gourd leaves have a strong aromatic odor, and lemon fruit peel also has a strong fragrance[16−18]. Properties including bitterness, aromatic odor, and fragrance indicate that plants are rich in bioactive compounds that may be useful in biopesticide production. Considering all these properties, jute seed, bottle gourd leaves, and the peel of lemon fruits were selected to prepare extracts for this experiment. In other studies, jute seed extract (concentration of, 10% w/v) caused 98.33% mortality of black bean aphids within 48 h[19]; a bottle gourd extract was used as a natural insecticide against mustard aphid, *Lipaphis erysimi* Kalt[20]; and lemon peel successfully controlled aphids under greenhouse and field conditions[21]. Lemon essential oil showed insecticidal activity against green peach aphid, *Myzus persicae*, indicating that it has potential applications in managing this pest in an environmentally safe manner to produce high-quality crops[22]. Malathion is an organophosphate insecticide that is widely used in agriculture, residential landscaping, public recreation areas, and in pest control programs for public health[23]. The objectives of this study were to determine the efficacy of these three aqueous plant extracts in controlling aphids on cabbage plants in a field experiment, and to determine their effects on the growth and yield of cabbage. Natural aphicides from potent plant extracts may be alternatives to chemical pesticides, thereby reducing pollution and protecting the environment.

Materials and methods

Experimental site and plot preparation

This experiment was conducted in the winter or rabi crop season from November 15 2020, to February 14 2021, at the Botanical Pesticides Research Field of the Institute of Environmental Science, University of Rajshahi, Bangladesh. The experimental area was located at 24.37°N latitude and 88.7°E longitude at an altitude of 21 m above sea level. The experiment was laid out in a randomized complete block design with three replications and 12 treatments. There were eight cabbage plants in each replicate. The plot size was 1.2 m × 1.8 m, the distance between blocks was 0.75 m, and the distance between plots was 0.5 m. To prepare the field for transplanting, the plot was plowed five times which was followed by laddering. Crop stubble and weeds were removed from the field, and land was leveled before planting cabbage seedlings. To support plant growth, manures, and fertilizers were applied to the experimental plots at the doses recommended by the Soil Resources Development Institute (SRDI), Bangladesh. Then, 15-day-old cabbage seedlings (variety: Sakata F1 Hybrid Atlas 70) were transplanted in the experimental plot.

Collection of plant materials and preparation of extracts

Seeds of jute (*Corchorus capsularis* L.), leaves of bottle gourd (*Lagenaria siceraria* Molina Standl.), and fruit peel of lemon (*Citrus limon* L. Osbeck) were collected from the campus of University of Rajshahi, Bangladesh, as plant materials with potential biopesticide properties.

The samples were first visually examined for any kind of infection, spores, damage, discoloration, and distortion. Undamaged fresh samples were thoroughly washed with running tap water. For the preparation of 40% w/v plant extracts, 400 g ground jute seed, 400 g chopped bottle gourd leaves, and 400 g chopped lemon peel were added separately to 1,000 mL distilled water and boiled for 30 min. The solutions were cooled and filtered through a muslin cloth. Different concentrations (5%, 10%, 20%, and 30%) of the extracts were prepared by dilution with water. The diluted extracts were kept in plastic bottles at room temperature until use.

The positive control, Malathion (57 EC formulation), was applied at a rate of 75 mL per 3.785 L (1 gallon) of water. This trial included a control (water only) and a chemical insecticide treatment, Malathion (57 EC), as the positive control.

Aphid monitoring and spraying of plant extracts

Aphid infestation was monitored in the experimental cabbage field under open field conditions. The number of aphids on both sides of the leaves was counted visually in the field in the morning. Prepared plant extracts were sprayed in the field with a home garden hand sprayer (1 L) onto cabbage plants twice a week at 3-day intervals in the morning (9 am). The spray treatments were started at 15 d after transplanting (DAT) of cabbage seedlings and continued until the end of the growing season (53 DAT). During this growing period, cabbage plants were sprayed with plant extracts 10 times in total.

Sampling and analytical methods

The aphid population was monitored from the start of aphid colonization until the cabbage plants reached maturity. Aphids were visually counted on the leaves of each plant in each treatment. First, three outer leaves of cabbage were collected and the number of aphids visible to the naked eye was counted on both the upper and lower side of the leaves. The average count from three leaves was considered as the aphid population per plant. The number of aphids was counted using the per-leaf sampling system[24]. Then, the average population per leaf was calculated. The average life cycle of an aphid is 30 d, so aphid infestation data were collected on 45 DAT and 60 DAT. Plant growth was measured in the field on February 14 2021, and yield data were collected after harvesting. The total cabbage yield (kg/plot) was recorded and the percentage yield increase over that of the water control was calculated as follows[25]:

$$\text{Yield increase (\%)} = \frac{\text{Treatment yield} - \text{Control yield}}{\text{Control yield}} \times 100$$

The abundance of aphids (%) over that in the positive control group (treated with Malathion 57 EC) was calculated as follows:

$$\text{Aphid abundance (\%)} = \frac{\text{Number of aphids in treatment group} - \text{Number of aphids in Malathion 57 EC treatment group}}{\text{Number of aphids in Malathion 57 EC treatment group}} \times 100$$

Preparation of plant extracts for phytochemical and gas chromatography–mass spectrometry analysis

Each plant part (seed, leaves, fruit peel) was washed with tap water and then left to dry in the light at room temperature (37 °C). The dried plant parts were ground using a DFT-100 plant grinding machine (Linda Machinery Co. Ltd., Wenling, China). About 100 g of ground powder was placed in a conical flask and 400 mL methanol was added. The mixture was incubated at room temperature with shaking at 110 rpm (MON1063 Rotary Shaker, Mainland, China) for 24 h, then centrifuged for 20 min at 2,075 ×g (LaboGene 406, LaboGene, Hillerød, Denmark). The supernatant was filtered through Whatman no. 1 filter paper, then concentrated by removing methanol with a rotary evaporator at 48 °C. The concentrated sample was stored at 4 °C until further analysis.

Phytochemical screening

Phyto-chemical analysis was done only potent plant extract following the standard proceudres described previously[26–28].

Sample preparation for GC–MS analysis

A 20 mg portion of potent plant extract was added to a 50 mL Falcon tube. Then, methanol (Sigma-Aldrich GC Grade) was added to the tube until the sample became colorless. The upper layer 2 mL was collected for gas chromatography–mass spectrometry (GC–MS) analysis.

GC–MS analysis

The plant extract was analyzed using a Shimadzu QP-2020 GC–MS (Shimadzu Corporation, Kyoto, Japan) instrument equipped with an SH-Rxi-5Sil MS column (length, 30 m; 0.25 mm in diameter; film thickness, 0.25 μm), an auto-sampler (AOC-20s), and an auto-injector (AOC-20i). The temperature program was as follows: initial oven temperature 80 °C (hold time 2 min), increased at 50 °C/min to 150 °C (hold time 5 min), and then increased to a final temperature of 280 °C. The carrier gas was helium (99.99%) at a flow pressure of 1.72 mL/min (hold time 8 min). The injection volume was 6.0 μL at a 20:1 split ratio (split injection mode), the injector temperature was 230 °C, and the ion source temperature was 280 °C. The electron ionization energy was set to 70 eV. Mass spectra in the range of 45 m/z to 350 m/z were captured for 50 min. The total run time was 50 min, with a solvent cut time of 3.2 min. The components were identified by comparing their mass spectra with those in the NIST08s, NIST08, and NIST14 libraries.

Data analysis

The biopesticide activities of different plant extracts against aphids on field-grown cabbage plants were tested in an experimental plot using a randomized complete block design. The data were entered into Excel (Microsoft) and subjected to one-way ANOVA. Significant differences among treatments were detected using Duncan's Multiple Range Test ($p < 0.05$) with SPSS v. 20 software (SPSS Inc., Chicago, IL, USA)[29].

Results

Effect of plant extracts on the number of aphids/leaf on field grown cabbage

Among the 12 treatments, the bottle gourd leaf extracts at 10% and 20% significantly ($p < 0.05$) decreased the number of aphids. The lowest aphid population was on cabbage plants treated with the 10% bottle gourd leaf extract, and the highest was in those treated with the 10% jute seed extract and the control at both 45 DAT and 60 DAT (Figs 1 & 2).

Effects of plant extracts on number of leaves, plant spread, head diameter, and head weight per plant

Table 1 shows the number of leaves per plant, plant spread, head diameter, and head weight per plant of cabbage in the treatment groups, control group, and positive control group. The number of leaves per plant was highest in the 30% bottle gourd leaf extract group and lowest in the 5% jute seed extract group. The number of leaves per plant in the 30% bottle gourd leaf extract group was 1.38 times that in the control. Among all the treatment groups, the 30% bottle gourd leaf extract group showed the best performance in terms of plant spread, head diameter, and head weight.

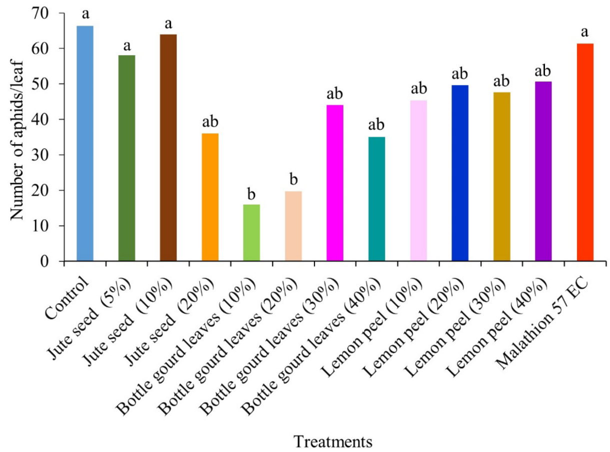

Fig. 1 Effect of plant extracts on the number of aphids/leaf on field grown cabbage at 45 DAT. Different letters within the same column indicate significant difference at $p < 0.05$; DAT= Days after transplanting; EC= Emulsifiable concentrate.

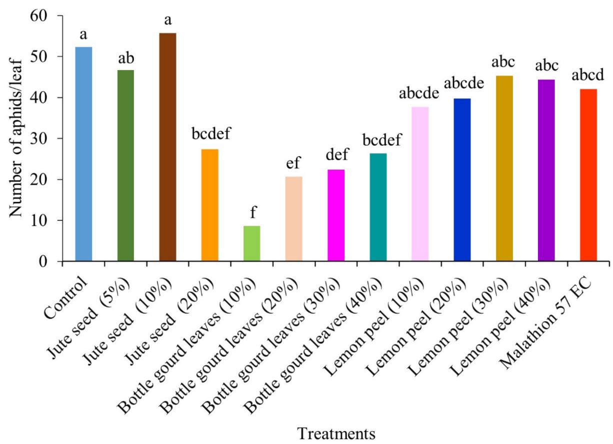

Fig. 2 Effect of plant extracts on the number of aphids/leaf on field grown cabbage at 60 DAT. Different letters within the same column indicate significant difference at $p < 0.05$; DAT= Days after transplanting; EC= Emulsifiable concentrate.

Table 1. Effects of plant extracts on number of leaves per plant, plant spread, head diameter, and head weight/plant of field-grown cabbage.

Treatment	Number of leaves per plant	Plant spread (cm)	Head diameter (cm)	Head weight (kg)/plant
Control	22.12 ± 1.58^{de}	32.75 ± 4.07^{fg}	10.81 ± 0.31^{ab}	2.17 ± 0.28^{de}
Jute seed (5%)	12.91 ± 0.66^{f}	20.73 ± 1.20^{h}	7.20 ± 0.50^{ab}	1.26 ± 3.40^{f}
Jute seed (10%)	21.76 ± 8.09^{ef}	32.21 ± 2.41^{fg}	10.74 ± 0.51^{ab}	2.56 ± 1.01^{cd}
Jute seed (20%)	23.95 ± 4.72^{bc}	35.46 ± 2.53^{ef}	12.31 ± 0.92^{bc}	2.66 ± 0.68^{bc}
Bottle gourd leaves (10%)	23.44 ± 1.71^{ef}	34.69 ± 4.31^{ef}	11.45 ± 0.01^{a}	2.47 ± 0.27^{cd}
Bottle gourd leaves (20%)	24.80 ± 5.64^{de}	36.69 ± 9.11^{de}	12.80 ± 0.82^{bc}	2.45 ± 0.50^{cd}
Bottle gourd leaves (30%)	30.58 ± 0.53^{a}	45.80 ± 1.45^{a}	15.11 ± 0.9^{bc}	3.30 ± 0.72^{a}
Bottle gourd leaves (40%)	27.37 ± 9.90^{de}	40.52 ± 3.21^{bc}	13.37 ± 0.82^{bc}	2.80 ± 4.41^{fg}
Lemon peel (10%)	29.57 ± 7.26^{bc}	40.82 ± 6.14^{bc}	14.44 ± 0.81^{bc}	3.15 ± 0.55^{ab}
Lemon peel (20%)	27.43 ± 0.38^{ab}	43.77 ± 3.18^{ab}	13.56 ± 0.46^{ab}	3.12 ± 1.47^{ab}
Lemon peel (30%)	21.49 ± 2.70^{cd}	31.80 ± 2.23^{g}	11.04 ± 0.18^{a}	2.12 ± 0.52^{a}
Lemon peel (40%)	28.11 ± 0.61^{ab}	41.60 ± 3.10^{ab}	13.82 ± 0.54^{ab}	2.84 ± 0.50^{ab}
Malathion 57 EC	25.96 ± 1.92^{ab}	38.42 ± 4.61^{cd}	12.67 ± 0.90^{bc}	2.52 ± 0.62^{bc}
p value	<0.0001**	<0.0001**	<0.0001**	<0.0001**
F value	17.664	46.541	8.644	4.892
DF	12	12	12	12

Different letters within the same column indicate significant difference at $p < 0.05$; ** significance at $p \leq 0.01$; DAT= Days After Transplanting; EC = Emulsifiable Concentrate.

Effect of plant extracts on the abundance of aphids/plant and abundance of aphids (%) over that in the Malathion 57 EC group

The results showed that, compared with the application of Malathion, the application of 10% bottle gourd leaf extract significantly decreased aphid infestation on cabbage by 73.91% and 79.36% at 45 DAT and 60 DAT, respectively. Aphid infestation on cabbage was notably reduced by using 20% bottle gourd leaf extract at 45 and 60 DAT, by 67.93% and 50.79%, respectively. Similarly, compared with the application of Malathion, the application of 30% bottle gourd leaf extract considerably reduced the aphid infestation by 28.26% at 45 DAT and by 46.83% at 60 DAT (Table 2).

Effects of plant extracts on yield per plot and yield over that of the control and Malathion 57 EC groups

The cabbage yield was highest in the 30% bottle gourd leaf extract group (122.23 mt/ha), moderately high in the 10% and 20% lemon peel extract groups (116.68 and 115.57 mt/ha, respectively), and lowest (46.67 mt/ha) in the 5% jute seed extract group. The 30% bottle gourd leaf extract had the best effect on cabbage production, resulting in a 52.07% yield increase over that of the control group (Table 3).

Phytochemical screening

The phytochemical analysis revealed that the bottle gourd leaf extract was rich in alkaloids, flavonoids, terpenoids, phenols, and cardiac glycosides. No saponins, tannins, or anthraquinones were detected in the bottle gourd leaf extract.

Phytochemical components analysis by GC–MS

Investigations using GC–MS revealed that the methanolic extract of bottle gourd leaf comprises 13 prominent chemical components. There are higher amounts of phenol; 9,12-octadecadienoic acid; phytol and 1,2-benzenedicarboxylic acid compared to other components. From the literature survey, it is found that among these constituents 1,3,6,10-Dodecatetraene, 3,7,11-trimethyl-, (Z, E)-; hexadecenoic acid; phenol and phytol are highly significant in the management of aphids. Table 4 represents the basic information about the different components of bottle gourd leaf extract.

Discussion

Insecticides can have negative effects on humans in the form of acute or chronic toxicity. Synthetic pesticides are dangerous when used frequently because they are toxic to natural predators, pollinators, and other wildlife contaminate groundwater, cause populations to develop resistance, and spread secondary pests or pests that are not typically controlled by their natural predators[30]. Humans are generally exposed to pesticides through diet, with pesticide residues present in foods, particularly fruits and vegetables, but also in foods derived from animals. Agricultural workers carry pesticides home on their clothing, thereby exposing their families, while people living near areas where pesticides are applied can be exposed through pesticide drift and volatilization[31,32].

Under favorable conditions, aphids attack field-grown cabbage crops very rapidly, and consequently, crop quality decreases markedly. Although chemical pesticides are the main method to control aphids at present, some aphid strains have developed resistance to such pesticides in various parts of the world[33]. Environmental pollution by chemical pesticides is also a matter of concern. Many different types of insecticides like organophosphates, pyrethroids, and organochlorides are used to control aphids[34,35]. Environmental pollution occurs when pesticide contamination spreads away from the intended plants. These accumulate in various parts of the food chain and cause damage to the ecosystem. There is an increasing need for eco-friendly natural products to replace chemical pesticides.

Plants have evolved various mechanisms to resist pest attack. Their chemical defense systems consist of secondary metabolites including phenols, flavonoids, quinones, terpenes, tannins, alkaloids, lectins, polypeptides, saponins, and sterols[36]. Plant extracts rich in such secondary metabolites can disrupt cell membranes, inactivate various enzymes, and disrupt the metabolic processes of insects, leading to growth inhibition or death. Plant extracts tend to have broad-spectrum activity, are relatively specific in their mode of action, and are easy to process and use at the farm-level. Previous studies have demonstrated that plants are a rich source of natural substances that can be used in the development of environmentally safe

Table 2. Abundance of aphids in treatment groups, control group, and Malathion 57 EC group, and abundance of aphids (%) over that in the Malathion 57 EC group.

Treatment	Aphid abundance (number/plant)		Abundance (%) over Malathion 57 EC	
	45 DAT	60 DAT	45 DAT	60 DAT
Control	198.99 ± 7.54[a]	156.99 ± 2.40[a]	+8.15	+24.60
Jute seed (5%)	174.00 ± 8.19[a]	140.01 ± 8.84[ab]	−5.43	+11.12
Jute seed (10%)	192.00 ± 9.07[a]	167.01 ± 6.36[a]	+4.35	+32.55
Jute seed (20%)	108.00 ± 7.94[ab]	81.99 ± 4.81[bcdef]	−41.30	−34.93
Bottle gourd leaves (10%)	48.00 ± 4.62[b]	26.01 ± 0.88[f]	−73.91	−79.36
Bottle gourd leaves (20%)	59.01 ± 5.21[b]	62.01 ± 5.93[ef]	−67.93	−50.79
Bottle gourd leaves (30%)	132.00 ± 21.66[ab]	66.99 ± 4.91[def]	−28.26	−46.83
Bottle gourd leaves (40%)	105.00 ± 10.26[ab]	78.99 ± 9.02[bcdef]	−42.93	−37.30
Lemon peel (10%)	135.99 ± 13.37[ab]	113.01 ± 9.68[abcde]	−26.09	−10.31
Lemon peel (20%)	149.01 ± 17.82[ab]	119.01 ± 7.17[abcde]	−19.01	−5.55
Lemon peel (30%)	143.01 ± 11.26[ab]	135.99 ± 7.26[abc]	−22.27	+7.93
Lemon peel (40%)	152.01 ± 3.33[ab]	132.99 ± 3.84[abc]	−17.38	+5.55
Malathion 57 EC	183.99 ± 6.64[a]	126.00 ± 5.20[abcd]	–	–
p value	<0.0001**	<0.0001**	–	–
F value	2.051	4.741	–	–
DF	12	12	–	–

Different letters within the same column indicate a significant difference at $p < 0.05$; ** significance at $p \leq 0.01$; DAT = Days After Transplanting; EC = Emulsifiable Concentrate; Increased (+) aphid abundance compared with that in Malathion 57 EC group; Reduced aphid abundance (–) compared with that in Malathion 57 EC group.

Table 3. Effects of plant extracts on yield per plot and yield over that of the control and Malathion 57 EC groups.

Treatment	Yield (kg/plot)	Yield (mt/ha)	Yield over control (%)	Yield over Malathion 57 EC (%)
Control	17.36	80.37	–	−13.90
Jute seed (5%)	10.08	46.67	−42	−50
Jute seed (10%)	20.48	94.81	+17.97	+1.58
Jute seed (20%)	21.28	98.53	+22.58	+5.56
Bottle gourd leaves (10%)	19.76	91.49	+13.83	−1.98
Bottle gourd leaves (20%)	19.60	90.75	+12.90	−2.77
Bottle gourd leaves (30%)	26.40	122.23	+52.07	+30.95
Bottle gourd leaves (40%)	22.40	103.71	+29.03	+11.11
Lemon peel (10%)	25.20	116.68	+45.16	+25.01
Lemon peel (20%)	24.96	115.57	+43.78	+23.82
Lemon peel (30%)	16.96	78.53	−2.29	−15.87
Lemon peel (40%)	22.72	105.19	+30.88	+12.70
Malathion 57 EC	20.16	93.34	+16.13	–

Increased (+) yield compared with control and Malathion 57 EC; Decreased (–) yield compared with control and Malathion 57 EC.

Table 4. Thirteen (methanol-soluble) compounds detected in bottle gourd leaf extract by GC–MS.

Name of the compounds	Molecular formula	Retention time	Molecular weight (g/mol)	% of composition
1,3,6,10-Dodecatetraene, 3,7,11-trimethyl-, (Z, E)-	$C_{15}H_{24}$	14.369	93.00	2.557
Hexadecanal	$C_{16}H_{32}O$	22.775	57.00	2.109
Dodecane, 1,1-dimethoxy-	$C_{14}H_{30}O_2$	26.991	75.00	6.363
Hexadecanoic acid, 15-methyl-, methyl ester	$C_{18}H_{36}O_2$	28.213	74.00	4.346
Cyclopropanepentanoic acid, 2-undecyl-, methyl ester, trans-	$C_{20}H_{38}O_2$	31.927	55.00	1.293
Phenol, 2-methoxy-4-(2-propenyl)-, acetate	$C_{12}H_{14}O_3$	12.329	164.00	16.666
Pentadecanoic acid, 14-methyl-, methyl ester	$C_{16}H_{32}O_2$	28.217	74.00	2.748
1,2-Benzenedicarboxylic acid, butyl 2-ethylhe	$C_{20}H_{30}O_4$	28.827	149.00	6.532
9,12-Octadecadienoic acid, methyl ester, (E, E)-	$C_{19}H_{34}O_2$	31.795	67.00	17.713
9-Octadecenoic acid (Z)-, methyl ester	$C_{19}H_{36}O_2$	31.950	55.00	4.697
Undecanoic acid, 10-methyl-, methyl ester	$C_{13}H_{26}O_2$	28.197	74.00	6.294
Phytol	$C_{20}H_{40}O$	32.134	71.00	12.015
1,2-Benzenedicarboxylic acid, bis (2-methylpropyl) ester	$C_{16}H_{22}O_4$	26.554	149.00	16.667

methods for insect control[37]. For example, treatment with neem and crinum (7.5% w/v concentration) resulted in cabbage yields that were comparable to those obtained in a dimethoate (40% EC) treatment[38]. Leaf extracts of *Citrullus colocynthis* (L.), *Cannabis indica* (L.), and *Artemisia argyi* (L.) showed significant insecticidal properties against *Brevicoryne brassicae* aphid and field evaluations indicated that they had potential applications as botanical insecticides[39]. *Melia azedarach* and *Mentha* *piperita* plant extracts were effective in controlling cabbage aphid[40]. Zaki investigated the effects of plant extracts on aphids, as well as their parasites and predators, in a field study[41]. Islam et al. found that a water gourd (bottle gourd) leaf extract showed good efficacy against aphids in a cabbage field experiment. Although jute seed extract was found to be very effective against diamondback moth infestation but jute seed extract (10%) had phytotoxic effects on cabbage plants, causing leaf deformation and stunting of plant growth[42]. Khatun et al. found that treatment with a lemon fruit peel extract reduced aphid damage to field-grown bean plants[43].

Among all other treatments and controls, the application of 10% and 20% bottle gourd leaf extract significantly decreased the aphid infestation on the cabbage plant. The application of 30% bottle gourd leaf extract considerably decreased the aphid infestation by 28.26% and 46.83% at 45 and 60 DAT and led to a 30.95% increase in yield. Table 3 demonstrates that lemon peel 40% has a positive increase over yield, but lemon peel 30% has a negative impact. In addition to plant extract, a variety of other variables including plant health, soil texture, water content, weather, fertilizer dosage, and intercultural operations etc. might affect yield. The severity of aphid attack is dependent on weather conditions and plant maturity. In this experiment, aphids were barely detectable in the first 30 DAT. Out of the 12 treatments in this study, the bottle gourd leaf extract treatments (both 10% and 20%) effectively protected cabbage plants against aphids, compared with the other treatments. At both 45 and 60 DAT, the aphid population was smaller in the 10% bottle gourd leaf extract group than in the 20% bottle gourd leaf extract group. This might be because, at a higher concentration, less of the biopesticide compound was released into the solvent because of an imbalance in the solute-to-solvent ratio. This phenomenon is also observed in enzymatic reactions, where after a certain concentration is reached, the rate of the enzyme reaction does not further increase but decreases. From an economic viewpoint, a 10% extract is less costly and more sustainable than a 20% extract.

Treatment with the 30% bottle gourd leaf extract treatment resulted in the best yield performance, with the yield being 52.07% and 30.95% higher than that in the control and the Malathion groups, respectively. Thirteen compounds were identified from air-dried leaves of bottle gourd by GC−MS analysis. Among those compounds, 1,3,6,10-dodecatetraene, 3,7,11-trimethyl-, (Z, E)- or farnesene are known to function as insect semiochemicals and alarm pheromones for aphids and termites[44,45]. Several plants, including potato species, have been shown to synthesize this pheromone as a natural insect repellent[46]. Hexadecenoic acid also has antioxidant, hypocholesterolemic, nematicide, and pesticide properties[47]. Phenolic compounds detrimentally affect insects, and therefore, are effective control agents[48]. A previous study concluded that phytol, (E)-nerolidol, and spathulenol show considerable potential for development as effective and eco-friendly green insecticides against aphids[49]. The findings of our study show that bottle gourd leaf extract functions as an effective insecticide against cabbage aphids (*B. brassicae* L). In further research, it will be useful to further improve the formulation of the bottle gourd leaf extract for practical application to control cabbage aphid on crops under field conditions.

Conclusions

In this study, the abilities of extracts prepared from jute seed, bottle gourd leaves, and lemon fruit peel to control aphids on field-grown cabbage plants were compared. Compared with the application of Malathion, application of 10% and 20% bottle gourd leaf extract significantly decreased the aphid infestation by up to 50%–80% at 45 DAT and 60 DAT. Among all the treatments, the 30% bottle gourd leaf extract treatment not only controlled aphids, but also increased the yield of cabbage compared with that of the control and Malathion groups. Therefore, bottle gourd leaf extract can be used as an eco-friendly biopesticide instead of toxic chemical pesticides to control aphids in cabbage fields in a sustainable and cost-effective way.

Author contributions

The authors confirm contribution to the paper as follows: study conception, conducting experiments, selection of methodology, data analysis, and draft preparation: Sultana MS; study design and supervision: Azad MAK; draft review and editing: Shimizu N; GC−MS analysis: Rana GMM, Yeasmin MS. All authors reviewed the results and approved the final version of the manuscript.

Data availability

All data generated or analyzed during this study are included in this published article.

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Conflict of interest

The authors declare that they have no conflict of interest.

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References

1. Richardson KVA. 2016. Evaluation of the broccoli (*Brassica oleraceae* L. var. *italica*) variety imperial. *Crop Research Report No. 23*, Gladstone Road Agricultural Centre, Bahamas. pp. 1−5
2. Embaby S, Lotfy D. 2015. Ecological studies on cabbage pests. *Journal of Agricultural Technology* 11(5):1145−60
3. Liu T, Yue B. 2001. Comparison of some life history parameters between alate and apterous forms of turnip aphid (Homoptera: Aphidadae) on cabbage under constant temperatures. *The Florida Entomologist* 84:239−42
4. Bridges M, Jones AME, Bones AM, Hodgson C, Cole R, et al. 2002. Spatial organization of the *glucosinate–myrosinase* system in bras-

sica specialist aphids is similar to that of the host plant. *Proceedings of the Royal Society B-Biological Sciences* 269:187−91
5. Gray S, Gildow FE. 2003. Luteovirus-aphid interactions. *Annual Review of Phytopathology* 41:539−66
6. Rana JS. 2005. Performance of *Lipaphis erysimi* (Homoptera: Aphididae) on different *Brassica species* in a tropical environment. *Journal of Pest Science* 78:155−60
7. Lane A, Walters KFA. 1991. Effect of pea aphid (*Acyrthosiphon pisum*) on the yield of combining peas. *Aspects of Applied Biology* 27:363−68
8. Kaygin AT, Görür G, Cota F. 2008. Contribution to the aphid (Homoptera: Aphididae) species damaging on woody plants in Bartin, Turkey. *International Journal of Natural & Engineering* 2(1):83−86
9. Sing B, Singh R, Mahal MS. 1984. Assessment of loss in yield of *Brassica juncea* by *Lipaphis erysimi* (Kalt.). III Timing and duration of infestation. *Indian Journal of Ecology* 1:139−45
10. Wubie M, Negash A, Guadie F, Molla G, Kassaye K, et al. 2014. Repellent and insecticidal activity of *Mentha piperita* (L.) plant extracts against cabbage aphid (*Brevicoryne brassicae*) Linn. (Homoptera: Aphididae). *American-Eurasian Journal of Scientific Research* 9(6):150−56
11. Munthali DC, Tshegofatso AB. 2014. Factors affecting abundance and damage caused by Cabbage Aphid, *Brevicoryne brassicae* on four Brassica leafy vegetables: *Brassica oleracea* var. Acephala, B. chinense, B. napus and B. carinata. *The Open Entomology Journal* 8:1−9
12. Bodaiah B, Kumar A, Varma R, Anuhya G, Sudhakar P. 2016. Pesticidal activity of plants on selected insects. *International Journal of Recent Scientific Research* 7(3):9298−304
13. EPA US. 2008. EPA's Report on the Environment (ROE). *EPA/600/R-07/045F (NTIS PB2008-112484)*, US Environmental Protection Agency, Washington, DC.
14. Weaver DK, Subramanyam BH. 2000. Botanicals. In *Alternatives in Stored-Product IPM*, eds Subramanyam BH, Hagstrum DW. Boston, USA: Kluwer Academic Publishers. pp. 303−32. doi: 10.1007/978-1-4615-4353-4_11
15. Chougule PM, Andoji YS. 2016. Antifungal activity of some common medicinal plant extracts against soil borne phytopathogenic fungi *Fusarium oxysporum* causing wilt of tomato. *International Journal of Development Research* 3:7030−33
16. Hassan AZ, Mekhael MKG, Hanna AG, Simon A, Tóth G, et al. 2019. Phytochemical investigation of *Corchorus olitorius* and *Corchorus capsularis* (Family Tiliaceae) that grow in Egypt. *Egyptian Pharmaceutical Journal* 18(2):123−34
17. Patel SB, Attar UA, Ghane SG. 2018. Antioxidant potential of wild *Lagenaria siceraria* (Molina) Standl. *The Thai Journal of Pharmaceutical Sciences* 42(2):90−96
18. Paw M, Begum T, Gogoi R, Pandey SK, Lal M. 2020. Chemical composition of *Citrus limon* L. burmf peel essential oil from north east India. *Journal of Essential Oil Bearing Plants* 23(2):337−44
19. Sultana P, Alam MJ, Das K, Azad MAK, Islam MT. 2016. Screening of botanicals for controlling vegetables pest. *Bangladesh Journal of Environmental Sciences* 30:59−64
20. Mishra D, Shukla AK, Dubey AK, Dixit AK, Singh K. 2006. Insecticidal activity of vegetable oils against Mustard aphid, *Lipaphis erysimi* Kalt., under field condition. *Journal of Oleo Science* 55(5):227−31
21. Gupta G, Agarwal U, Kaur H, Kumar NR, Gupta P. 2017. Aphicidal effects of terpenoids present in *Citrus limon* on *Macrosiphum roseiformis* and two generalist insect predators. *Journal of Asia-Pacific Entomology* 20(4):1087−95
22. Al-Antary TM, Belghasem IH, Araj SEA. 2017. Evaluation of eco-friendly lemon oil against the green peach aphid *Myzus persicae* Sulzer (Homoptera: Aphididae) using four solvents. *Fresenius Environmental Bulletin* 26(12a):8298−303
23. Bonner MR, Coble J, Blair A, Beane Freeman LE, Hoppin JA, et al. 2007. Malathion exposure and the incidence of cancer in the agricultural health study. *American Journal of Epidemiology* 166(9):1023−34
24. Church BM, Strickland AH. 1954. Sampling cabbage aphid populations on Brussels sprouts. *Plant Pathology* 3:76−80
25. Islam S, Azad MAK, Islam MR, Sultana MS, Khatun JA, et al. 2021. Efficacy of some botanical extracts on the control of late blight disease in experimental potato field. *Advances in Bioscience and Biotechnology* 12:426−35
26. Harborne JB. 1973. *Phytochemical methods*. Dordrecht: Springer. pp. 49−188. doi: 10.1007/978-94-009-5921-7
27. Sofowara A. 1993. *Medicinal plants and traditional medicine in Africa*, 2nd edition. Ibadan, Nigeria: Spectrum Books Ltd. 289 pp.
28. Edeoga HO, Okwu DE, Mbaeble BO. 2005. Phytochemical constituents of some Nigerian medicinal plants. *African Journal of Biotechnology* 4:685−88
29. Duncan DB. 1951. A significance test for differences between ranked treatments in an analysis of variance. *Virginia Journal of Science* 2:171−89
30. Dubey NK, Shukla R, Kumar A, Singh P, Prakash B. 2010. Global scenario on the application of natural products in integrated pest management programmes. *Natural Products in Plant Pest Management* 1:1−20
31. Hernández AF, Lozano-Paniagua D, González-Alzaga B, Kavvalakis MP, Tzatzarakis MN, et al. 2019. Biomonitoring of common organophosphate metabolites in hair and urine of children from an agricultural community. *Environment International* 131:104997
32. Teysseire R, Manangama G, Baldi I, Carles C, Brochard P, et al. 2021. Determinants of non-dietary exposure to agricultural pesticides in populations living close to fields: a systematic review. *Science of The Total Environment* 761:143294
33. Mustafa G. 1998. Efficacy of some foliar insecticides against aphid on Brassica crop. *Annual report*, Ayub Agricultural Research Institute, Faisalabad. pp. 106−07
34. Parasad SK. 1992. Relative efficacy of some synthetic pyrethroid and phosphaamidon against the mustard aphid, *Lipaphis erysimi*. *Annals of Agricultural Research* 13(2):137−40
35. Bakhetia DKC, Brar KS, Sekhon BS. 1986. Bio-efficacy of some insecticides for the control of mustard aphid, *Lipaphis erysimi* (Kalt.) on rapeseed on mustard. *Indian Journal of Entomology* 48(2):137−43
36. War AR, Paulraj MG, Ahmad T, Buhroo AA, Hussain B, et al. 2012. Mechanisms of plant defense against insect herbivores. *Plant Signaling & Behavior* 7(10):1306−20
37. Sadek MM. 2003. Antifeedant and toxic activity of *Adhatoda vasica* leaf extract against *Spodoptera littoralis* (Lep., Noctuidae). *Journal of Applied Entomology* 127:396−404
38. Nahusenay DG, Abate GA. 2018. Evaluation of selected botanical aqueous extracts against cabbage aphid *Brevicoryne brassicae* L. (Hemiptera: Aphididae) on cabbage (Brassicae oleraceae L.) under field condition in Kobo District, North Wollo, Ethiopia. *Journal of Horticulture and Forestry* 10(5):69−78
39. Ahmed M, Qin P, Gu Z, Liu Y, Sikandar A, et al. 2020. Insecticidal activity and biochemical composition of *Citrullus colocynthis, Cannabis indica* and *Artemisia argyi* extracts against cabbage aphid (*Brevicoryne brassicae* L.). *Scientific Reports* 10(1):522
40. Birhanu M, Awoke Y, Tahgas A and, Raja N. 2011. Efficacy of *Melia azedarach* and *Mentha piperita* plant extracts against cabbage aphid, *Brevicoryne brassicae* (Homoptera: Aphididae). *World Applied Sciences Journal* 12(11):2150−54
41. Zaki FN. 2008. Field application of plant extracts against the aphid, *B. brassicae* and the whitefly, *B. abaci* and their side effects on their predators and parasites. *Archives of Phytopathology and Plant Protection* 41(6):462−66
42. Islam MM, Yesmin D, Sultana S, Azad MAK. 2020. Efficacy of some plant extracts for controlling aphid and diamond back moth of cabbage. *Bangladesh Journal Ecology* 2(2):107−11

43. Khatun JA, Azad MAK, Ahmed MS. 2018. Eco-friendly management of aphid with botanical pesticides in country bean field at Rajshahi, Bangladesh. *Rajshahi University Journal of Environmental Science* 7:1−10
44. Gibson RW, Pickett JA. 1983. Wild potato repels aphids by release of aphid alarm pheromone. *Nature* 302(5909):608−09
45. Šobotník J, Hanus R, Kalinová B, Piskorski R, Cvačka J, et al. 2008. (*E*,*E*)-α-Farnesene, an alarm pheromone of the termite *Prorhinotermes canalifrons*. *Journal of Chemical Ecology* 34(4):478−86
46. Avé DA, Gregory P, Tingey WM. 1987. Aphid repellent sesquiterpenes in glandular trichomes of *Solanum berthaultii* and *S. tuberosum*. *Entomologia Experimentalis et Applicata* 44(2):131−38
47. Sheela D, Uthayakumari F. 2013. GC-MS analysis of bioactive constituents from coastal sand dune taxon-*Sesuvium portulacastrum* (L.). *Bioscience Discovery* 4(1):47−53
48. Goławska S, Kapusta I, Łukasik I, Wójcicka A. 2008. Effect of phenolics on the pea aphid, *Acyrthosiphon pisum* (Harris) population on *Pisum sativum* L. (Fabaceae). *Pestycydy/Pesticides* 3(4):71−77
49. Benellia G, Pavelab R, Drenaggid E, Desneuxe N, Maggid F. 2020. Phytol, (*E*)-nerolidol and spathulenol from *Stevia rebaudiana* leaf essential oil as effective and eco-friendly botanical insecticides against *Metopolophium dirhodum*. *Industrial Crops and Products* 155:112844