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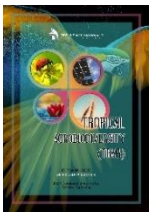

RESEARCH ARTICLE

MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER USING EXCLUSION NETS

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ABSTRACT

The brinjal shoot and fruit borer, *Leucinodes orbonalis* is one of the most serious pests of the brinjal crop in Bangladesh and causes damage up to 90% yield loss. It is very difficult to control. An experiment was conducted at the Entomology Field Laboratory, Department of Entomology, Bangladesh Agricultural University (BAU), Mymensingh from December 2020 to April 2021 on the management of Brinjal Shoot and Fruit Borer (BSFB) using three colored exclusion nets, *viz.,* white, blue, and yellow, along with an untreated control. Brinjal, specifically the Singnath variety, was used as an experimental crop. The experiment was laid out in a Randomized Complete Block Design (BCBD) with three replications of each treatment. The effectiveness of three exclusion nets was evaluated based on the following parameters: plant height (cm), number of healthy and infested shoots and fruit, percent protection of shoot and fruit over control, length and diameter of healthy and infested fruit, yield attributes, and benefit cost ratio (BCR). The results clearly indicated that these mentioned parameters were highly significant with the application of different colored exclusion nets. From the results, the white net showed the greatest reduction of shoot (50.51%) and fruit (65.58%) infestation over control, the highest percentage of shoot (20.55%) and fruit (25.92%) infestation, the minimum number of infested shoots (14.00) and fruits (28.54), plant height (46.34cm), and the maximum length (21.67cm) and diameter (10.07cm) of healthy fruit and returned the highest yield (24.55 t/ha), percentage increase of yield (56.70%) and benefit cost ratio (2.15) compared to other tested exclusion nets. And then, this result was followed by blue and yellow, respectively. Hence, white-colored net could be recommended as the best exclusion net for the sustainable management of BFSB in the field.

KEYWORDS

Brinjal, Shoot and Fruit Borer, Infestation, Exclusion Net, Yield

1. INTRODUCTION

Brinjal (*Solanum melongena*), also known as eggplant or aubergine, belongs to the family Solanaceae. It is the most important edible vegetable in Bangladesh because it is extensively grown both in the summer and winter seasons and is available throughout the year. In Bangladesh, more than 70% of the total vegetables are produced in the Rabi season and less than 30% in the Kharif season (BBS, 2021). About 15 percent of the country's total vegetable acreage is devoted to brinjal, which produces 1.6 million tons yearly. The amount of brinjals grown is only 60-65 t ha^{-1}, which is not enough to meet the growing demand in the country (Ahmad et al., 2009).

The brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee, is one of the largest and most devastating insect pests of brinjal in Bangladesh. It is one of the many types of brinjal insect pests (Ahmad et al., 2009). During the vegetative stage, the larvae bore into the shoots of the plant, causing the stems to droop and eventually dry out and wilting. It is an internal feeder that, during its life span, can infest anywhere from 4 to 7 fruits. This insect is responsible for a significant portion of the annual output's loss, which ranges from 67 to 80 percent per year (Majumdar and Powell, 2011). The young larvae of the pest bore into petioles and midribs of large leaves and tender shoots, causing shoots to wilt, and later they bore into flower, buds and fruits. Thus, the affected fruits lose their market value, besides a considerable reduction in yield (Ahmad et al., 2009).

The activity of this pests interrupts the plant's growth and ultimately, yield is reduced. Insecticides offer a practical method of insect control. Use of insecticides has a positive impact on brinjal yields and insecticides are often highly effective, fast-acting, convenient and economical, making them the most powerful tools in pest management. In many cases, however, injudicious and indiscriminate insecticide use causes or accelerates insecticide resistance, pest resurgence, secondary pest outbreaks, environmental contamination, persistent residual toxicity, and the annihilation of beneficial insect populations (Ahmad et al., 2009). In addition, pesticides induced the resurgence and contamination of food and the eco-system.

Besides, farmers of brinjal production in Bangladesh or other countries are also adopted with the use of synthetic chemical insecticides of different groups like organophosphate, organ carbamate, pyrethroids, nicotinoids to control this pest. It causes environmental pollution and food adulteration, which create different types of disease in the human body. Beneficial faunae of nature, collectively known as natural enemies, are categorized as predators or parasites. Conservation of natural enemies in the brinjal ecosystem should be of the prime strategy for sustainable control of brinjal shoot and fruit borer (Majumdar and Powell, 2011).

Therefore, to reduce environmental pollution and to conserve the ecosystem, an alternative method instead of chemical insecticides is necessary to develop & adopt eco-friendly and sustainable management system for brinjal production. Of the many options, application of mechanical methods is the alternative to manage the pest and develop the eco-system so that farmers can get a satisfactory yield, as well as consumers can get fresh and safe food. From the above scenario, in this present research, we have managed several new mechanical exclusion

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nets that are available in the local market for the management of brinjal shoot and fruit borer, under field conditions and their effect on brinjal yield.

2. Materials and Methods

2.1 Experimental Location, Site, Soil and Weather

The research experiment was conducted on brinjal at the field laboratory of Entomology, Bangladesh Agricultural University (BAU), Mymensingh during the period of October 2019 to April 2020 to manage BSFB under net condition. The site of the study is located at 24.75^0 N latitude and 90.50^{0}E longitude at a mean altitude of 18m above the mean sea level. The soil of the research area was the dark grey floodplain soil type belonging to the Old Brahmaputra Floodplain under the Agro Ecological Zone (AEZ)-09 (Alam et al., 2020a, b). The climate is subtropical, characterized by heavy rainfall during the month of April to September and scanty rainfall from October to March. The field had a medium-high land with a well-drained silty-loam texture, a pH of 6.5, and a moderate fertility level with 1.67% organic matter content and other nutrient components that were well (Alam et al., 2020c).

2.2 Raisings of Seedlings

The seedling nurseries were prepared well by ploughing the soil. Weeds and stubble were removed from the field by hand. Seeds of the Singnath variety were soaked in water overnight before sowing in the seedbed. And then, soaked seeds were sown in the seedbed by hand. Seedlings were raised in the seedbed in the Entomology field laboratory of Bangladesh Agricultural University (BAU), Mymensingh. Healthy seedlings were transplanted in the main field when the seedlings became 25 days old.

2.3 Land Preparation and Crop Development

The experiment land was ploughed and cross-ploughed well with a power tiller six times to get a good tilth. After that, it was laddered and spaded. Before planting the seeds, all the weeds were taken out of the field. Total cowdung (12 t/ha) was applied in the field during final land preparation. After three weeks, the plot was treated with half urea and half muriate of potash (MOP). The remaining urea and MOP were administered five weeks later. The recommended doses of N-P-K-S (375-150-250-100 kg/ha) were applied in the form of urea, triple super phosphate, muriate of potash and gypsum (FRG, 2012). The collected seedlings were transplanted into the main experimental plots according to design and layout of the experiment. The remaining urea and MOP were applied in three equal installments to brinjal at the pre-vegetative, full vegetative, and early fruiting stages. Weeding, watering, and other intercultural operations were performed as needed for improved growth and development of brinjal saplings after transplantation. Staking had been given to each plant by a bamboo stick to keep them erect when the plants were well established.

2.4 Experimental Design and Plot Size

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment, including the control, where the unit plot size was 4 m^2 (2m×2m), row-to-row and plant-to-plant spacing was 80×80cm, and the distance between plots was 1 m to facilitate cultural operations and insecticide applications. The total number of plots was 12.

2.5 Detail of Treatments and Application Procedure

The experiment was carried out with four treatments within three exclusion nets and one uncovered control. The three exclusion nets were as follows: T_1=Blue color net, T_2=White color net, T_3=Yellow color net, T_4=Control. After seedlings were transplanted into the main field, all plants in each replication of each treatment were covered with the corresponding exclusion net.

2.6 Data Collection Procedure

The efficacy of the exclusion nets was assessed on the percent of leaf & fruit infestation and marketable & brinjal yield. Data were collected at 7 days after application of each treatment from seedling to harvesting. The number of healthy & infested shoot & fruits were counted and recorded the data from randomly selected 4 plants per plot as replication. The length and diameter of the shoot and fruit of brinjal were also calculated in the same way. And then, percentage of infested shoot and fruit were calculated using following formula (Alam et al., 2020a, b, c):

$$\text{Shoot or fruit infestation (\%)} = \frac{\text{Number of infested shoot or fruit}}{\text{Total number of shoot or fruit}} \times 100$$

And then, the percent protection of infestation over control was calculated through the following formula (Alam et al., 2020a, b, c):

Protection of shoot or fruit (%) over control=

$$\frac{\text{Infestation (\%)in control} - \text{infestation (\%) in treatment}}{\text{Infestation (\%) in control}} \times 100$$

Besides, the benefit cost ratio (BCR) was calculated for each treatment. BCR was calculated by dividing the total benefit by total cost for each treatment (Alam et al., 2020a):

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

2.7 Data Analysis

All collected data on different parameters was compiled and arranged for statistical analysis. Then the data was analyzed statistically using R statistics software version 3.5.3 package programme. The means were separated by the help of Duncan's Multiple Range Test (DMRT), when necessary (Gomez and Gomez, 1984).

3. Results

3.1 Plant Height (cm)

The effect of different exclusion nets on the height of plants is shown in figure 1. The result clearly showed that the selected exclusion net had a significant effect on the height of the plant compared to control (P≤0.05). The tallest height of plant was recorded in the white colored net (46.34 cm) followed by the blue color (42.26 cm) and the yellow color (39.85 cm), respectively. The shortest (34.15 cm) height of plant was obtained from the control plot under field conditions.

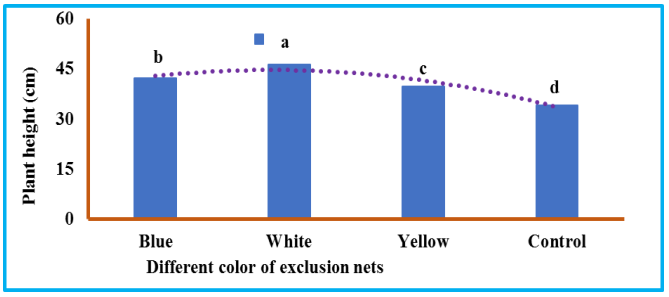

Figure 1: Effect of different colored exclusion nets on plant height of brinjal under field condition

3.2 Effect of Various Colored Exclusion Nets on Number of Shoots Per Plot

Table 1: Effect of Different Colored Exclusion Nets on A Number of Shoots Per Plot

Treatments	Total no. of Shoots	No. of Healthy Shoots	No. of Infested Shoots
Blue color net	62.24b	44.04b	18.20bc
White color net	68.00a	54.00a	14.00d
Yellow color net	60.75bc	39.09c	21.66b
Control	58.12d	33.99d	24.13a
Level of significance	*	***	*
CV (%)	5.37	7.52	6.43
SE (±)	1.12	0.76	1.18

Table no. 1 demonstrates that the number of shoot infestations by fruit and shoot borer is highly influenced by the application of different color exclusion nets. The results showed a significant difference in the number of healthy or infested shoots (P≤0.05, 0.01 and 0.001). The higher total number of shoots per plot (68.00) was found in the white colored exclusion net followed by the blue color (62.24) and the yellow color (60.75), respectively. The minimum total number of shoots per plot (58.12) was found in control. The highest number of healthy shoots per plot (54.00) was found in the white net followed by blue (44.04) and yellow (39.09), respectively. The minimum healthy shoots (33.99) were recorded in a controlled plot. The control plot had the most infested shoots (24.13), which was followed by the yellow net (21.66) and the blue net

(21.66), respectively, whereas on a white-colored exclusion net, a minimum of 14.00 infested shoots were counted (Table 1).

3.3 Effect of Different Colored Exclusion Nets on Percent Shoot Infestation

The effect of all exclusion nets had a significant difference (P≤0.01) on the fruit infestation compared to the control. The highest percentage of shoot infestation (41.52%) was observed in the case of untreated control followed by yellow color (35.66%) and blue color (29.24%), respectively, while the lowest percentage of infestation of shoots (20.55%) was recorded in the white colored exclusion net. During the experiment, the white colored exclusion net was found to be excellent in excluding BSFB compared to other net colors, resulting in the highest percent reduction of shoot infestation (50.51%) over control, followed by blue color nets (29.57%) while the lowest percent reduction of shoot infestation (14.11%) over control was obtained in the applied plot with yellow color exclusion net (Figure 2).

Table 2: Effect of Different Colored Exclusion Nets on Percent Shoot Infestation Per Plot

Treatments	% Shoot infestation
Blue color net	29.24c
White color net	20.55d
Yellow color net	35.66b
Control	41.52a
Level of significance	**
CV (%)	6.57
SE (±)	1.24

In the column, means followed by different letters are significantly different, **means at 1% level of probability.

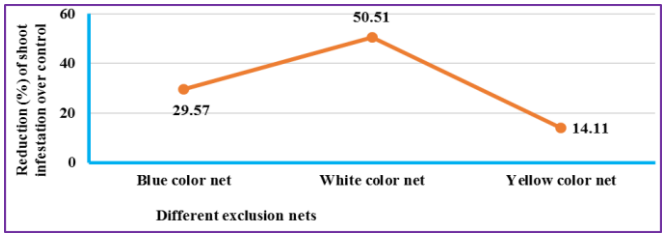

Figure 2: Reduction (%) of shoot infestation applied by different exclusion nets over control

3.4 Effect of Various Colored Exclusion Nets on Number of Fruits Per Plot (Count Base)

Table 3 shows significant differences (P≤0.05, 0.01 and 0.001) between healthy and infested fruits. The maximum total number of fruits per plot (94.14) was found in the white colored nets, which was followed by blue colored (88.63) and yellow colored (84.26) net, respectively. A minimum total number of fruits per plot (80.56) was found in control. Fruits were mostly healthy (65.60) in the white colored net, which was followed by the blue colored net (50.86) and the yellow-colored net (46.08), respectively. The lowest healthy fruits (34.87) were in the controlled plot. Fruits were recorded that were infested by BSFB. The maximum fruit infestation (45.69) was in a controlled plot, whereas the minimum (28.54) was in a white-colored net.

Table 3: Effect of Different Color Exclusion Nets on The Number of Fruits (Count Base)

Treatments	Total fruits	Healthy fruits	Infested fruits
Blue color net	88.63b	50.86b	37.77b
White color net	94.14a	65.60a	28.54c
Yellow color net	84.26c	46.08b	38.18b
Control	80.56d	34.87c	45.69a
Level of significance	**	*	***
CV (%)	6.57	5.74	6.52
SE (±)	1.25	1.05	1.11

In the column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability and ***means at 0.1% level of probability

3.5 Percent Fruit Infestation (Count Base)

All the tested exclusion nets significantly (P≤0.01) reduced percent fruit infestation in comparison to the control treatment (Table 4). The white color net showed the minimum percentage of fruit infestation (25.92%) per plot, which was followed by blue color (35.67%) and yellow color (51.30%), respectively, and the infestation percentage of fruits was the highest (75.30%) in control plot. The white colored exclusion net was found superior to other net colors, resulting in the minimum percentage of fruit infestation and the highest fruit infestation reduction (65.58%) over control, and the minimum percentage of infestation was obtained in the applied with yellow color exclusion net.

Table 4: Effect of Different Colored Exclusion Net on Percent Fruit Infestation (Count Basis)

Treatments	% Fruit infestation	Reduction (%) over control
Blue color net	35.67c	52.63
White color net	25.92d	65.58
Yellow color net	51.30b	31.87
Control	75.30a	
Level of significance	**	
CV (%)	6.56	
SE (±)	1.03	

In the column, means followed by different letters are significantly different, **means at a 1% level of probability

3.6 Percent Fruit Infestation (Weight Base)

The results of the effects of different exclusion nets are depicted in Table 5. The effect of various exclusion nets based on weight had a significant (P≤0.05) on percent of fruit infestation compared to the control. The highest percentage of fruit infestation per plot (70.63%) was found in control, which was followed by yellow color (57.18%) and blue color (32.29%), respectively. The lowest percentage of fruit infestation per plot (23.10%) was found in the white colored exclusion net. The maximum percent reduction of fruit infestation over control (67.29%) was recorded in the white colored net, followed by the blue color (54.28%) while the lowest percent reduction of fruit infestation ((19.04%) over control was found in the yellow-colored net. So, the white colored net gave the highest protection of fruit over control.

Table 5: Effect of different colored exclusion net on percent fruit infestation (Weight basis)

Treatments	% Fruit infestation	Reduction (%) over control
Blue color net	32.29c	54.28
White color net	23.10d	67.29
Yellow color net	57.18b	19.04
Control	70.63a	
Level of significance	*	
CV (%)	6.55	
SE (±)	1.17	

In the column, means followed by different letters are significantly different, *means at a 5% level of probability

3.7 Fruit Length and Diameter

The results of this experiment are presented in Table 6. The results showed that the efficacy of different exclusion nets on fruit length and diameter were evaluated, and the effects of different colors were significantly differed in comparison to control treatment. The white net had the greatest healthy fruit length (21.67 cm) and diameter (10.07 cm), followed by blue and yellow, respectively, while fruit in the controlled plot without a net condition had a minimum length of 12.06 cm and a diameter of 5.11 cm. Besides, the length (16.65 cm) and diameter (7.96 cm) of infested fruit were found to be greatest in the case of the white net,

followed by blue and yellow, respectively, whereas the controlled plot had the smallest fruit length (8.14 cm) and diameter (4.37 cm).

Table 6: Effect of different colored exclusion net on fruit length of brinjal (cm)

Treatments	Healthy Fruit length (cm)	Infested Fruit length (cm)	Healthy Fruit diameter (cm)	Infested fruit diameter (cm)
Blue color net	17.16b	12.32b	8.13bc	6.13ab
White color net	21.67a	16.45a	10.07a	7.96a
Yellow color net	15.65bc	10.28b	7.28c	5.06bc
Control	12.06d	8.14c	5.11d	4.37d
Level of significance	*	**	***	*
CV (%)	7.12	5.33	6.23	7.72
SE (±)	1.16	1.37	1.29	1.24

In the column, means followed by different letters are significantly different, *means at a 5% level of probability, **means at a 1% level of probability and ***means at a 0.1% level of probability

3.8 Effect of Various Colored Exclusion Nets on Yield of Brinjal

All exclusion nets significantly reduced shoot and fruit infestation, and the yield of brinjal differed significantly among the tested exclusion nets. The results of the yield of brinjal are depicted in Table 7. The plot covered by a white-colored net yielded a maximum of 24.55 tons per hectare, while the control plot yielded a minimum of 10.63 t/ha. 19.65 and 16.88 tons per hectare yield were recorded in the plot where the blue and yellow colored exclusion net were applied, respectively. The white color net showed the maximum percentage increase of yield (56.70%) over control, which was followed by the blue color net (45.90%) while the minimum percentage increase of yield (37.03%) was obtained from the yellow color net (Figure 3). The highest BCR (2.15) was estimated in the white exclusion net, while the second highest was (1.38) found in the blue-colored net, followed by yellow (0.88). The controlled plot showed the lowest benefit-cost ratio (0.54) (Table 7).

Table 7: Effect of different colored exclusion net on yield and BCR

Treatments	Yield (t/ha)	BCR
Blue color net	19.65b	1.38
White color net	24.55a	2.15
Yellow color net	16.88c	0.88
Control	10.63d	0.54
Level of significance	*	
CV (%)	6.65	
SE (±)	0.97	

In the column, means followed by different letters are significantly different, *means at a 5% level of probability

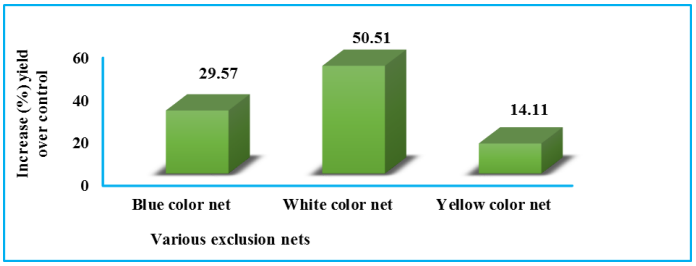

Figure 3: Increase (%) of yield applied by various exclusion nets over control

The effectiveness of three exclusion nets was evaluated based on following parameters *namely* plant height (cm), number of healthy and infested shoot and fruit, percent protection of shoot and fruit over control, length and diameter of healthy and infested fruit, yield attributes and benefit cost ratio (BCR). Result clearly indicated that these mentioned parameters were highly significant with the application of different colored exclusion nets. From the results, the white net showed the greatest reduction of shoot (50.51%) and fruit (65.58%) infestation over control, the highest percentage of shoot (20.55%) and fruit (25.92%) infestation, the minimum number of infested shoot (14.00) and fruits (28.54), plant height (46.34cm), and the maximum length (21.67cm) and diameter (10.07cm) of healthy fruit and returned the highest yield (24.55 t/ha), percentage increase of yield (56.70%) and benefit cost ratio (2.15) compared to others tested exclusion nets. And then, this result was followed by blue and yellow, respectively. Hence, white colored net could be recommended as the best exclusion net for the sustainable management of BFSB in the field.

4. Discussion

From the findings of this study, it was found that all the tested exclusion nets showed significance variable efficacy and were the most effective against shoot and fruit borer in reducing shoot and fruit infestation and increasing marketable fruit yield. Among all tested exclusion nets, the exclusion or barrier given by white colored net explored the superiority over all tested nets because the exclusion nets were able to reduce the infestation level of shoot and fruit of brinjal which is caused by shoot and fruit borer and returned the maximum yield without using environmentally hazardous insecticides i.e. the highest plant height (46.34cm) and the maximum number of healthy shoots (54.00) and fruits (65.60) were also obtained in the plot where the white colored exclusion net was applied (Dutta et al., 2011). However, based on the benefit cost ratio (BCR), white colored net is the best performance against brinjal shoot and fruit borer, resulting in the highest percentage marketable yield increase (56.70%).

Therefore, the exclusion net might be useful for management of shoot and fruit borer, and it helps to get chemical-free, safe, and fresh brinjal as well as higher yield (24.55 t/ha), which is economically profitable for brinjal production (Patel et al., 2020). The main mechanism of this result was white colored net provides optimal light intensity and aeration as well as it acts as exclusion of shoot and borer (Shukla and Khatri, 2010; Singh, 2013). The present findings of three exclusion nets against brinjal shoot and fruit borer are in conformity with the result of who also reported exclusion white colored net was found best exclusion net in reducing shoot and fruit borer of brinjal (Kiptoo et al., 2015). On the other hand, among the tested exclusion nets (white, blue, and yellow), the white-colored net had the maximum plant height (46.34cm), and the maximum percentage reduction of shoot (50.51%) and fruit (65.58%) infestation over control.

This result might be supported by the findings of who studied the effectiveness of different colored exclusion nets against brinjal shoot and fruit borer and observed only 45.63% and 67.42% reduction of shoot and fruit infestation where the white colored exclusion net was also remarkably better than other applied exclusion nets (blue-, green- and yellow-colored nets) (Singh, 2013). A variation in plant height in different netting fields was found. A similar opinion was put forward (Majumdar and Powell, 2011; Patel et al., 2020). Shukla and Khatri also observed similar results in the tomato plant (Shukla and Khatri, 2010). This was due to enhanced photosynthesis and respiration in the favorable micro-climatic conditions in the white colored net house.

Differences in shoot and fruit numbers and percentage reduction of shoot and fruit infestation over control happened because of a variation in flower numbers under the white net conditions. The findings were supported by the study conducted by Singh which revealed that the maximum percentage of shoot and fruit infestation over control was found in the plot planted with the white colored net house (Singh, 2013). On the contrary, based on the fruit formation and yield of brinjal, the white-colored net produced the maximum fruit length and diameter as a result, getting a higher yield and benefit cost ratio (BCR) than other tested nets. Similar trends of results were obtained from the results of an experiment that was conducted (Shukla and Khatri, 2010). Majumdar and Powell studied the effects of the different colored nets on the vegetative parameters of plants and showed a difference in light penetration and increased photosynthesis efficiency (Majumdar and Powell, 2011). Some countries in Europe and Southeast Asia have also been able to grow brinjal and cabbage with the help of white nets.

5. Conclusion

Considering the efficacy of tested exclusion nets against the infestation caused by shoot and fruit borer as well as brinjal, the exclusion nets can be categorized as follows: white-, blue- and yellow-colored nets. Thus, all the tested exclusion nets were effective in reducing shoot and fruit infestation and increasing of marketable fruit yield. However, based on the benefit

cost ratio (BCR), white colored net is the best performance against brinjal shoot and fruit borer, resulting in the highest marketable yield increase. Therefore, the exclusion net might be useful for management of shoot and fruit borer, and it helps to get chemical-free, safe, and fresh brinjal, which is economically profitable for brinjal production.

Author's Contribution

Professor Dr. Kazi Shahanara Ahmed (KSA) and Professor Dr. Mohammed Abul Monjur Khan (MAMK) conceptualized, designed, formulated, and supervised the experiment. Ummay Kulsum (UK) performed the field experiment and collected and recorded the data from the experimental field. Upazila Agriculture Officer (UAO) Marufa Iftekhar Siddika (MIS) collected materials and tools for the experiment and helped to set up the experiment. PhD Fellow Md. Jewel Alam (MJA) complied and analyzed the data and made tables and graphs from the data. MJA, UK, and MIS helped to compile information regarding materials and methods, a review of literature, and a discussion of this experiment. Ummay Kulsum and Md. Jewel Alam drafted the manuscript, which was critically reviewed by KSA and MHR.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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