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Research Article

Efficacy of Some Botanical Extracts Against Insect Infestation of Jute (*Corchorus olitorius* L.) as Leafy Vegetables

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Abstract

Two studies were carried out to evaluate the efficacy of nine botanical extracts against the pest incidence and severity of leafy vegetables experimental jute (*Corchorus olitorius* L.) field at University of Rajshahi, Bangladesh during 2023-2024. In the first study, Crude aqueous extract of cloves of *Allium sativum* (garlic), leaves of *Elettaria cardamomum* (Cardamon), leaves of *Pimenta dioica* (All Spice), leaves of *Tamarindus indica* (Tamarind), leaves of *Annona squamosa* (Custard Apple), leaves of *Artocarpus heterophyllus* (Jackfruit), clove of *Curcuma longa* (turmeric) and leaves of *Ficus caria* (Ficus) were applied at 10% (w/v) concentration for evaluation. Out of nine botanicals, *Annona squamosa* (Custard Apple) was found most effective in controlling different pest incidence and severity up to 8 WAS (weeks after sowing) and increased the yield by 14.39% compare to untreated control. The major insect pest was Brown Marmorated stink bug *(Halyomorpha halys)*, Jute hairy caterpillar *(Spilosoma oblique),* Jute semilooper (*Anomis sabulifera)*, Mealy bug (*Ferisia pseudococcus),* the highest infestation caused by Brown Marmorated stink bug *(Halyomorpha halys)*, *others* were farely common in different plot. The efficacy of *Tamarinds indica* (Tamarind) leaves extract extract against different insects was found promising and increased the yield by 10.50% Other four botanical extracts of *Allium sativum* (garlic), *Elettaria cardamomum* (Cardamon), *Pimenta dioica* (All Spice), *Artocarpus heterophyllus* (Jackfruit), *Curcuma longa* (turmeric) and *Ficus caria* (Ficus) showed moderate efficacy against the incidence and severity of different insects, and increased yield compare to control. On the other hand the efficacy of chemical insecticides (malathion 2ml/ litre water) against different insects was found promising and increased the yield by 16.63%. Further 2nd study was carried out to confirm the efficacy of two promising botanical extracts (*Annona squamosa* and *Tamarindus indica*). Dose dependent, 5%, 10% and 20% (w/v) concentration was used. The results suggest that botanical extract of *Annona squamosa* (Custard Apple) 20% (w/v) concentration was found most effective in controlling different pest incidence and severity up to 8 WAS (weeks after sowing) and increased the yield by10.24% compare to untreated control. On the other hand the efficacy of chemical insecticides (malathion 2ml/ litre water) against different insects was found promising and increased the yield by 11.26%. Hence, the leaf of *Annona squamosa* (Custard Apple) 20% solution can be recommended to be used for managing insect pests of jute (as leafy vegetables) in eco-friendly way.

Keywords

Botanical Extract, Jute, Insect Infestation, Malathion, Experimental Field

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1. Introduction

Jute (*Corchorus* sp.) is consumed as a leafy vegetable in many parts of the world. It is an annual flowering plant in the Tiliaceae family and the most significant source of natural fiber, covering about 80% of global bast fiber production [1]. Its leaves are in abundance of iron, folate, protein, fiber, calcium, riboflavin, carotene, vitamin C, and phenols, and have high zinc bioavailability and appreciable amounts of other proximate components. And minerals [2] Cooked leaves and tender shoots that are eaten along with food staples are recommended for pregnant and nursing mothers because of their high iron content [3]. Health-flourishing effects of plant-derived secondary metabolites in human health, including antioxidative, anticarcinogenic, antibiotic, and pharmacological effects, are well documented [4]. Leaves of C. olitorius possess an abundance of antioxidant compounds associated with various biological properties, which include diuretic, analgesic, antipyretic, and antimicrobial activities, antitumor [5] and phenolic antioxidative compounds [6] hypoglycemic [7] antiobesity [8] and gastroprotective [9].

Jute (Corchorus olitorius L.) leaves may contain lycopene, a strong antioxidant, but amounts in jute leaves are not known. It is a leafy green vegetable and fiber crop native to tropical and subtropical regions of Africa and Asia. Today, it is widely distributed across the tropics and subtropics. Under optimal conditions, jute as vegetables can produce total yields of 15–20 tons per hectare, although leaf yields are commonly about 2.5 tons per hectare. Growth periods range from 60 to 90 days, depending on the variety and environmental conditions. The leaves of jute are cooked as a vegetable, although they turn slimy or gelatinous when boiled. The dried leaves are used to thicken soups. The leaves are rich in vitamins A, B6 and C, potassium, iron, folate and dietary fiber. Jute is also used as feed for cattle in some production systems. Jute fiber is used for the production of high-quality writing and printing papers and a variety of specialty papers, as well as ropes and coarse fabrics such as sackcloth. Jute is used in traditional medicine to treat gonorrhea, chronic cystitis and some cancers. It is also used as an analgesic, anti-inflammatory and diuretic and to reduce fever.

The use of pesticides in vegetable production is increasing day by day in Bangladesh. Due to increased demand for vegetables, the frequency and quantity of pesticide use have increased over the past years in tomato, eggplant, cucumber, bitter gourd, beans, cauliflower, and cabbage and okra production. There has been a trend to pesticide use in vegetable production as it gives better output in a cost-effective way. This leads to higher contamination of vegetables with pesticide residues and causes many health problems for consumers. The problems are not limited to Bangladesh, and it is a pressing issue on a global scale. It has been reported in Pakistan, India, and China that pesticides are used indiscriminately in vegetable production and cause many health problems to consumers. Vegetables are a crucial part of our diet. They provide us with important nutrients that we need for a healthy lifestyle. There are many different types of vegetables that we can consume. Vegetables are herbaceous plants whose leaves and stems are used as food. Vegetables are the good source of vitamins and minerals. Vegetable is important for nutritional, financial, and food security in Bangladesh. Infestations by sucking insect pests do not only affect the crop but also hamper the crop health by transmitting pathogenic diseases. The incidence and dynamics of insect pests on jute are essential to develop sustainable management strategies. Extensive use of insecticides has resulted to the problems of pest resistance, resurgence, pesticides residues, destruction of beneficial fauna and environmental pollution [10].

The problem of acute malnutrition and food storages might be overcome by producing more vegetables to a significant extent which will ultimately lead to build a healthy nation [11]. Climate and soil of Bangladesh is very much suitable for growing vegetables round the year [12]. It can be produced even small amount of land and also in homestead area. It can be grown within a short time period and more than one crop can be grown within a crop season. There are a large number of vegetables having different varieties, which can be grown throughout the year. However, the largest numbers of vegetables are grown in the winter season. Vegetables contribute 3.2% of the agriculture Gross Domestic Product [13].

Leafy vegetables in Bangladesh are suffered serious losses due to different insects and diseases [14]. It has prepared a list of the insect and mite pest species associated with the important vegetable crops ecosystems in Bangladesh attempting to use the current scientific names of the insect and mite pest species with synonyms of some cases. In a pest surveys, as many as seven dozens of insects pest have been recorded on nine kinds of vegetables and 170 diseases on 27 vegetable crops. In Bangladesh, pest-induced losses are a serious problem for higher production of vegetables and the major insect pest and diseases cause 30-40% yield losses to vegetable crop [15]. To minimize the losses of leafy vegetables, application of toxic pesticides is the common practices in Bangladesh. The indiscriminate use of chemical pesticides in agriculture has created serious health and environmental problems in many developing countries [16]. Synthetic pesticides are generally persistent in nature. It has been established that use of synthetic organic pesticides, particularly the chlorinated hydrocarbons lead to serious environmental pollution (water, air and soil), affecting human health and causing death of non-target organisms (animals, plants, and fish) [17].

However, asides chemical control of insect pest, the parts of some plants (seed, root, bark, leaf) as botanical extracts have been discovered to be effective in pest management considering their environmental safety. However, the parts of some plants (seed, root, bark, leaf) as botanical extracts have been discovered to be effective in pest management considering their environmental safety. Botanicals are group of safe

bios-insecticides with a broad spectrum of anti-pest activity, relatively to specific mode of action, low mammalian toxicity and more tendency to disintegrate, in nature or metabolic in a biological system [18]. Most of the previous efforts to combat the pest problem associated with jute were based on pesticide approaches. Chemical pesticides not only cause environmental and health hazards but also encourages pest resurgence and secondary pest outbreak. It is reported that integration of improved cultural management practices, use of bio pesticides and conservation of natural enemies and a need-based use of chemicals could effectively control the insect and mite pest complex problem associated with jute [19]. Efforts were also made for integrated management of insect, mite and diseases of olitorius jute [20]. Such management included: using seed treatment with carbosulfan 25 DS at 3% w/w and through soil application of neem cake at 1500 kg/ha, carbofuran 3 G at 3 kg active substance (a.s.)/ha and neem coated urea at 88 kg/ha was also used for controlling root-knot nematode on jute [21].

Many studies focus on common botanicals (e.g., neem, garlic, chili), but there may be under-researched plant extracts with insecticidal properties. There are some research gaps on Screening of lesser-known or locally available botanical extracts against jute pests. This study particularly focused on understudied botanicals, formulation improvements, ecological safety, or integration into IPM. Therefore, aimed at controlling the attack of insect pests of jute using botanical extracts of some selected herbs which are readily available and cheaper. The results from the research work brought out the efficacy of different botanical extracts deployed for the management of insect pests of jute and the best performed.

2. Materials and Methods

2.1. Study Location

The study was carried out in the Botanical Pesticide Experimental Field of the Institute of Environmental Science, University of Rajshahi, Bangladesh during November 2023 to December 2024. The experiment area is located at 24.37˚N latitude and 88.7˚E longitude at an altitude of 21 meters above sea level.

2.2. Soil Type

The soils of experimental area are classified as loamy and clayey, with low to medium organic matter content. Which area is very close to the mighty river Padma, within Agro-Ecological Zone (AEZ) 26, the Level Barind Tract. Soil pH varies from pH 4.5 to pH 7.9.

2.3. Experimental Layout

The treatments; nine botanical extracts and a synthetic insecticide were arranged in Completely Randomized Design (CRD) and replicated three times.

2.4. Source of Botanicals

Botanicals were screened considering the odor, anti-fungal activity and phyto-toxicity. Previous studies and ethno-botanical knowledge were also considered to select the plants. Most of the plant materials were collected from Rajshahi University campus and some were purchased from local market. Nine plant materials such as cloves of *Allium sativum* (garlic), leaves of *Elettaria cardamomum* (Cardamon), leaves of *Pimenta dioica* (All Spices), leaves of *Tamarindus indica* (Tamarind), leaves of *Moringa oleifera* (Drum stick), leaves of *Annona squamosa* (Custard Apple), leaves of *Artocarpus heterophyllus* (Jackfruit), clove of *Curcuma longa* (turmeric) and leaves of *Ficus caria* (Ficus) were evaluated against the insect infestation in jute crops (as leafy vegetables) under field conditions.

2.5. Preparation of Leaf Extracts

The leaves were carefully removed from the branches. Plant parts were washed through running tap water 2 - 3 times. For the preparation of 10% aqueous extract (w/v), 100 g of each was dissolved separately in 1000 ml of water in container and boiled for 40 minutes with an electric heater. Garlic bulbs were cut into small pieces and blended by blender before boiling. Then aqueous extract was filtered through three-layer cheesecloth to collect the final extract for spray and stored in separate containers with labeling at room temperature.

2.6. Treatments

Eleven treatments were used in this study including two controls (one untreated and one chemical treated) and nine plant extracts (Table 1).

Table 1. *Description of treatments of first experiment.*

Treatment	Concentration
T0- Untreated Control (Water)	-
T1- Allium sativum (garlic)	10% (w/v)
T2- Elettaria cardamomum (Cardamon)	10% (w/v)
T3- Pimenta dioica (All Spices)	10% (w/v)
T4- Tamarindus indica (Tamarind)	10% (w/v)
T5- Moringa oleifera (Drum stick)	10% (w/v)
T6- Annona squamosa (Custard Apple)	10% (w/v)
T7- Artocarpus heterophyllus (Jackfruit)	10% (w/v)
T8- Curcuma longa (Turmeric)	10% (w/v)
T9- Ficus caria (Ficus)	10% (w/v)
T10- Chemical Treated (Insecticide - Malathion)	2 ml/l

Figure 1. *Experimental plots in Rajshahi University Campus.*

2.7. Seed Sowing

The jute seeds for first experiment were sown on 20 March, 2024 for 2nd experiment on 19 May, 2024. The unit plot size was 1 m × 1.5 m. The seed rate was 10 kg/ha. Application of water was done when necessary and weeding was done by hand pulling.

2.8. Thinning

At 3 week after sowing (WAS) jute seedlings were thinned out.

2.9. Fertilizer Application

MoP, TSP and DAP were applied during bed preparation, then Urea fertilizer were applied at 3 and 5 weeks after sowing (WAS).

2.10. Application of Botanical Extracts and Systemic Insecticides

The extracts were applied at 3, 4, 5, 6 and 7 weeks after sowing (WAS).

3. Data Collection

3.1. Number of Infested Plants

The number of infested plants were counted at 4, 5, 6, 7 and 8 WAS.

3.2. Number of Perforated Leaves

The number of perforated leaves were counted at 4, 5, 6, 7 and 8 WAS.

3.3. Plant Height

Jute plants were measured from the base of the plants to the tip of the longest leaves using meter rule at 4, 5, 6, 7, 8 WAS.

3.4. Fresh Weight After Harvest

Fresh weight of the top portion of the jute plant was taken which are used as leafy vegetables after 8 WAS on 16 May, 2024 (for first experiment) and on 16 July, 2024 (for second experiment).

Figure 2. *Data collection from Experimental plots.*

3.5. Data Analysis

The data collected from all parameters were subjected to analysis of variance (ANOVA) using statistical Analysis system procedure. The treatment means were separated using Duncan multiple range test (DMRT) at $p< 0.05$.

4. Results and Discussion

The insect infestation symptoms in jute field were observed regularly and Insect infestation and severity were determined on counting number of infested plants and perforation on leaves. At 4 WAS the highest (8.66 ±1.24a) insect infestation was observed in T8 and lowest (5.66 ±1.24a) incidence in T4 (Table 2). It stated that Neem extract with acetone and custard apple extract with methanol solvent were found effective to toxic and residual effects against pulse beetle of three plant extracts applied [22]. Out of nine botanicals, the treatment T6 showed the best efficacy to control the insect at 8 WAS, Other botanical treatments showed good efficacy (Table 2). At 8 WAS only T4 and T6 showed better efficacy over untreated control (water). But T6 showed the best efficacy among the botanical extracts (Table 2). Other botanical treatments controlled the incidence of insect infestation as good over controlled (Table 2).

This supports the findings of Chudasama and Sagarka, 2015. Who reported that Custard apple leaves and seed extracts as well as neem leaves and seed extracts effective to

some degree in reducing the ovipositional preferences and increasing the inhibition rates [23]. It is showed that among different aqueous extracts of plants materials, maximum percentage of oviposition deterrence was observed in custard apple seed extract (67.19%), custard apple leaf extract (65.95%) [24]. On 8 WAS, the highest insect infestation (36±2.16a) was observed in T0 (untreated control). At the same period, second highest (27±0.81a) were observed in T2 (Table 2).

Table 2. *Effect of botanical extracts on Number of infested plant of jute.*

	No. of infested plant of jute at different weeks				
Treatment	**4 WAS**	**5 WAS**	**6 WAS**	**7 WAS**	**8 WAS**
T0- Untreated Control (Water)	6±0.81a	15 ±0.81a	18±0.81a	30±3.55a	36±2.16a
T1- Allium sativum (garlic)	7.33±1.24a	15.66±0.94a	13.33±1.24a	21±1.63a	25.33±0.94a
T2- Elettaria cardamomum (Cardamon)	6 ±0.81a	15±1.63a	13.33±1.24a	21.66±0.47a	27±0.81a
T3- Pimenta dioica (All Spices)	8.33±0.47a	14±1.63a	14.66±1.24a	19.33±1.69a	26.66±1.69a
T4- Tamarindus indica (Tamarind)	5.66±1.24a	12.33±1.69a	13±1.63a	16.33±2.05a	20±2.16a
T5- Moringa oleifera (Drum stick)	7.66 ±0.47a	15.66±1.24a	14.33±0.47a	17.33±0.47a	24.33±0.47a
T6- Annona squamosa (Custard Apple)	7.66±1.24a	12±0.81a	12.66±1.24a	16±1.63a	16.66±1.69a
T7- Artocarpus heterophyllus (Jackfruit)	7.33 ±1.24a	15.66±1.24a	17±0.81a	20±0.81a	22.66±1.24a
T8- Curcuma longa (Turmeric)	8.66±1.24a	17.66±2.86a	17±0.81a	19.66±1.24a	22.33±1.24a
T9- Ficus caria (Ficus)	9±0.81a	17.33±1.24a	16.33±0.47a	19±0.81a	25.33±1.24a
T10 Chemical Treated (Insecticide - Malathion)	2.33±0.47a	4.26±0.1.24a	12.33±1.24a	15±0.81a	14.33±1.24a

Again, out of nine botanicals, effect of extracts on number of perforated leaves of jute, the treatment T6 showed the best efficacy against the insect at 8 WAS and other botanical treatments showed good efficacy (Table 4) than controlled. In case of plant height At 8 WAS T2, T4, T5, T6, T9, and T10 showed same effect on plant height (Table 5). But T6 showed the best efficacy among the botanical extracts (Table 2). Other botanical treatments controlled the incidence of insect infestation as good over controlled (Table 2). On 8 WAS, the highest insect infestation (36±2.16a) was observed in T0 (untreated control). The major insect pest was Brown Marmorated stink bug *(Halyomorpha halys)*, Jute hairy caterpillar *(Spilosoma oblique)*, Jute semilooper (*Anomis sabulifera)*, Mealy bug (*Ferisia pseudococcus)*, the highest infestation caused by Brown Marmorated stink bug *(Halyomorpha halys)*, *others* were farely common in different plot (Tables 3, 9). Jaswanth *et al*., (2002) prepared a liquid mosquito insecticide formulation with the methanolic extract of leaves of Annona squamosa using deodorized kerosene as the solvent and investigated for its mosquitocidal effect against C. quinquefasciatus. The extract formulation produced dose-dependent activity and the results suggest the potential mosquitocidal effect of Annonasquamosa on C. quinquefasciatus. [25].

Table 3. *Insect observation with status.*

Insect name	**Scientific Name (Family: Order)**	**Status**
1. Brown Marmorated stink bug	*Halyomorpha halys* (Pentatomidae: Hemiptera)	High infestation
2. Jute hairy caterpillar	Spilosoma oblique (Arctiidae: Lepidoptera)	Low infestation
3. Mealy bug	*Ferisia pseudococcus* (Pseudococcidae: Homoptera)	Low infestation
4. Jute semilooper	*Anomis sabulifera* (Noctuidae: Lepidoptera)	Low infestation

Table 4. Effect of botanical extracts on number of perforated leaves of jute.

	Number of perforated leaves of jute at different weeks				
Treatment	**4 WAS**	**5 WAS**	**6 WAS**	**7 WAS**	**8 WAS**
T0- Untreated Control (Water)	15±0.81a	29±0.81a	34 ±2.94a	40.33±4.02a	47 ±0.816a
T1- Allium sativum (garlic)	15.66±0.94a	25±0.81a	37.33±1.69a	36±0.81a	37.33 ±0.94a
T2- Elettaria cardamomum (Cardamon)	15±1.63a	22.66±2.05a	36±4.96a	34.33±1.69a	36.66 ±2.05a
T3- Pimenta dioica (All Spices)	14±1.63a	18±2.44a	31.66±2.86a	35±2.16a	36.33 ±2.05a
T4- Tamarindus indica (Tamarind)	12.33±1.69a	17.66±2.62a	19.66±4.02a	24.66±1.88a	23.66 ±2.49a
T5- Moringa oleifera (Drum stick)	15.66±1.24a	21±0.81a	28.66±1.69a	30±0.81a	31 ±1.63a
T6- Annona squamosa (Custard Apple)	12±0.81a	16±0.81a	21.66±0.94a	26.66±2.05a	26.66 ±1.69a
T7- Artocarpus heterophyllus (Jackfruit)	15.66±1.24a	23±0.81a	25.33±1.24a	31.33±0.47a	32.66 ±0.94a
T8- Curcuma longa (Turmeric)	17.66±2.86a	25±0.81a	28±0.81a	32.66±0.47a	34.66 ±0.47a
T9- Ficus caria (Ficus)	17.33±1.24a	22.33±1.69a	25.66±1.24a	33±0.81a	35 ±2.16a
T10 Chemical Treated (Insecticide - Malathion)	5±0.81a	8±0.816a	21.66±0.94a	25±0.81a	22.33 ±1.24a

At the same period, second highest (27 ±0.81a) were observed in T2 (Table 2). Again Out of nine botanicals, *Annona squamosa* (Custard Apple) was found most effective in case of yield, that is increased by 14.39% and in *Tamarinds indica* (Tamarind) leaves extract increased the yield by 10.50% compare to untreated control (Table 6). In case of other botanical extracts increased yield compare to control. On the other hand the efficacy of chemical insecticides (malathion 2ml/ litre water) against different insects was found promising (Tables 2, 4) and increased the yield by 16.63% (Table 6).

Table 5. Effects of botanical extracts on plant height of Jute.

	plant height of Jute at different weeks				
Treatment	**4 WAS**	**5 WAS**	**6 WAS**	**7 WAS**	**8 WAS**
T0- Untreated Control (Water)	11.66±1.24a	14±0.816a	17.33±0.94a	21±2.16a	23.33±0.94a
T1- Allium sativum (garlic)	12.33±0.47a	15.33±0.47a	18.33±0.47a	22±0.816a	26±0.81a
T2- Elettaria cardamomum (Cardamon)	11±0.81a	14.66±0.47a	18.66±1.24a	24.33±0.47a	27±0.81a
T3- Pimenta dioica (All Spices)	10.66±0.47a	13.66±0.471a	19±0.81a	24.66±0.47a	28±0.81a
T4- Tamarindus indica (Tamarind)	12±0.81a	15.66±0.471a	20.33±0.942a	26±0.81a	27±0.81a
T5- Moringa oleifera (Drum stick)	12.33±0.47a	15±0.81a	19.33±1.24a	24±0.81a	27.66±1.24a
T6- Annona squamosa (Custard Apple)	11.66±1.69a	15.33±1.24a	18.66±1.69a	25±0.81a	27±0.81a
T7- Artocarpus heterophyllus (Jackfruit)	11.33±0.47a	14.33±0.47a	17.66±0.47a	23±1.63a	25.33±1.69a
T8- Curcuma longa (Turmeric)	11±0.81a	14±0.81a	16.66±0.47a	22.66±0.47a	25±0.81a
T9- Ficus caria (Ficus)	12±0.816a	15±0.81a	18±0.81a	24±0.81a	27.33±0.47a
T10 Chemical Treated (Insecticide - Malathion)	15±0.816a	16±1.63a	20±0.81a	24.66±1.24a	27±0.81a

Table 6. Effects of botanical extracts on the yield (as vegetables) of jute.

Treatment	Yield (as vegetables) of jute		
	Wt. after harvest, kg/1.5 m² (8 WAS)	MT / ha	Yield increase over control (%)
T0- Untreated Control (Water)	2.77±0.09a	18.46	
T1- Allium sativum (garlic)	2.96±0.12a	19.70	6.71%
T2- Elettaria cardamomum (Cardamon)	2.95±0.04a	19.60	6.17%
T3- Pimenta dioica (All Spices)	3.03±0.09a	20.20	9.42%
T4- Tamarindus indica (Tamarind)	3.06±0.10a	20.40	10.50%
T5- Moringa oleifera (Drum stick)	3.05±0.14a	20.33	10.13%
T6- Annona squamosa (Custard Apple)	3.16±0.047a	21.06	14.08%
T7- Artocarpus heterophyllus (Jackfruit)	3.15±0.26a	21.00	13.75%
T8- Curcuma longa (Turmeric)	3.03±0.12a	20.20	9.42%
T9- Ficus caria (Ficus)	3.06±0.04a	19.40	5.09%
T10 Chemical Treated (Insecticide - Malathion)	3.23±0.04a	21.53	16.63%

Further 2nd study was carried out to evaluate the efficacy of two among of nine botanical extracts which were better, those were *Annona squamosa* (Custard Apple) and *Tamarindus indica* (Tamarind). This study was dose dependent, i.e. 5%, 10% and 20% (w/v) concentration (Table 7).

Table 7. Description of treatments of second experiment.

Treatments	Concentration
Control (Water)	-
T1- *Tamarindus indica* (Tamarind) 5% solution	5% (w/v)
T2- *Tamarindus indica* (Tamarind) 10% solution	10% (w/v)
T3- *Tamarindus indica* (Tamarind) 20% solution	20% (w/v)
T4- *Annona squamosa* (Custard Apple) 5% solution	5% (w/v)
T5- *Annona squamosa* (Custard Apple) 10% solution	10% (w/v)
T6- *Annona squamosa* (Custard Apple) 20% solution	20% (w/v)
T7- Insecticide (Malathion)	2 ml/L water

The insect infestation symptoms in jute field were observed regularly and Insect infestation and severity were determined on counting number of infested plants and perforation on leaves. Out of eight treatment T6 showed the best efficacy to control the insect at 8 WAS, Other botanical treatments showed good efficacy (Table 2). At 8 WAS only T4 and T6 showed better efficacy over untreated control (water). But T6 showed the best efficacy among the botanical extracts (Table 8). Other treatments controlled the incidence of insect infestation as good over controlled (Table 8). It is revealed that the custard apple extract showed the highest efficiency (80%) reduction against the aphid and the mite in hydroponic cucumber. Again, out of eight treatments effect on number of perforated leaves of jute, the treatment T6 showed the best efficacy against the insect at 8 WAS and other botanical treatments showed good efficacy (Table 10) than controlled. Kamaraj *et al.*, (2011) assessed the role of larvicidal activities of hexane, chloroform, ethyl acetate, acetone, and methanol dried leaf and bark extracts of Annona squamosa L., Chrysanthemum indicum L., and Tridax procumbens L. against the fourth instar larvae of malaria vector, Anopheles subpictus Grassi and Japanese encephalitis vector, Culex tritaeniorhynchus Giles (Diptera: Culicidae) [26]. In case of plant height At 8 WAS, T1, T3, T4, and T7 showed same effect on plant height (Table 11).

In this experiment the results suggest that botanical extract of *Annona squamosa* (Custard Apple) 20% (w/v) concentration has a great potential and was found most effective in controlling different pest incidence and severity up to 8 WAS (days after sowing) (Tables 8, 10). The crude oils from seeds of custard apple at 2.5 and 5 percent concentrations significantly reduced leaf damage caused by S. litura larvae [27]. On the other hand the efficacy of chemical insecticides (malathion 2ml/ liter water) against different insects was found promising and increased the yield by 11.26%. Among the

treatments of different doses of botanicals used hence, the leaf of *Annona squamosa* (Custard Apple) 20% solution can be recommended to be used for managing insect pests of jute (as leafy vegetables) in eco-friendly way. Kawazu *et al*., (1989) isolated neoannonin, a novel insecticidal from the seed of custard apple, which were found to be toxic to fruit fly [28].

Table 8. *Effects of treatments on Number of infested plant of jute.*

	No. of infested plant of jute at different weeks				
Treatment	**4 WAS**	**5 WAS**	**6 WAS**	**7 WAS**	**8 WAS**
Control (Water)	4.66±0.94a	20.66±1.69a	23.66±4.02	23.66±4.02	33±2.16a
T1- *Tamarindus indica* (Tamarind) 5% solution	5.66±1.24a	8.66±1.24a	12.33±1.24a	12.33±1.24a	13.33±1.69a
T2- *Tamarindus indica* (Tamarind) 10% solution	5.33±0.47a	10.33±1.24a	11.66±2.05a	11.66±2.05a	14.66±2.05a
T3- *Tamarindus indica* (Tamarind) 20% solution	8±2.16a	10±2.16a	15±1.63a	15±1.63a	15±0.81a
T4- *Annona squamosa* (Custard Apple) 5% solution	6.33±1.24a	9.66±0.47a	13.33±1.24a	13.33±1.24a	13.33±0.47a
T5- *Annona squamosa* (Custard Apple) 10% solution	6±2.16a	9±1.63a	17±0.81a	17±0.81a	16±0.81a
T6- *Annona squamosa* (Custard Apple) 20% solution	4.66±0.47a	7.33±1.24a	10.33±1.24a	10.33±1.24a	8.66±0.94a
T7- Insecticide (Malathion)	2±0.81a	5±1.63a	7±0.81a	6±0.81a	5±0.81a

Table 9. *Insect observation with status.*

Insect name	**Scientific Name (Family: Order)**	**Status**
1. Brown Marmorated stink bug	*Halyomorpha halys* (Pentatomidae: Hemiptera)	High infestation
2. Jute hairy caterpillar	*Spilosoma oblique* (Arctiidae: Lepidoptera)	Low infestation
3. Mealy bug	*Ferisia pseudococcus* (Pseudococcidae: Homoptera)	Low infestation
4. Jute semilooper	*Anomis sabulifera* (Noctuidae: Lepidoptera)	Low infestation

Table 10. *Effects of botanical extracts on number of perforated leaves of jute.*

	Number of perforated leaves of jute at different weeks				
Treatment	**4 WAS**	**5 WAS**	**6 WAS**	**7 WAS**	**8 WAS**
Control (Water)	10±0.81a	23.33±2.05a	35.66±1.69a	38±2.44a	48±3.26a
T1- *Tamarindus indica* (Tamarind) 5% solution	11±0.81a	15.66±1.24a	22±0.81a	22±0.81a	22.33±1.24a
T2- *Tamarindus indica* (Tamarind) 10% solution	9.33±1.24a	16±1.63a	20.66±1.69a	20.66±1.69a	23.66±2.62a
T3- *Tamarindus indica* (Tamarind) 20% solution	13±2.16a	16.33±1.24a	21.66±4.02a	21.66±4.02a	21±2.44a
T4- *Annona squamosa* (Custard Apple) 5% solution	10.33±2.62a	17.66±1.24a	22.33±2.49a	22.33±2.49a	25.66±2.05a
T5- *Annona squamosa* (Custard Apple) 10% solution	7.66±0.47a	14.33±2.05a	19±4.08a	19±4.08a	23.33±2.86a
T6- *Annona squamosa* (Custard Apple) 20% solution	7.66±1.24a	9±0.81a	14.33±2.62a	14.33±2.62a	15±0.81a
T7-Insecticide (Malathion)	4±1.94a	8.66±0.47a	9±2.44a	8±2.44a	10±1.63a

Table 11. Effects of botanical extracts on plant height of Jute.

Treatment	Plant height of jute at different weeks				
	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS
Control (Water)	12±0.81a	15.33±0.47a	17.66±1.24a	21.66±1.24a	25±1.41a
T1- *Tamarindus indica* (Tamarind) 5% solution	12±0.81a	14.66±1.24a	17.33±1.24a	21±1.63a	24.66±1.24a
T2- *Tamarindus indica* (Tamarind) 10% solution	12.33±1.24a	15±1.41a	18±1.63a	22±1.63a	25±0.81a
T3- *Tamarindus indica* (Tamarind) 20% solution	10±0.81a	13±0.81a	17±0.81a	21±0.81a	24.66±1.24a
T4- *Annona squamosa* (Custard Apple) 5% solution	10.66±0.94a	14±0.81a	17±0.81a	20.66±0.47a	24.66±1.24a
T5- *Annona squamosa* (Custard Apple) 10% solution	12.66±0.47a	15.33±0.47a	18±0.81a	23±0.81a	26.66±0.47a
T6- *Annona squamosa* (Custard Apple) 20% solution	11±0.81a	14.33±0.47a	17.66±0.47a	23±0.81a	27±0.81a
T7-Insecticide (Malathion)	10.33±0.47a	13.66±0.47a	15±0.81a	21.33±0.47a	24.66±0.47a

Table 12. Effects of botanical extracts on the yield (as vegetables) of jute.

Treatments	Wt. after harvest, kg/1.5 m² (8 WAS)	MT / ha	Yield increase over control (%)
Control (Water)	2.93±0.16a	19.53	-
T1- *Tamarindus indica* (Tamarind) 5% solution	3.06±0.04a	20.40	4.45%
T2- *Tamarindus indica* (Tamarind) 10% solution	3.2±0.21a	21.33	9.21%
T3- *Tamarindus indica* (Tamarind) 20% solution	3.16±0.20a	21.06	7.83%
T4- *Annona squamosa* (Custard Apple) 5% solution	3.1±0.08a	20.66	5.78%
T5- *Annona squamosa* (Custard Apple) 10% solution	2.93±0.12a	19.53	0%
T6- *Annona squamosa* (Custard Apple) 20% solution	3.23±0.20a	21.53	10.24%
T7-Insecticide (Malathion)	3.26±0.26a	21.73	11.26%

5. Conclusions

Out of nine botanicals, the application of *Annona squamosa* (Custard Apple) 20% solution was found to enhance the growth, increased production and suppressed insect pest attack on jute in experimental field. *Annona squamosa* (Custard Apple) leaf extract may be a good source of effective insecticide for the control of jute insect pest in this study area with no adverse effect to the environment, human, aquatic resources and natural enemies of the insect pests. *Annona squamosa* (Custard Apple) leaf extract is recommended as botanical pesticide to substitute synthetic pesticides for the control of insect pests of jute. This will help the farmers to obtain the potential optimum growth and production of jute as vegetables with less adverse effects on human and environment. However further studies should be conducted on the feasibility test of the application of *Annona squamosa* (Custard Apple) 20% solution in farmer level and to find out the active ingredients in the *Annona squamosa* (Custard Apple) plants that functions as insecticidal material(s).

Abbreviations

WAS Week After Sowing
CRD Completely Randomized Design

Author Contributions

Md Masud Rana: Formal Analysis, Investigation, Writing Original Draft, Writing-review &editing

Md Abul Kalam Azad: Data curation, Supervision, Writing – original Draft, Writing - review &editing

Conflicts of Interest

The authors declare no conflicts of interest.

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