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Farmers Perception on Pest Management Practices and Profitability Analysis for Five Winter Vegetable Production

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ABSTRACT

The purpose of the study was to determine the farmers' perceptions of management measures against insect and disease pests and the profitability of five winter vegetables grown in Bangladesh's Sirajganj area. The highest incidences of fungal infections, including curd rot of cauliflower and early blight of tomato, were discovered. One of the most destructive diseases of brinjal and tomato was wilt, which was caused by both fungi and bacteria. Farmers took the necessary steps to control aphids (40-150 insects m^{-2} or 20-50 infected shoots m^{-2}), brinjal shoot and fruit borer (10-50 insects $10m^{-2}$ or 20-60 infected shoots or fruits 10m–2), and other insects at the threshold level. They employed physical, chemical, and Integrated Pest Management (IPM) techniques to manage the disease and insect pests. The greatest amount of insecticide spraying (35-45 times) was performed to control brinjal shoot and fruit borer insects. The entire manufacturing cost followed the pattern tomato > brinjal > bean > cauliflower > bottle gourd. The cultivation of brinjal yielded the highest return, gross margin, and net return (Tk. 987,000.00, Tk. 800,572.00, and Tk. 763,117.00 ha^{-1}, respectively; US$ 1 = Bangladesh currency Tk. In contrast, bottle gourd farming yielded the lowest return (Tk 700,000.00 ha^{-1}), and tomato cultivation yielded the lowest gross margin and net return (Tk 539,152.00 and 507,325.00, respectively). The brinjal cultivation had the highest profitability index, benefit-cost ratio (both variable and total cost basis), and rate of return on investment, whereas tomato cultivation had the lowest. Rot, blight disease, shoot and fruit borer, or fruit borer, and aphid were the most common pests of winter vegetables in the region surveyed. Finally, we discovered that brinjal is the most profitable vegetable in our area of study.

1. Introduction

Agriculture is the single largest producing sector of Bangladesh that contributes about 13.02% to the total GDP of the country and has been playing a significant role in the growth and stability of the national economy of the country (BBS, 2021). The agricultural sector viz. crops, fisheries, and livestock, accommodating around 40.6% of the labour force (BBS, 2021), which has also been emerged as a major source of income and employment opportunities in Bangladesh. Due to high nutritive value, relatively higher yield, and higher return, vegetables are considered as one of the most important components of crop agriculture (Sharmin, 2015). Vegetables are commonly low in fat and calories. Moreover, vegetables supply dietary fibre and are important sources of essential vitamins, minerals, and trace elements. It also reduces hidden hunger and malnutrition effectively. To ensure food safety and alleviate malnutrition, the second goal of UN Sustainable Development Goals, in our country, it is necessary to increase hygienic vegetable production and consumption. Vegetables provide digestion, combating malnutrition, curing nutritional disorders, and protect against diseases (Chowdhuri *et al*., 2014). Besides nutritional importance, labour intensive vegetable production systems help to create employment opportunities, raise farm income (profit), and reduce poverty in developing countries (Weinberger & Genova, 2005; Mitra & Yunus, 2018). Compared to cereals, vegetables provide maximal yield and greater income per unit area of land to small-scale farmers. (Chowdhury & Hasan, 2013). Vegetable production experienced tremendous growth in the last 40 years in Bangladesh, secured the seventh position (16.2 million metric tons) around the world in vegetable production (https://www.statista.com/statistics/264662/top-producers-of-fresh-vegetables-worldwide/). In winter season, the largest amount of vegetables are produced and supplied in the Bangladesh market. The common winter vegetables of Bangladesh are tomato, water gourd, cauliflower, cabbage, brinjal, pumpkin, radish, bean, green spinach, etc. However, vegetable farmers, particularly smallholders, confront several constraints in vegetable production. Most importantly population dynamics and incidence of insect and disease pests' attacks on crops, due to climate change events especially the continuous rise in winter temperature (Deutsch *et al*., 2018; Burdon & Zhan, 2020) that inversely affects the winter vegetable production of the Bangladesh and its adjacent regions. Due to pest's attack, 30 to 40% of total vegetables have been reduced every year in Bangladesh (https://ipmworld.umn.edu/rahman). Therefore, the farmer's knowledge about the eco-friendly pest management practices is very important for safe and nutritious vegetable production to increase in farm income. Both the yield loss and market price depending on the intensity of the pest severity varied from place to place, the existence of different races, and biotypes or strains of the insect or pathogens (Sastry & Hegde, 1989; Hossain *et al*., 2010). Along with several insects, 454 diseases have been recorded in about 100 cultivated crops in Bangladesh (Anon., 2006). There are numerous types of pests, including leaf miners, aphids, thrips, cutworms, armyworms, cabbage looper beetles, earworms and hornworms, green vegetable bugs, spiders, mites, stem borers, and root-knot nematodes attack and reduces the yield quality of the vegetables in Bangladesh (Fores, 2021). Winter vegetables are affected by different insects e.g., Epilachna beetle, aphid, shoot and fruit borer, and thrips and different diseases caused by fungi, bacteria, virus and internal disorders, which are associated with the environment, nutrition, salinity, and water stress (Rao *et al*., 2016).

Various insects, diseases, and disorders can affect the growth and yield of vegetables. The farmers' diseases and insects management practices hamper limits in obtaining eco-friendly crop production and ensuring our food safety. Farmers of our country generally do not follow the judicious and safety protocols of pesticides application to control different types of pests. For example, Farmers utilize chemical pesticides (30-40 times) to control the shoot & fruit borer and pumpkin beetle of various summer vegetables. (Chanda *et al*., 2021). Overdose and frequent use of pesticides is a threat to both agroecology and agrobiodiversity, which cause death to beneficial insects and microorganisms, ensued human health hazard, and consumers suffer for a long time in different chronic diseases. In addition to the health and environmental issues, inorganic pesticides increase the costs of production. Moreover, vegetable diseases and insect pests are becoming resistant to pesticides due to inappropriate doses. As a result, farmers lose agricultural production, receive low market prices, and the national economy is negatively impacted. The extensive usage of chemical pesticides in Bangladesh is a significant problem in vegetable cultivation in particular (Gautam et al., 2017). Misuse of pesticides exposes consumers and farm workers to significant health hazards, contributes to unsustainable agricultural practices, and reduces agricultural exports. Therefore, research is required to assess farmers' understanding of pesticide use in vegetable farming. Little is known about the attitudes of farmers regarding pest and disease management strategies and cost analyses for increased farm income and profitability (Chowdhuri et al., 2014; Hasan et al., 2014; Sharmin, 2015; Akter et al., 2016; Chanda et al., 2021). In order to establish the nature of insect and disease infestation in winter vegetables, as well as the control measures employed by vegetable growers, and to conduct a financial analysis of winter vegetable farming in the Sirajganj district of Bangladesh, this study was conducted.

2. Methods

Five Upazilas, including Royganj, Ullapara, Kazipur, Kamarkhanda, and Sadar of Sirajganj district were selected for the study bearing in mind farmers' cooperation regarding data collection. Winter vegetable producing time September 2019 to February 2020 was considered for the study to characterize the insect and disease infestation management practices at farmers level and financial analysis of five winter vegetables, including bottle gourd, brinjal, tomato, bean, and cauliflower cultivation. A total of 150 (5 Upazilas × 30 farmers from each) winter vegetables producing farmers were purposively selected for the present study. Data were collected through face-to-face interviews and sometimes group discussion methods using a well-developed survey questionnaire. Information solicited in the questionnaire was on the nature of insect and disease infestation and management practices and costs and return associated.

The data were analyzed using descriptive statistics and the "Farm Budgetary Technique" for financial analysis (Peter *et al*., 2019). The descriptive statistics were used to describe the management practices of insect and disease infestation in the winter vegetable production at the farmer's level in the study area.

In financial analysis, the determination of total cost, total revenue, , net income, profitability index, gross margin, benefit-cost ratio, and return on investment are the primary analytical tools. The methodologies have been utilized extensively for calculating the costs, returns, and net revenue of farm companies in order to aid in making production decisions based on their merit. Its usefulness and simplicity help to demonstrate the relationship between costs and the return of agricultural enterprises. To represent the results of the study, descriptive statistics, as well as tabular analysis, were done following the Microsoft Excel® package program. The interest rate was assumed to be 10%. The vegetable season was considered for six months. As per the objective of the study, the collected data were investigated. The following equations were used in financial analysis for winter vegetable production.

Total return $TR = P \times Q$

Where, P = Price of the product (Tk.; Bangladesh currency Tk. 85.27 = US$ 1 on 24 September 2021); Q = Yield per hectare (kg)

Total cost $TC = TFC + TVC$

Where TFC = Total fixed cost (Tk.); TVC = Total variable cost (Tk.)

The Gross Margin is the difference between the Total Revenue (TR) and the Total Variable Cost (TVC).

$GM = TR – TVC$

Where GM = Gross margin (Tk. ha^{-1}); TR = Total revenue (Tk. ha^{-1}); TVC = Total variable cost (Tk. ha^{-1})

Net return analysis is calculated as the difference between the Total Revenue (TR) and the Total Cost (TC) incurred in the vegetable production process.

Net return, NR = TR – TC

Where NR = Net return; TR = Total revenue; TC= Total cost

Profitability Index is (PI) analysis calculated as the ratio of the Net Return to Total Variable Cost.

Profitability Index (PI) =NR/TVC

Where NR = Net return; TVC= Total variable cost

Benefit-cost ratio (variable cost basis) = Total return/Total variable cost

Benefit-cost ratio (Total cost basis) = Total return/Total cost

The rate of return on investment (RRI) is obtained as a ratio of Net Return to Total Cost of investment in vegetable production. It is used to measure how efficiently the vegetable farm utilized its total costs which covered the investment to produce revenues (Olukosi & Erhabor, 1988).

Rate of Return on Investment (RRI) = NR/TC×100

Where NR = Net return; TC= Total cost

3. Results and Discussion

Nineteen diseases infections were found in the five selected winter vegetables, which are shown in Table 1. Table 1 also described the disease symptoms and economic threshold level from farmers' perspective, which means when farmers took necessary measures to control the diseases. Of these disases, the causal organism of fifteen diseases was identified as fungi, two among fungi, bacteria and *Verticillium*, and two as viruses (Table 2). The curd rot of cauliflower and early blight of tomato were the most frequently observed fungal diseases. The fungal disease incidences caused the maximum loss, which reduced up to 40% in vegetable yield and production. The seedling blight of cauliflower caused 25-40%, wilt of brinjal caused 18-30%, and root rot of tomato caused 17-30% loss of crop yields, which were the most detrimental pest among 19 diseases. Disease syndrome appeared on different parts of vegetables, including seedlings, roots, leaves, plants, fruits, pods, and heads. Root rot diseases were the most devastating for all crops. Generally, farmers could not predict disease outbreaks. However, farmers and Sub-Assistant Agriculture Officers collected different disease infested vegetable parts and shared their neighbour farmers' knowledge (Abang *et al*., 2014). Farmers believe that a disease-resistant variety may help to relieve this problem. The disease early warning system, using disease epidemiological models, and seasonal forecasts, might be useful for the pre-season planning of local or national level disease control (Kim & Choi, 2020). This type of forecasting for insects might also find to be useful. The highest yield losses 25-40% was found in seedling blight and the lowest 0.5-1.5% in mildew diseases (Table 2). Khan (1999) reported that disease infestation causes 30-50% yield loss, 15-20% in general, and 30-50% in severe cases of brinjal fruit rots caused by the Phomopsis vexans fungus (Das, 1998). Sastry and Hegde (1989) reported that the amount of crop fruit losses caused by a specific pathogen varied from location to location due to the presence of various races, biotypes, or strains of the pathogen (Hossain et al., 2010). Farmers adopted a variety of physical and chemical measures to combat various disease outbreaks (Table 2). They used different doses of pesticide 2-3 times frequency. Farmers also claimed that Tilth 250EC was the most commonly used fungicide applied against six diseases.

Table 1. Disease symptoms and economic threshold (farmer's perception) for winter vegetables in Sirajganj District. * Range and mean value within the bracket.

Vegetable	Diseases	Symptoms	Infected plant parts
Bottle Gourd	Powdery Mildew	White powdery appearance on leaves	7-15 (9) Leaves Plant^{-1}
	Downy Mildew	White powdery appearance underside of leaves	12-30 (14) Leaves Plant^{-1}
	Root rot	Rot on collar zone	10- 20 (13) Seedlings 10m^{-2}
	Gummy Stem Blight	Reddish gummy substance exudes from the stem	10-15 (14) Leaves Plant^{-1}
Brinjal	Wilt	Wilt seedlings	6- 10 (8) Seedlings 10m^{-2}
	Root rot	Rot on collar zone	20- 60 (23) Seedlings 10m^{-2}
	Little Leaf	Characterized by small & malformed yellowish leaves	20- 30 (22) Leaves Plant^{-1}
	Phomopsis Blight	Pale, sunken lesion on the fruit surface and become depressed	30-75 Fruits 10m^{-2}
Tomato	Early blight	Circular or irregular dark spots on the lower, more mature leaves	5-10 Plants 10m^{-2}
	Late Blight	Blackish/brown necrotic lesions on leaves and stems	8-20 Plants 10m^{-2}
	Wilt	Epinasty the seedlings	10-25 Seedlings 10m^{-2}
	Fruit rot	Lesions on the fruit surface and become depressed	25-40 Fruit 10m^{-2}
	Root rot	Rot on collar zone	10-20 Seedlings 10m^{-2}
Bean	Anthracnose	Tan to rust coloured lesions with a raised black ring & brownish red border on pod	20-50 Pods Plant^{-1}
	Mosaic Virus	Green to bluish-green mottled or mosaic pattern on leaves exhibiting downward curling	10-30 Leaves Plant^{-1}
Cauliflower	Seedlings blight	Damp-off or rot at the soil line eventually collapse and die.	10-30 Seedlings 10m^{-2}
	Leaf blight	Circular or concentric rings (target spots) on leaves	10-15 Leaves 10m^{-2}
	Curd rot	Water-soaked lesions on flower heads	3-5 Heads 10m^{-2}
	Root rot	Rot on collar zone	25-40 Plants 10m^{-2}

*Leaves were assessed from top to bottom.

Table 2. Causal agent, yield loss and control measures of different diseases in Sirajganj District.

Vegetable	Diseases	Causal agent	Yield loss (%)	Control measure	Frequency
Bottle Gourd	Powdery Mildew	Fungus	0.5-1.5	1. Removes infected leaves 2. Spray Ridomil gold @ 2gm L^{-1} water	2 - 3 times
	Downy Mildew	Fungus	0.5-1.5	1. Removes infected leaves 2. Spray Ridomil gold @ 2gm L^{-1} water	2 - 3 times

	Root rot	Fungus	10-25	1. Removes infected seedlings 2. Spray Mancozeb @ 2ml L^{-1} water	2 - 3 times
	Gummy Stem Blight	Fungus	5-12	1. Removes infected leaves 2. Spray Ridomil gold @ 2gm L^{-1} water	2 - 3 times
Brinjal	Wilt	Multiple	18-30	1. Removes infected seedlings 2. Spray Tilth 250 EC @ 1ml L^{-1} water	1 - 2 times
	Root rot	Fungus	15-35	1. Removes infected seedlings 2. Spray Mancozeb @ 2ml L^{-1} water	2 - 3 times
	Little Leaf	Virus	5-8	1. Removes infected plants 2. Spray Tido @ 1.5ml L^{-1} water	1 - 2 times
	Phomopsis Blight	Fungus	8-20	1. Removes infected fruits 2. Spray Tilth 250 EC @ 1ml L^{-1} water	2 - 3 times
Tomato	Early blight	Fungus	5-7	1. Removes infected fruits 2. Spray Score 250 EC @ 1ml L^{-1} water	2 - 3 times
	Late Blight	Fungus	15-20	1. Removes infected fruits 2. Spray Score 250 EC @ 1ml L^{-1} water	2 - 3 times
	Wilt	Multiple	15-25	1. Removes infected seedlings 2. Spray Tilth 250 EC @ 1ml L^{-1} water	1 - 2 times
	Fruit rot	Fungus	5-15	1. Removes infected fruits 2. Spray Tilth 250 EC @ 1ml L^{-1} water	2 - 3 times
	Root rot	Fungus	17-30	1. Removes infected seedlings 2. Spray Companion @ 2gm L^{-1} water	2 - 3 times
Bean	Anthracnose	Fungus	5-7	1. Removes infected fruits 2. Spray Secure @ 2ml L^{-1} water	2 - 3 times
	Mosaic Virus	Virus	3-10	1. Removes infected fruits 2. Spray Admire @ 1ml L^{-1} water	2 - 3 times
Cauliflower	Seedlings blight	Fungus	25-40	1. Removes infected leaves 2. Spray Tilth 250EC @ 1ml L^{-1} water	1 - 2 times
	Leaf blight	Fungus	2-5	1. Removes infected leaves 2. Spray Tilth 250EC @ 1ml L^{-1} water	2 - 3 times
	Curd rot	Fungus	5-8	Chemical treatments are not available; control relies on cultural practices	
	Root rot	Fungus	10-17	1. Removes infected seedlings 2. Spray Companion @ 2gm L^{-1} water	2 - 3 times

In the survey area, 11 insect species were found in five winter vegetables, which were shown in Table 3; although the number of insect pests were relatively higher during the summer season (Chanda *et al.*, 2021). Farmers took necessary management strategies to control the different type of insect populations or infested plant parts of winter vegetables below the threshold level. Farmers decided to control aphid (40-150 insect population m^{-2} or 20-50 infected shoot m^{-2}) and brinjal shoot and fruit borer (10-50 insect population $10m^{-2}$ or 20-60 infected shoot or fruits $10m^{-2}$) and threshold level of other insects population or infected plant parts to be found in Table 3. Cutworm was the most common insect pest that affected three winter vegetables, which include brinjal, tomato and cauliflower. Farmers asserted that Dursban and other chemicals were used to control cutworm (Table 4). However, shoot and fruit borer or fruit borer and aphid were the most common insects in winter vegetables, surpassing all others. (Praveen & Dhandapani, 2002; Kekeunou *et al*., 2006).

Table 3. Symptom and economic threshold (farmer's perception) due to insect infestation for winter vegetable cultivation in Sirajganj District. * Range and mean value within the bracket.

Vegetable	**Insects**	**Indicator of chemical control**		**Symptoms (Farmer's perspective)**
		Insects*	**Infected plants (%)**	
Bottle Gourd	Red pumpkin beetle	4-12 (8)	8-20 (13) Leaves $Plant^{-1}$	Several beetles are found feeding together on the leaf
	Epilachna beetle	10-15 (13)	10-20 (17) Leaves $Plant^{-1}$	Feed on leaves making irregular holes
	Fruit fly	5-25 (15)	10-30 (18) Fruits $5Plant^{-1}$	Distorted, malformed fruits and Premature dropping of fruits
Brinjal	Shoot Fruit Borer	10-50 (30)	20-60 (35) Shoots or fruits $10m^{-2}$	Wilting tender shoots and affected fruits plugged with excreta
	White fly	5- 10 (6)	12-25 (14) Leaves $2Plant^{-1}$	Found of leaves feeding on leaves secreting honeydew that attract ants
	Jassid	5-15 (10)	10-26 (16) Leaves $2Plant^{-1}$	Red colour develops at the leaves edges due to sucks sap from the leaves
	Cutworm	10-50 (26)	8-25 (14) Leaves $10m^{-2}$	The caterpillars cut and buried the plants just above the soil surface.
Tomato	Fruit borer	15-45 (29)	10-30 (16) Fruits $10m^{-2}$	Boring fruits & affected fruits plugged with excreta making distinct holes
	White fly	10-15 (14)	15-20 (17) Leaves $10m^{-2}$	Whiteflies feed on the underside of foliage and exude honeydew, which attracts ants.
	Cutworm	5-10 (7)	5-10 (8) Seedlings $10m^{-2}$	The caterpillars cut and buried the plants just above the soil surface.
	Mites	5-9 (7)	10-20 (14) Leaves $Plant^{-1}$	Affected leaves become mottled, turn brown and curling.
Country Bean	Aphid	40-150 (57)	20-50 (32) Shoots or plant m^{-2}	Shoots appear dark in colour due to aphid colony
	Fruit borer	12-30 (13)	15-50 (31) Fruits $10m^{-2}$	Boring fruits & affected fruits plugged with excreta making distinct holes
Cauli-flower	Cutworm	16-60 (17)	15-65 (43) Seedlings $10m^{-2}$	The caterpillars cut and buried the plants just above the soil surface.
	Flee beetle	6-8 (7)	11-17 (13) Leaves $10m^{-2}$	Tiny round pits or holes found on leaves creating a shot hole pattern.
	Caterpillar	12-30 (12)	16-40 (24) Leaves $10m^{-2}$	Caterpillars eating holes in the outer and inner leaves

*Leaves were assessed from top to bottom.

Table 4. Yield loss and control measures of different insect pests in Sirajganj District.

Vegetable	Insect	Yield loss (%)	Control measure	Frequency
Bottle Gourd	Red pumpkin beetle	3-7	1. Removes infected leaves, 2. Dusting ash, 3. Picking insects through hand net, 4. Spray Sunmectin @ 2gm L^{-1} water, 5. IPM practices	2- 3 times
	Epilachna beetle	3-8	1. Removes infected leaves, 2. Dusting ash, 3. Picking insects through hand net, 4. Spray Sunmectin @ 2gm L^{-1} water, 5. IPM practices	2- 3 times
	Fruit fly	8-17	1. Removes infected fruits, 2. Use Pheromone trap, 3. Use insecticide mixed pumpkin/potato paste in pots at different places, 5. IPM practices	-
Brinjal	Shoot Fruit Borer	40-50	1. Remove infected Shoots/fruits, 2. Use Pheromone trap, 3. Spray Sobicron @ 2gm L^{-1} water, 4. IPM practices	35-45 times
	Whitefly	2-3	1. Removes infected leaves, 2. Spray Cartaf @ 2gm L^{-1} water, 3. IPM practices, 4. Yellow Sticky trap	1- 2 times
	Jassid	3-5	1. Removes infected leaves, 2. Spray Tido @ 2gm L^{-1} water, 3. Yellow Sticky trap	1- 2 times
	Cutworm	15-20	1. Makes furrow around seedlings, 2. Apply a mixture of Dursban+ Molasses+ Rice burns at dusk, 3. Irrigation	1- 2 times
Tomato	Fruit borer	15-30	1. Removes infected Shoots/fruits, 2. Use Pheromone trap, 3. Spray Abamectin @ 2gm L^{-1} water	3- 5 times
	Whitefly	2-3	1. Removes infected leaves, 2. Spray Cartaf @ 2gm L^{-1} water, 3. Yellow Sticky trap	1- 2 times
	Cutworm	15-20	1. Makes furrow around seedlings, 2. Apply a mixture of Dursban+ Molasses+ Rice burns at dusk, 3. Irrigation	1- 2 times
	Mites	8-12	1. Removes infected leaves, 2. Spray Vertimec @ 2gm L^{-1} water	2- 3 times
Country Bean	Aphid	30-40	1. Remove infected shoots, 2. Spray soapy water, 3. Spray Malathion @ 1.5ml L^{-1}water, 4. Yellow sticky trap	2- 3 times
	Fruit borer	15-20	1. Removes infected Shoots/fruits, 2. Use pheromone trap, 3. Spray Abamectin @ 2gm L^{-1} water	3- 5 times
Cauliflower	Cutworm	15-25	1. Makes furrow around seedlings, 2. Apply a mixture of Dursban+ Molasses+ Rice burns at dusk, 3. Irrigation	1- 2 times
	Flea beetle	3-5	1. Removes infected Shoots, 2. Spray soapy water, 3. Spray Malathion @ 1.5ml L^{-1}water	1- 2 times
	Caterpillar	5-10	1. Removes infected Shoots, 2. Spray soapy water 3. Spray Carate @ 1.5ml L^{-1} water	1- 2 times

Several feeding types are appeared in different winter vegetables (Table 3). The highest yield loss, which was 40-50% occurred due to shoot and fruit borer compare to other insects pest infestation (Table 4). Kapoor (1993) also reported that brinjal shoot and fruit borer is the most devastating pest in many parts of the world, which may cause more than 60% loss of yield. Initially, farmers were practising physical and mechanical control methods, including removes infested plants or plant parts, use a sweeping net, handpicking, pheromone trap, and yellow sticky trap. However, sometimes these methods were found to be unsuitable management practices to control disease and insect pests (Missanga & Rubanza, 2018). In addition, weeding could be an effective method of controlling insect and disease pests, as weeds act as vectors and (or) an alternate host of the same (AVRDC, 1998). Most insect pests are vectors of disease organisms and insects disseminate virus, blight and bacterial disease as well (Meyer, 2016). Farmers use inorganic pesticides to increase vegetable production and they do have not enough knowledge about the residual effect of pesticides. In the case of borer insects, farmers use insecticide 35-45 times in a single growing season (Table 4). Despite the fact that farmers in the Sirajgang region applied insecticides in excess of the recommended dosage and frequency, no insecticide resistance was observed (Chowdhuri & Hasan, 2013). Jessore farmers used more insecticides and pesticides than cultivators in any other region of Bangladesh (Rashid et al., 2018). Farmers use chemical pesticides 30 to 40 times to control insects such as shoot & fruit borer and gourd beetle on various summer vegetables (Chanda et al., 2021).

With poor management skills and a lack of appropriate knowledge on chemical insecticide usages, farmers use more insecticides for insect management. The incorrect pesticide use, which includes overuse, unsafe use, and use of obsolete products caused environmental and human health risks much higher because a large section of the population is engaged in farm work and therefore, directly exposed to pesticides. Hence, there is a wide scope to reduce the cost of pesticides (both material and application) through judicious pest management with the help of extension personnel for eco-friendly crop cultivation and farm profit maximisation. Canico *et al*. (2013) reported that farmers applying insecticide in vegetables at different rates and different frequencies. According to Obopile et al. (2008), many producers apply insecticides to vegetables three times per week. Integrated Pest Management training for Bangladeshi vegetable producers increased farmers' knowledge of insect pests, decreased spraying frequency, and contributed to safer pesticide handling (Gautam et al., 2017).

The results in Tables 5 and 6 demonstrate the relationships between costs incurred in vegetable production and the returns accrued by winter vegetables producing farmers in the study region. The relationships help in the determination of the profitability earned by winter vegetables farming households per hectare. In this study, costs are measured in terms of variable and fixed cost basis. Variable costs include the cost of seed, ploughing, fertilizer, bamboo, irrigation, weeding, pesticide, harvesting & marketing, and interest on operating capital. Land use cost and family labour cost are considered as fixed costs. Furthermore, returns were calculated based on the average price that farmers received per kg of vegetable production. The total variable costs varied from 80.72% to 89.12% of the total cost of production (Table 5). The result shows the average total variable cost (Tk. ha^{-1}) were estimated to be 141,166.00**,** 186,428.00, 260,848.00, 184,128.00 and 182,401.00, respectively for cultivating bottle gourd, brinjal, tomato, bean and cauliflower (Table 5). Family labour and land rent cost were considered as fixed costs. Total fixed cost (Tk. ha^{-1}) incurred by farmers 33,705.00 for bottle gourd, 37,455.00 for brinjal, 31,830.00 for tomato, 35,580.00 for bean and 29,955.00 for cauliflower cultivation. The highest production cost (Tk. ha^{-1}) was required for tomato cultivation (292,678.00) and the lowest (174,871.00) in bottle gourd cultivation.

Table 5. Cost analysis for winter vegetable production in Sirajganj District (Tk. ha^{-1})

Particulars	Name of vegetables				
	Bottle gourd	**Brinjal**	**Tomato**	**Bean**	**Cauliflower**
a. Variable cost					
Seed	3742	4491	14970	5988	7485
Plough	8982	8982	8982	5988	8982
Fertilizer	22455	56136	44909	33682	61937
Bamboo	41167	0	22455	44909	0
Irrigation	7485	7485	5988	2994	8982

Weeding	22455	44909	59879	14970	26945
Pesticide	8982	29939	44909	33682	29939
Harvesting & Marketing	22455	29939	52394	37424	33682
Interest on operating capital	3443	4547	6362	4491	4449
Total variable cost (A)	**141,166**	**186,428**	**260,848**	**184,128**	**182,401**
b. Fixed cost					
Land Rent cost for six month	22455	22455	22455	22455	22455
Family labour	11250	15000	9375	13125	7500
Total Fixed cost (B)	**33,705**	**37,455**	**31,830**	**35,580**	**29,955**
Total Cost (A+B)	**174,871**	**223,883**	**292,678**	**219,708**	**212,356**

Land rent per annum Tk. 25,000 ha^{-1}; interest @ 10% per annum. 1 US$ = 85.27 Tk. on 24 September 2021 <https://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To=BDT>

Table 6. Return analysis for winter vegetable production in Sirajganj District (Tk. ha^{-1})

Particulars	**Name of vegetables**				
	Bottle gourd	**Brinjal**	**Tomato**	**Bean**	**Cauliflower**
Yield (kg ha^{-1})	35,000	32,900	32,000	22,000	33,000
Price (Tk. kg^{-1})	20	30	25	40	25
Total Return (Tk. ha^{-1})	**700,000**	**987,000**	**800,000**	**880,000**	**825,000**
Gross Margin	558,834	800,572	539,152	695,872	642,599
Net Return	525,129	763,117	507,322	660,292	612,644
Profitability Index (PI)	3.72	4.09	1.94	3.59	3.36
Benefit Cost Ratio (Variable cost basis)	4.96	5.29	3.07	4.78	4.52
Benefit Cost Ratio (Total cost basis)	4.00	4.41	2.73	4.01	3.88
Rate of Return on Investment (RRI)	300.30	340.86	173.34	300.53	288.50

The results also revealed that the total return generated (Tk. ha^{-1}) for cultivating bottle gourd, brinjal, tomato, bean, and cauliflower were estimated 700,000.00, 987,000.00, 800,000.00, 880,000.00 and 825,000.00, respectively (Table 6). The highest return (Tk. ha^{-1}) was calculated 987,000.00 from brinjal cultivation and the lowest 700,000.00 from bottle gourd cultivation. The highest gross margin and net return (Tk. ha^{-1}) were found 800,572.00 and 763,117.00, respectively from brinjal cultivation and the lowest 539,152.00 and 507,322.00 from tomato cultivation. The brinjal cultivation yielded the highest profitability index (PI), benefit-cost ratio (BCR; variable cost basis), benefit-cost ratio (total cost basis), and rate of return on investment (RRI), while tomato cultivation yielded the lowest. Hasan et al. (2014) estimated the BCR based on variable costs for bottle gourd, brinjal, and cucumber cultivation to be 2.83, 4.88, and 4.57, respectively. On the basis of total cost, brinjal cultivation was found to have the highest BCR (3.72), while bottle gourd cultivation had the lowest (2.40). The results of the present study corroborate the findings of Hasan et al (2014). The BCR of a crop may also be affected by numerous (external) variables, such as the season, location, farm size, etc. For example, Mitra and Sharmin (2019) calculated the BCR value 2.31 for tomato production in the Mymensingh area. Karim *et al.* (2009) found that the BCR for small, medium and large farmers was 4.22, 4.16 and 4.19, respectively for summer tomato cultivation. Moreover, it is also well-known that the price of vegetables is extra-ordinarily higher during the early part of the respective cropping season; which might be reflected in higher BCR values.

4. Conclusion

A total of 19 disease infections and 11 insect species were found in the five selected winter vegetables in the Sirajganj district of Bangladesh. Of these diseases, the causal organisms of fifteen was identified as fungi, two as fungi, bacteria, and *Verticillium*, and two as viruses. The highest incidence of fungal diseases caused loss of a high amount of vegetable production; Tilth 250EC was the most commonly used fungicide to control these with the rate 1 ml per litre water. Among insects, shoot and fruit borer causes the highest yield loss to compare to other insects pest infestation. Initially, farmers were practising physical and mechanical control methods, including remove infested plants or plant limbs, use sweeping net, handpicking, pheromone trap, and yellow sticky trap. Farmers also used inorganic pesticides to manage insect infestation, yet they have enough knowledge about the residual effect of pesticides. With poor management skills and a lack of proper knowledge on the use of chemical insecticide, farmers use more insecticide for insect management. Wilt and blight are the most deadly diseases found in the study area. On the contrary, borer and aphid are the most serious insects to the vegetable. The highest gross margin and net return were found in brinjal cultivation and the lowest in tomato cultivation. The highest PI, BCR (variable and total cost bases), and RRI were found also in brinjal cultivation and lowest from tomato cultivation. The results revealed that brinjal production is the more profitable compared to the other four vegetables in the Sirajganj area. Therefore, farmers should be encouraged to produce brinjal with integrated pest management technology and judicious application of pesticides for eco-friendly crop cultivation and farm profit maximisation.

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6. Authors Note

The authors state that publication of this paper does not involve any conflicts of interest. The authors confirmed that the paper was original.

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