The Journal of Agricultural Sciences - Sri Lanka
Vol. 19, No 3, September 2024. Pp 482-496
http://doi.org/10.4038/jas.v19i3.10158

Netting and Bagging: An Eco-Friendly Management Approach Against the Common Cutworm *(Spodoptera litura* Fab.) of Bell Pepper

Md. A. Maleque[1], Z. J. Chowdhury[1], Md. S. Noman[2], A. A. Shitel[1], Md. F. Mondal[1], Md. A.R. Choudhury[1], N. Y. Poly[3], A. U. Khan[1*] and H. R. Ishii[4]

Received: 10th February 2023 / Accepted: 28th July 2024

ABSTRACT

Purpose: *Environment-friendly pest management techniques are safer, sustainable over the years, better for ecosystem services, and more convenient with lower risks. Netting and or bagging is one of the most suitable tools for pest management. To develop environmentally friendly management techniques against the common cutworm (Spodoptera litura Fab.), we compared the cost-effectiveness of netting and bagging for the production of bell peppers in Bangladesh.*

Research Method: *The study was undertaken in the field of Entomology, at Sylhet Agricultural University, Bangladesh, from October 2018 to April 2019. Netting and bagging significantly improved plant morphology, fruit quality, and yield and managed the insect pests.*

Findings: *In this paper, we tried to bring forth different prospects of netting and bagging in bell peppers to manage the common cutworm. Superior-quality fruits were harvested from the netting/bagging treatment compared to the control. Netting and bagging treatment increased yield by more than 10-fold over control and decreased fruit infestation to 10.67%. The maximum marginal benefit-cost ratio (MBCR = 18.06) was achieved from the netting/bagging treatment, while the lowest MBCR (7.29) was obtained from bagging only. Superior-quality fruits were obtained using white paper bags compared to brown paper bags. The common cutworm first appeared in February and gradually increased with the progress of the season, indicating that netting and bagging need to be applied at the early fruiting stage of bell pepper.*

Research Limitations: *The study focused on the environment-friendly management of common cutworms in bell peppers, revealing impressive results, but these need to be validated across the locations.*

Originality/Value: *Albeit labor-intensive, combining nylon netting with fruit bagging is a cost-effective, eco-friendly management technique against the common cutworm of bell pepper.*

Keywords: *Capsicum, Cost-effective, Insect pest, MBCR, Polyphagous.*

INTRODUCTION

The capsicum being quite non-pungent with thick skin, has been regarded as the world's second-most significant vegetable after the tomato. In Australia and New Zealand, sweeter and larger species are called *"Capsicums"*. In the United Kingdom, these are called "peppers" and in the United States, these are called "bell peppers". As the world's second-largest vegetable crop after the tomato, the bell pepper *(Capsicum annuum* L.) is commonly known as Capsicum (Aliyu, 2000). It has a wide range of health benefits, including both nutritional and medicinal ones. Bell peppers are an excellent source of vitamins A, B1, B2, C, E, and D, as well as calcium and iron (Auwalu and Muhamman, 2009).

[1]Department of Entomology, Sylhet Agricultural University, Sylhet-3100, Bangladesh.
[2]Bangladesh Jute Research Institute, Dhaka-1207, Bangladesh.
[3]Department of Biochemistry and Molecular Biology, Khulna Agricultural University, Khulna-9100, Bangladesh.
[4]Laboratory of Forest Resources, Graduate School of Agricultural Science, Kobe University, Kobe 657–8501, Japan.
*ahasanullahsau@gmail.com
https://orcid.org/0000-0002-7029-8215

One medium-sized green bell pepper provides up to 8% of the recommended daily vitamin A intake and 18% of the recommended daily vitamin C intake, as well as calcium (2%) and iron (2%) (Kelley and Boyhan, 2009). Bell pepper also contains lycopene, which is a carotene that helps protect against the formation of cancer cells (Lopez *et al.*, 2007). Bell pepper is the most vital, high-value seasonal vegetable crop in temperate regions. In recent years, efforts have been made to grow this temperate fruit in tropical monsoon climates like Bangladesh (Paul, 2009). In Bangladesh, the demand for bell pepper is increasing in domestic markets (Hasanuzzaman, 1999). Supermarket chains (e.g., Agora, Minabazar, Swapna) procure bell pepper from contracted growers to meet the local demand, but common people still have limited access to consuming this new vegetable due to low availability and high prices (Paul, 2009).

Bell pepper is very sensitive to environmental change, and thus it needs special care at every stage of production in the field (Bhatt *et al.*, 1999). It is highly vulnerable to several insect and mite pest species, such as the green vegetable bug (Nezara viridula), common cutworm *(Spodoptera litura* Fab.), gall fly *(Asphondylia capsici)*, papaya mealybug *(Paracoccus marginatus)*, etc. (ACIAR, 2013). Among these, the common cutworm is an economically devastating polyphagous pest of many crops worldwide (Kaur *et al.*, 2007), including bell pepper (Murthy *et al.*, 2006). It has high reproductive potential and can migrate over large distances as adults. The indiscriminate use of pesticides for the management of common cutworms resulted in several problems, such as high management costs, secondary pest outbreaks, the killing of beneficial organisms, the destruction of the ecosystem, pesticide residue in the environment, human health hazards, and pesticide resistance. In Pakistan and Bangladesh, the common cutworm has already developed resistance against widely used synthetic pyrethroids (Ahmad *et al.*, 2007; Rahman *et al.*, 2013). In accumulation, pesticide use can lead to the elimination of natural enemies, the buildup of pesticide residues, and eventually the low profitability of crop production (Chapman *et al.*, 2009).

To avoid the negative effects of pesticides, we must develop cost-effective, non-chemical pest management strategies for long-term crop management and production (Lamichhane, 2017). Production methods such as the use of a poly-house, polytunnel, and plastic mulching are effective in increasing yield, and these protective structures also serve as physical barriers that prevent the spread of insect pests and viral diseases (Singh *et al.*, 2010). In Bangladesh, the common cutworm caused 17 to 30% yield loss in bell peppers in the north-eastern districts like Sylhet and Moulvibazar, and the common cutworm cannot be sufficiently suppressed using single prevention methods such as netting (Roy *et al.*, 2018). This suggests environmentally safe pest management methods need to be effectively combined to manage the common cutworm of bell pepper.

Pre-harvest fruitlet bagging improves the aesthetic attraction of fruits and microclimatic requirements for fruit setting and development (Sharma *et al.*, 2014). Although labor-intensive, pre-harvest pod bagging is regarded as an inevitable part of fruit cultivation in Japan, China, the USA, and Australia (Sharma *et al.*, 2014). In Bangladesh, fruit bagging techniques were found effective against litchi fruit borer (Rahman *et al.*, 2006; Ahmed *et al.*, 2021), banana leaf and fruit beetle (Khorsheduzzaman and Nesa, 2013), and oriental fruit fly of guava and mango (Uddin *et al.*, 2017a,b). However, fruit bagging has not been adequately evaluated for the protection of vegetable fruits in Bangladesh (Leite *et al.*, 2014). Because fruit size and appearance are important characteristics for increasing the market value of bell peppers, the present experiment was agreed to evaluate the combined effects of netting and fruit bagging to develop a cost-effective, environment-friendly management tool against the common cutworm of bell peppers.

MATERIALS AND METHODS

Study Site

The study was conducted in the field of Entomology, at Sylhet Agricultural University, Sylhet, Bangladesh (24°54’38” N, 91°54’05” E, 25.6 m elevation) from October 2018 to April 2019 (Fig. 1). The study site is located within a 1 km aerial distance from the Meteorological Station, Shahi Eidgah, Sylhet, Bangladesh. Bell pepper *(Capsicum annuum* L.) was used as the experimental material of the study. Bell pepper is also known as Capsicum or sweet pepper. A tropical South American country, especially Brazil, is the origin of the Capsicum (Shoemaker and Teskey, 1955).

The study site is situated in the northeastern region of Bangladesh, which represents a sub-tropical climate categorized by high temperature and humidity, including torrential rainfall with irregular stormy winds during the *Kharif* season *(Kharif* 1: mid-March to mid-June; *Kharif* 2: mid-June to mid-October) and less rainfall with ascetically low temperature during the Rabi season (mid-October to mid-March). Mean

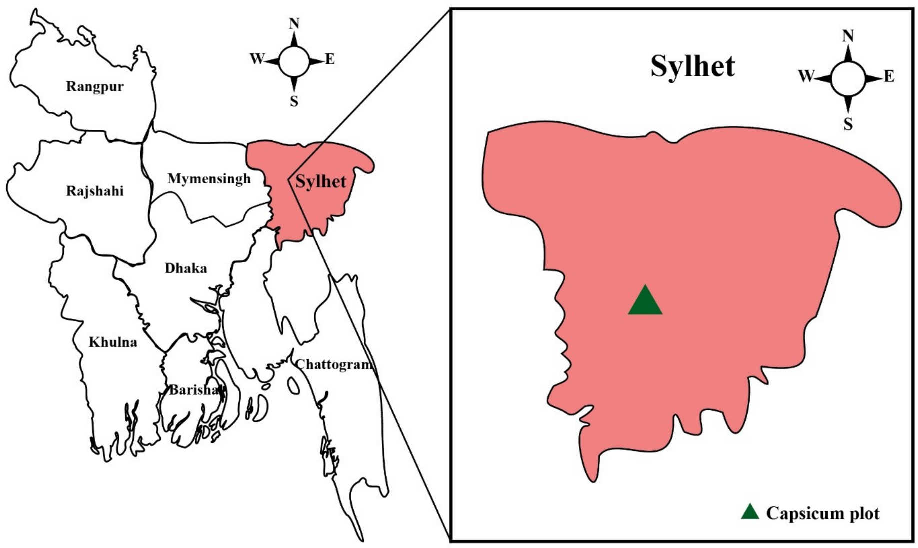

Figure 1: Map of the study site in central Sylhet, Bangladesh.

annual precipitation, temperature, and humidity in Sylhet district are 3876 mm, 24.8ºC, and 74.0%, respectively (BAMIS, 2020). The soil of the study field is sandy loam in texture with a pH of 5.47 (SRDI, 2018).

Experimental Material and Growth of Seedlings

The hybrid variety 'Brilliant Star' (F_1 hybrid seeds of Known-You Seed Co. Ltd., Taiwan) of bell pepper was used in this study as experimental material. Seedlings of bell pepper were raised from true seeds. Seeds were saturated in water for 12 hours overnight to promote sprouting. The next morning, the seeds were sown in the seedbed (3.0×1.0 m^2) of the Entomology Research Field on September 15, 2018. As a fertilizer, 10 t ha^{-1} of well-decomposed cow dung manure was incorporated into the prepared seedbed. The seeds were sown at one-centimeter depth for good emergence, as recommended by Berke *et al.*, (1999). After sowing seeds, the seedbed was covered with a thin layer of loose soil. The soil was ploughed and converted into loose friable to facilitate the raising of seedlings. Weeds, stubbles, and dead roots of plants were removed from the seedbed. The seedbed was watered with a fine-meshed sprinkler once a day until seedling emergence. At the end of seed germination, the shade was provided with a bamboo-made structure over the seedbed to protect the young plantlets from the damage of sizzling sunlight. Weeding, mulching, and light watering were done as and when required to deliver suitable microenvironments to ensure the proper growth of the seedlings. The seedbed was soaked for one hour before displacing the seedlings to diminish the harm to the roots of the seedlings.

Thirty-day-old, healthy seedlings were transplanted in the main field of the Department of Entomology, Sylhet Agricultural University, on October 15, 2018. A single seedling was planted in each pit. After transplanting seedlings, light irrigation was given to the seedlings for easy removal from the soil thereby ensuring the proper establishment of seedlings. Seedlings were soaked immediately after resettling in the afternoon. The young transplants were shaded with a fine nylon net at the seedbed to overcome the adverse impacts of intense sunlight.

Fertilizer Application and Cultural Practices

All types of weeds and debris from the previous crop were removed, and the basal doses of manures and fertilizers were added and mixed into the soil during final land preparation as per requirements. As per recommendation by Edison (1995), the crop was fertilized with cow dung, triple superphosphate (TSP), urea, muriate of potash (MoP), ZnO, and gypsum at 5 t ha^{-1}, 333, 217, 200, 5, and 111 kg ha^{-1}, respectively. Half the amount of cow dung, the entire amount of TSP, gypsum, ZnO, and MOP, and one-third of urea were functional throughout pit planning. The remaining urea, cow dung, and MOP were functional on two equal splits, 25 and 50 days after relocating seedlings in the experimental plots. A drainage system was developed surrounding each plot and the excavated soil was used to raise the plots about 15 cm high from the ground soil surface. Ridges were made encircling each plot to restrict the lateral run-off of irrigation water. The uprooted seedlings in the research plot were retained under close surveillance. Damaged saplings were immediately replaced with healthy seedlings from the stock plants. Light and required irrigation were given to the transplanted seedlings until they became well-established. The hand weeding was done as and when necessary to keep the designs free from weed infestation. Earthing up was done at 20 and 40 days after uprooting on both sides of the rows by enchanting soil from the space between the rows with a small spade. The soil around the base of each plant was pulverized. The established crop was irrigated whenever required, especially at flowering and mature stages.

Experimental Design and Treatments

We used a Randomized Complete Block Design (RCBD) with three replications to set up the study (Fig. 2). Each block of the study area was considered one replication, with the total study area being separated into three blocks. The experiment included eighteen plots in total. Block to block and plot to plot were 80 cm apart. The individual plot was 1.4×1.2 m^2. Two rows of plants were established in each plot. Four plants were planted in each row. Plant spacing was 60×40 cm^2. The treatments were: plot netting with nylon net (45-mesh/cm^2) + fruit bagging with perforated polythene bag (NBp), plot netting with nylon net (45-mesh/cm^2) + fruit bagging with a brown paper bag (NBb), plot netting with nylon net (45-mesh/cm^2) + fruit bagging with a white paper bag (NBw), fruit bagging with a brown paper bag (Bb), fruit bag with a white paper bag (Bw), and control plot [without netting and bagging] (C). Curved bamboo structures were prepared to spread nylon net (Fig. 3, NBp, NBb, and NBw). The size of each curved bamboo structure was 90×120 cm^2 [Height × Width]. Polythene fruit wrapping bags were procured from the local market in Rajshahi, Bangladesh. The brown and white paper bags, distributed by Shandong Seto Environmental Technologies Co., Ltd., are 18×20 cm^2, moisture-proof, bio-degradable, disposable, and shock-resistant. The brown paper bag (Kraft paper fruit bag, Laizhou Dechen Machinery Co., Ltd., Shandong, China) is double-layered with a black inner lining, while the white paper bag (Pomelo Pomegranate Paper Bag, Laizhou Guoliang Packing Products) is single-layered. Photographs of the treatment plots are shown in Fig. 3.

Collection of Plant and Weather Data

Girth (cm), length (cm), and weight (g) of individual fruits were measured for five randomly selected fruits at each harvest. The fruit yield of each plant was summed to obtain the yield (kg) at each harvest. At 60 days after transplanting, the number of leaves was counted, and leaf length (cm) and breadth (cm) were measured for five preselected plants per plot, excluding the small auxiliary leaves. The plant height (cm) of the five preselected plants was restrained from the pulverized level to the top of the tallest stem. Data on temperature (°C) were recorded using an automatic Humidity/Temperature Datalogger (RHT10, Extech Instruments, Boston, USA) at 1-hour intervals from October 2018 to April 2019. Temperature data from January to April 2019 were analyzed and presented in Fig. 4.

Total rainfall (mm) data were collected from the Meteorological Station, Shahi Eidgah, Sylhet, Bangladesh, and presented in Fig. 4. Weather data of Sylhet are provided in Supplementary Information (Appendix 1). Data of light intensity (Lux) were recorded on a clear sunny day on 14 April 2019. A Digital Light Meter (LX-1102, Shenzhen, China) was used to record light intensity data at 9.00 am, 12.00 pm, and 3.00 pm of daytime. Data units of lux were converted to kilolux, then analyzed and presented in Fig. 5.

Fruit Infestation and Yield

The fruits with the appearance of a caterpillar or pest exit hole were considered infested fruits. Fruit infestation of common cutworm was recorded for each fruit harvest by counting the total and infested fruits on individual plant life in each plot. Fruit infestation (%) was calculated as per the formula used by Khan *et al.*, (2020).

$$\text{Fruit infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100 \quad (1)$$

The harvest of mature fruits was started as soon as the fruits were firm and crispy (Shoemaker and Tesky, 1955). Harvest of fruits was done by hand with the help of secateurs and continued up to the end of crop fruiting season. Fruit yield under different treatments was recorded at each harvest, and calculated from the yield obtained in each experimental plot, and expressed in t ha^{-1}.

Data analysis

All data were checked for familiarity using the Shapiro-Wilk test. Analysis of Variance (ANOVA) tables derived by R Studio v3.4.3 (R Development Core Team, 2017). Means were compared using the Fisher-LSD test at a 5% significance level. Monthly averages of air temperature, rainfall, and relative humidity were used to explore correlations between pest abundance and climate. The cost-effectiveness of the different treatments was compared by calculating marginal benefit-cost ratios (MBCR). First, all costs incurred to purchase materials (bamboo, nylon netting, polythene sheets, and paper bags) and to hire laborers during

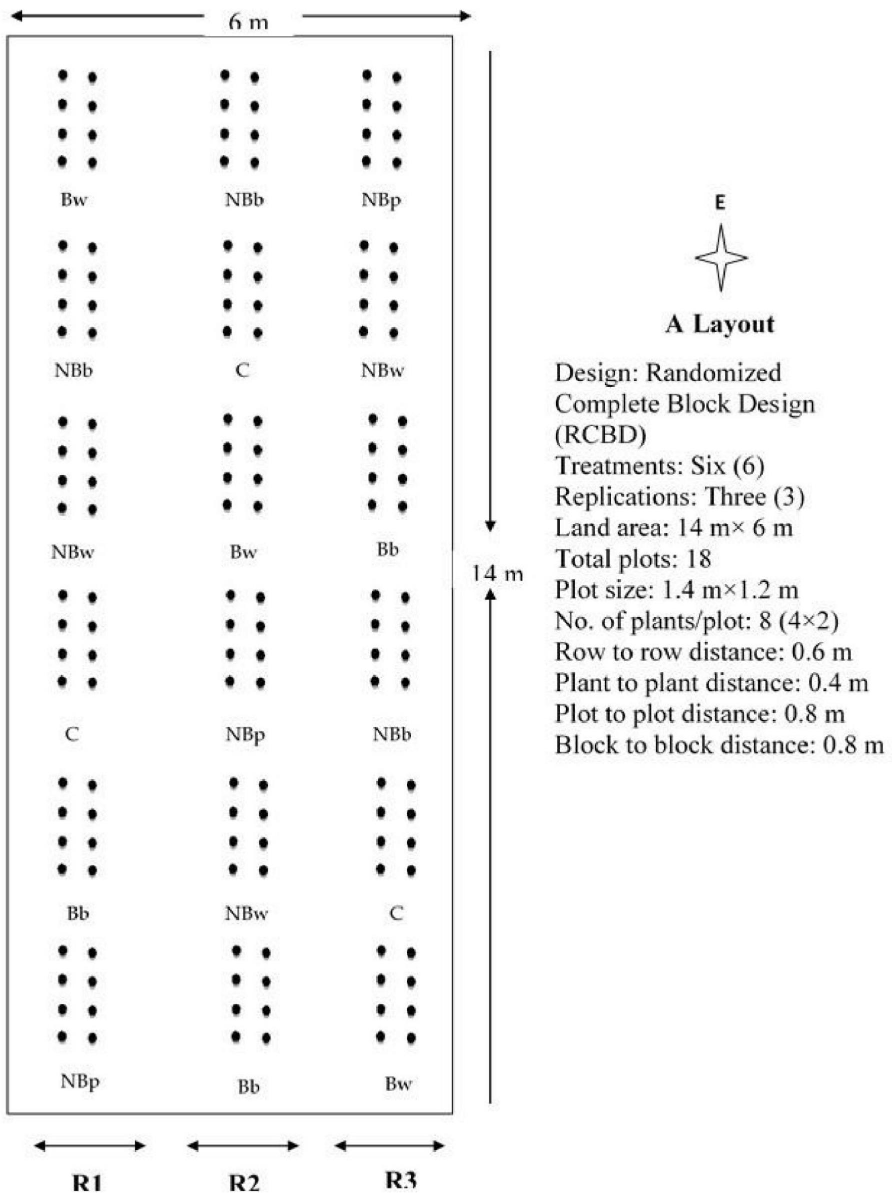

Figure 2: Layout of the six treatment plots, Entomology Research Field, Sylhet Agricultural University, Sylhet, Bangladesh.

the study were summed for each treatment. The gross return (USD) for each treatment was calculated by multiplying the total fruit yield from all harvests (kg ha^{-1}) by the unit price of fruit (USD kg^{-1}). The net return (USD) was planned by deducting treatment costs from the gross return. The adjusted net return (USD) was resolute by deducting the net return of the control plot from the net returns for each treatment. The cost-effectiveness of the different treatments was compared by calculating MBCR using the following formula (Nandi *et al.*, 2021).

$$\text{Marginal Benefit - Cost Ratio (MBCR)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \qquad (2)$$

RESULTS AND DISCUSSION

Seasonal Change in Pest Abundance

Cutworm-infested fruits were first observed on February 11 and then gradually increased with the progress of the season as temperatures increased (Fig. 4). The most marked increase occurred in April coinciding with stable high temperatures and precipitation at the beginning of the Kharif season. As a pest control tool, netting works well in situations where insecticide use is not feasible or too costly (Chouinard *et al.*, 2016; Wang *et al.*, 2020). In cabbage, netting significantly reduced or even eradicated pests such as *Pieris brassicae, Hellula undalis, and Helicoverpa armigera* (Simon *et al.*, 2014).

In okra, netting prevents fruit infestation by cutworms,

Figure 3: Photographs of the six treatment plots.

Note: NBp = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with perforated polythene bag, NBb = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with brown paper bag, NBw = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with white paper bag, Bb = Fruit bagging with brown paper bag, Bw = Fruit bagging with white paper bag, and C = Control plot (without netting and bagging).

as well as the indirect negative effects of worm infestation on leaves and stems (Muqtadir *et al.*, 2019). In bell pepper, netting reduced the infestation of leaves by sucking pests (e.g., chili aphid, jassid, whitefly, and white mite) by as much as 80%, contributing to the development of vigorous leaves and plant growth (Roy *et al.*, 2018).

Light Intensity Reduction due to Netting

Due to the placement of nylon net cover over the three treatment plots, light intensity was reduced by 17-18% at 9:00 am to as much as 28% at 3:00 pm (Fig. 5, paired t-test, P <0.05). Some researchers have reported that low temperatures and light intensity are essential to accumulating anthocyanins in the peel of apple fruit. UV-B light intensity may activate the anthocyanin accumulation process through photoreceptors, which ultimately enhances the formation of anthocyanins, leading to higher nutritional value (Dar *et al.*, 2019).

Plant Morphology

The treatments improved plant morphology compared to the control (Fig. 6). Compared to the control plot, leaf length was longer for all treatments (Fig. 6A), and leaf breadth was wider for NBw (Fig. 6B). When combined with bagging, netting had a slightly negative effect on leaf length (compare NBb and NBw with Bb and Bw, respectively, in Fig. 3). Leaf number per plant was greater for Bw (Fig. 6C), and plant height was taller for NBb, NBw, and Bw compared to the control (Fig. 6D). In recent years, bagging has become an essential method to ensure high-quality fruits and vegetables (Zhai *et al.*, 2006; Diabate *et al.*, 2020; Ahmed *et al.*,2021).

Fruit Morphology, Production, and Quality

Netting and bagging improved fruit morphology and quality (Figs. 7 and 8). Fruit girth and length did not vary among the treatments, while all were larger compared to the control (Figs. 7A, B). The treatments

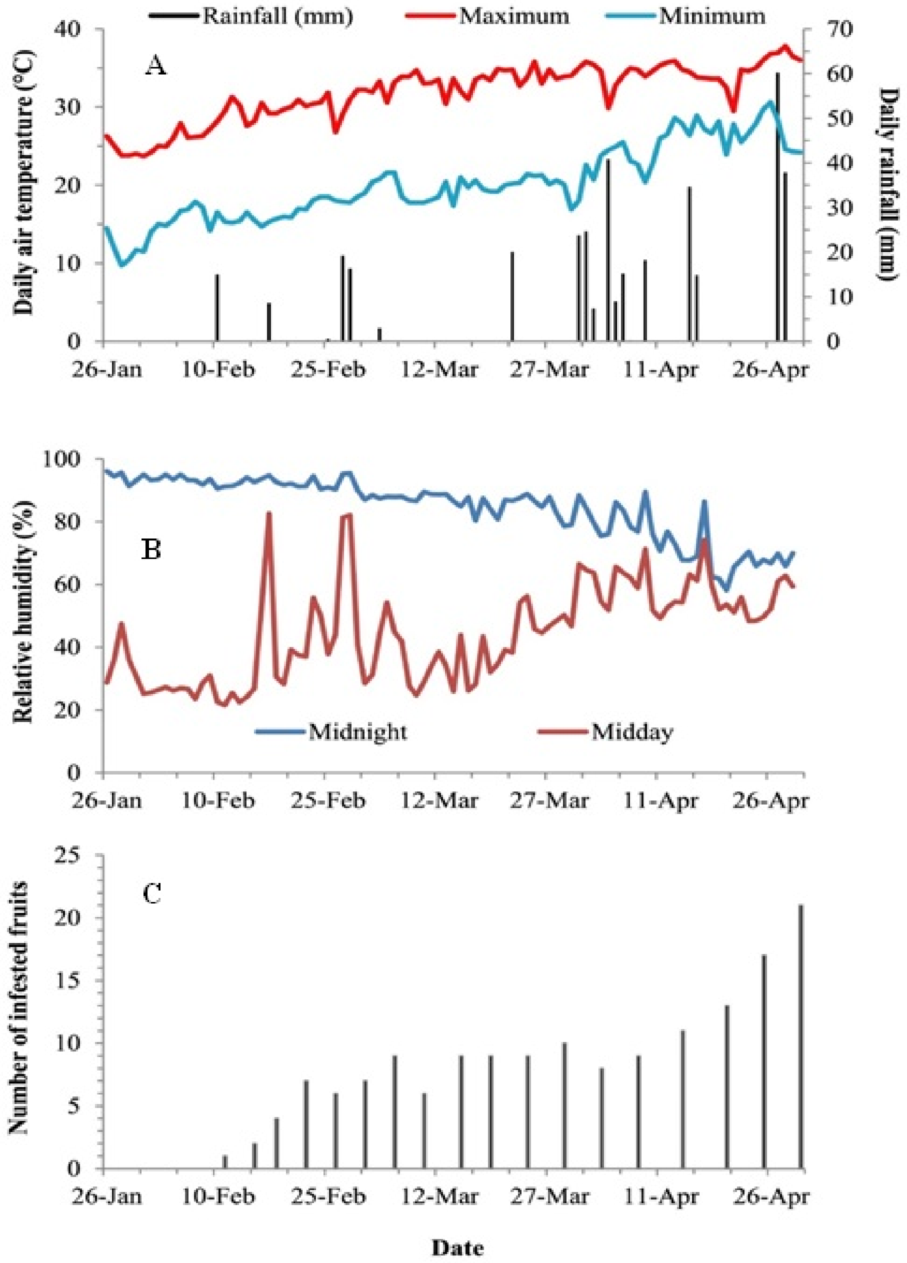

Figure 4: Seasonal changes in climate and cutworm abundance on bell peppers from January to April 2019.
Note: A = Air temperature (^{0}c), B= Relative Humidity (%), C=Number of Infested Fruits

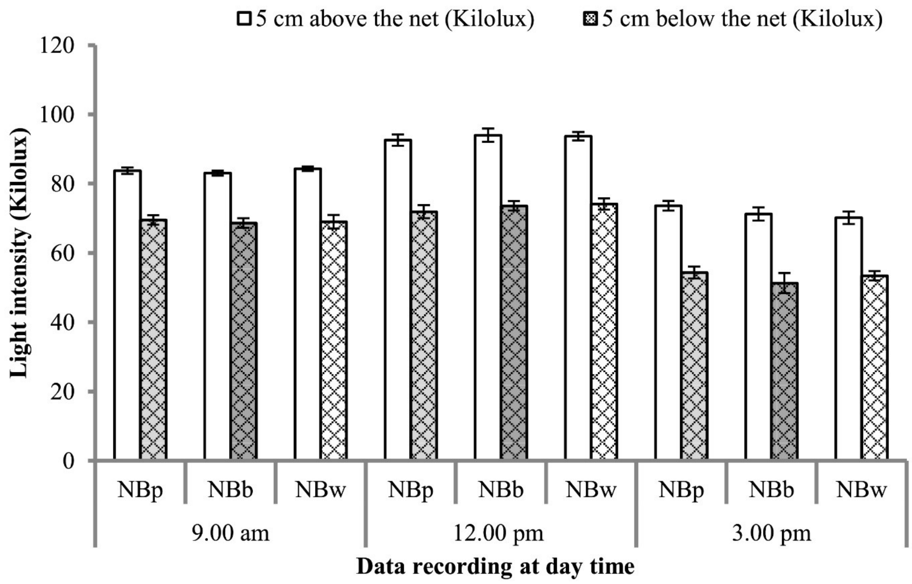

Figure 5: Light intensity reduction in bell pepper plots due to the placement of nylon net cover over the experimental plots from January to April 2019.

Note: Paired t-test was done for 9.00 am (P=0.0023), noon (P=0.0028), and 3.00 pm (P=0.0025). Where, NBp = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with perforated polythene bag, NBb = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with brown paper bag, NBw = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with white paper bag

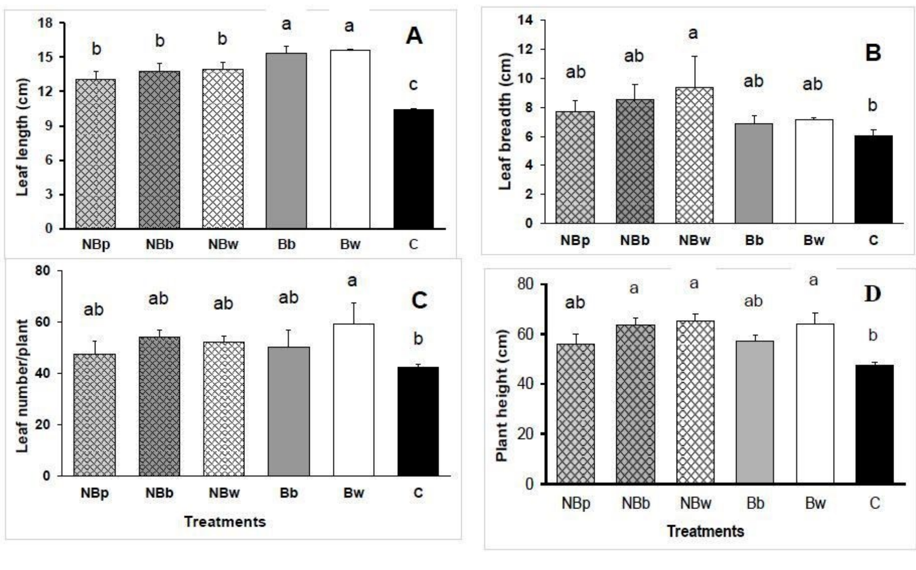

Figure 6: Leaf (A, B) and plant (C, D) morphology of bell pepper from October 2018 to April 2019.

Note: The Treatments were: NBp = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with a perforated polythene bag; NBb = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with brown paper bag; NBw = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with white paper bag; Bb = Fruit bagging with brown paper bag; Bw = Fruit bagging with white paper bag; and C = Control plot (without netting and bagging). (Error bars represent one standard deviation. Means labeled with the same letter are not significantly different (P > 0.05, ANOVA followed by Fisher LSD test).

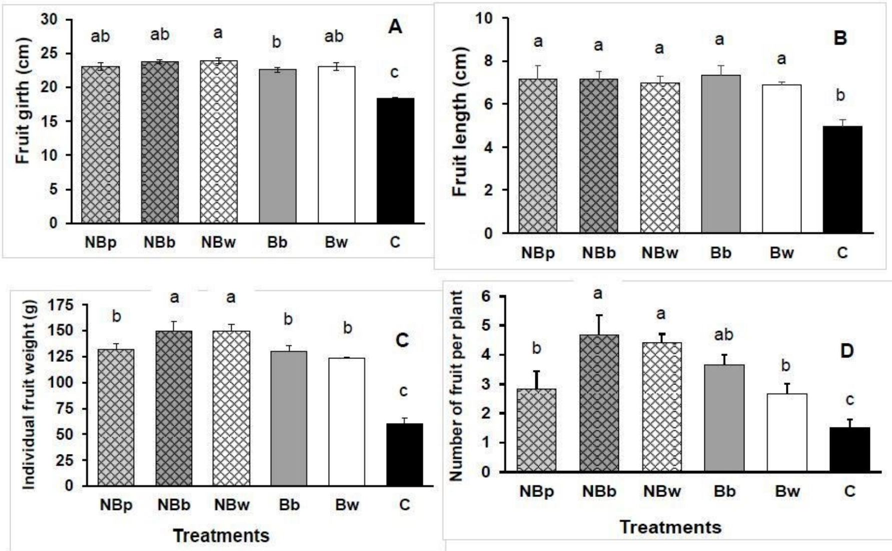

Figure 7: Fruit morphology and production of bell peppers from October 2018 to April 2019.
Note: Treatments and labels are as in Fig. 7A) fruit girth (cm), B) fruit length (cm), C) individual fruit weight (g), and D) number of fruits per plant. NBp = Plots netting with nylon net (45-mesh/cm2) + fruit bagging with a perforated polythene bag; NBb = Plots netting with nylon net (45-mesh/cm2) + fruit bagging with brown paper bag; NBw = Plots netting with nylon net (45-mesh/cm2) + fruit bagging with white paper bag; Bb = Fruit bagging with brown paper bag; Bw = Fruit bagging with white paper bag; and C = Control plot (without netting and bagging).

increased individual fruit weight by more than twofold compared to the control (Fig. 7C). When combined with bagging, netting had a greater positive effect on fruit weight than bagging alone (compare NBb and NBw with Bb and Bw, respectively in Fig. 7C. Fruit production (number per plant) increased more than two-fold compared to the control (Fig. 7D). When combined with white bags, netting had a greater positive effect on fruit production than white bags alone (compare NBw with Bw in Fig. 7). The best-quality fruits with a dark-green color were harvested from the Bw treatment (Figs. 8A, B), while medium-quality, pale-green fruits were harvested from the Bb treatment (Fig. 8C). The same trends were apparent when bags were combined with netting. In contrast, fruits harvested from the control plots were infested and of low quality (Fig. 8D). Many researchers reported that bagging improves the aesthetic and nutritional quality of various fruits, e.g., guava, banana, mango, pomegranate, apple, litchi, longan, and cocoa (Abbasi *et al.*, 2014; Rajan *et al.*, 2020). Bagging increases the fruit weight of various fruits, including tomatoes (Leite *et al.*, 2014) and pomegranates (Gethe *et al.*, 2021), by improving the microclimate around the fruit and facilitating fruit growth (Diabate *et al.*, 2020).

Fruit Infestation and Yield

Netting combined with bagging decreased fruit infestation (%) and increased fruit produce (t ha^{-1}) of the schemes compared to those of the control plot (Figs. 8A, B, C). The lowest infestation rate (10.67%) and the highest yield (18.33 t/ha) were recorded for the NBw treatment, followed by the NBb treatment. Fruit yield for these two treatments was five to nine times higher than that of the control. The highest yield increases over control (1096%) were recorded for the NBw treatment, followed by the NBb treatment (974%). When combined with bagging, netting decreased fruit infestation and increased yield markedly (compare NBb and NBw to Bb and Bw, respectively in Fig. 9). In our study, bagging reduced fruit infestation by as low as 10.67%. Bags serve as a physical barrier between the insects and the fruit, thus, reducing the frequency of insect pests as well as mechanical damage to the fruit (Sharma *et al.*, 2014).

Cost-effectiveness of Netting and Bagging

Net return, adjusted net return, gross return, and Marginal Benefit-Cost Ratio (MBCR) were calculated to compare the cost-effectiveness of the treatments (Table 01). The gross returns of the treatments were 7 to 24 times compared to those of the control. The NBw treatment produced the greatest gross return (129781.7±4557.3 USD ha-1), followed by NBb (106873±12365.1 USD ha-1). The same order of treatments was maintained for net return. As a result, the highest MBCR (18.06) was obtained from the NBw treatment, followed by NBb (12.78). Fruit bagging is effective against Drosophila suzukii infestation in raspberries (Stockton *et al.*, 2020), insect borers, leaf

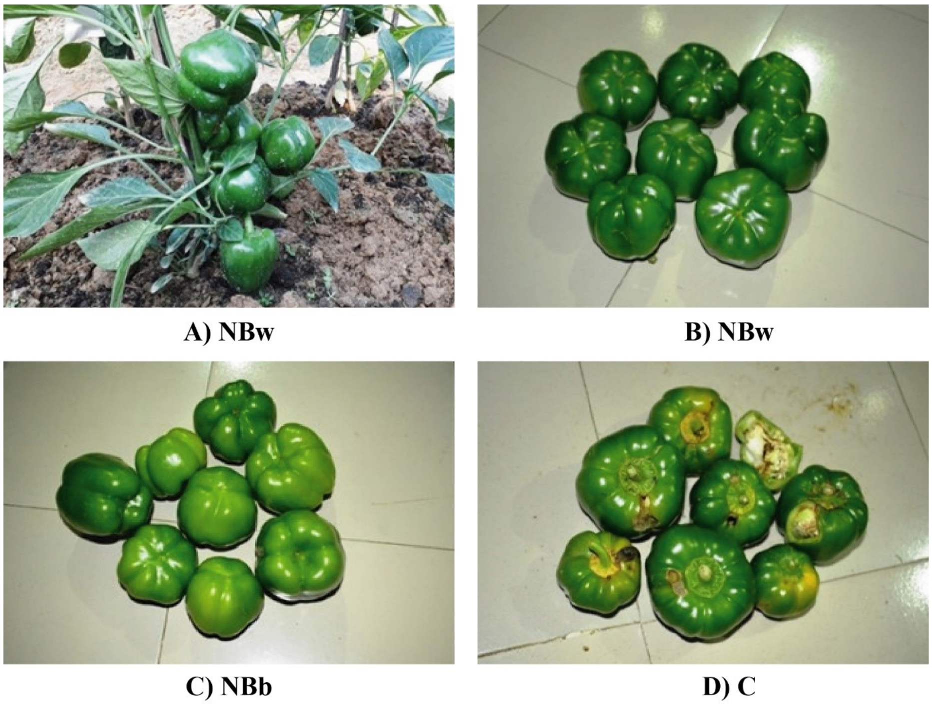

Figure 8: Superior-quality dark-green fruits were harvested from the plot of nylon netting and fruit bagging with a China white paper bag (A, B); Medium-quality pale-green fruits were harvested from the plot of nylon netting and fruit bagging with a China brown paper bag (C); Inferior quality; infested fruits harvested from the control plot (D).

Note: Treatments were: NBp = Plots netting with nylon net (45-mesh/cm_2) + fruit bagging with a perforated polythene bag; NBb = Plots netting with nylon net (45-mesh/cm_2) + fruit bagging with brown paper bag; NBw = Plots netting with nylon net (45-mesh/cm_2) + fruit bagging with white paper bag; Bb = Fruit bagging with brown paper bag; Bw = Fruit bagging with white paper bag; and C = Control plot (without netting and bagging).

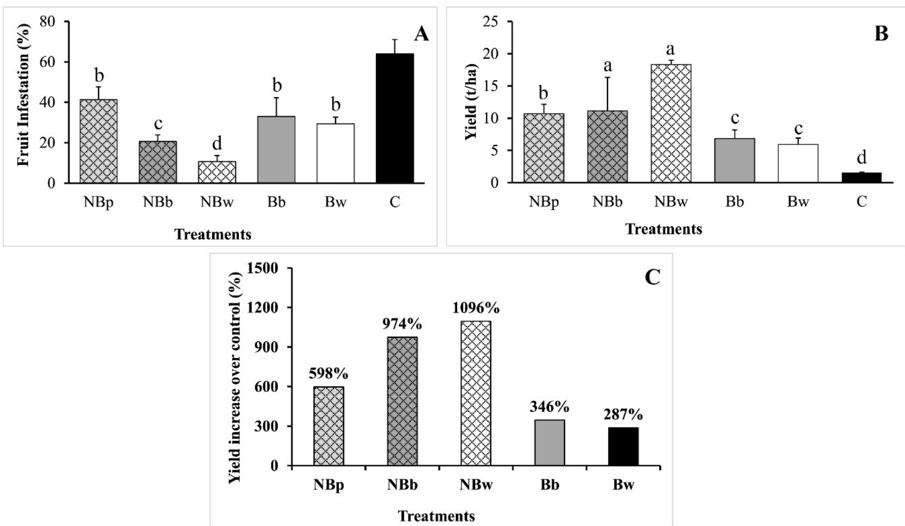

Figure 9: Fruit infestation rate and yield of bell peppers from October 2018 to April 2019. Treatments and labels are as in Fig. 9, A) Fruit infestation (%), B) yield (t/ha), C) Yield increase over control (%).

Note: Treatments were: NBp = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with a perforated polythene bag; NBb = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with brown paper bag; NBw = Plots netting with nylon net (45-mesh/cm^2) + fruit bagging with white paper bag; Bb = Fruit bagging with brown paper bag; Bw = Fruit bagging with white paper bag; and C = Control plot (without netting and bagging).

Table 1: Cost-effectiveness of different treatments on bell pepper from October 2018 to April 2019.

Treatments	Cost of treatment (USD ha-1)	Yield (t ha-1) Mean±SE	Price (USD kg1)	Gross return (USD) ha-1 (Mean±SE)	Net return (USD)	Adjusted net return (USD)	Marginal Benefit-Cost Ratio (MBCR)
NBp	5698.00	10.70±1.46b	5.899	63119.3±8595.8c	57421.3	51994.8	9.13
NBb	7360.00	16.47±1.91a	6.489	106852.2±12365.1b	99492.2	94065.7	12.78
NBw	6524.00	18.33±0.64a	7.079	129781.7±4557.3a	123257.7	117831.2	18.06
Bb	4047.00	6.83±1.34c	5.899	40309.8±7894.8d	36262.8	30836.4	7.62
Bw	3988.00	5.93±0.98c	6.489	38501.4±6372.6e	34513.4	29086.9	7.29
C	0.00	1.53±0.12d	3.539	5426.5±425.3f	5426.5	-	-

Note: NBp = Plot netting with nylon net (45-mesh/cm^2) + fruit bagging with a perforated polythene bag; NBb = Plot netting with nylon net (45-mesh/cm^2) + fruit bagging with China brown paper bag; NBw = Plot netting with nylon net (45-mesh/cm^2) + fruit bagging with China white paper bag; Bb = Fruit bagging with a China brown paper bag; Bw = Fruit bagging with China white paper bag and C = Control plot (without netting or bagging). SE = standard error of the mean. Prices per kg of bell pepper varied among the treatments based on the fruit qualities concerning their color, shape, and size.

miners, cotton bollworms, onion thrips, mites, and aphids in tomatoes (Leite *et al.*, 2014; Gogo *et al.*., 2014), fruit flies and other insect pests in mango, and moth infestation in grape berries (Karar *et al.*, 2019). Fruit bagging is considered the best, eco-friendly practice against the guava fruit fly (Mondal *et al.*, 2015). Low infestation rates contributed to high yields for the treatments in this study, leading to higher MBCR, i.e., profitability.

CONCLUSION

Based upon our results, we conclude that plot netting combined with fruit bagging in a white paper bag is the most effective and economically profitable method for controlling the common cutworm, a notorious polyphagous pest of bell pepper in Bangladesh. Considering the environmental and health protection issues, plot netting and fruit bagging are an affordable, and safe means of protecting fruits and improving fruit quality, which could be used as an alternative to synthetic pesticides.

ACKNOWLEDGEMENTS

We are grateful to Professor Dr. Md. Shahidul Islam, Department of Horticulture, Sylhet Agricultural University, Sylhet, Bangladesh, for his advice on selecting research materials before the study. We are also grateful to Professor Dr. Abdul Muqit, Department of Plant Pathology and Seed Science, Sylhet Agricultural University, Sylhet, Bangladesh, for his assistance in controlling diseases at the seedling stage of bell pepper. We are also grateful to the concerned officials of Sylhet Agricultural Research System (SAURES), Sylhet, Bangladesh for their managerial support during the project tenure. The study was funded by the University Grants Commission of Bangladesh during 2018-2019.

REFERENCES

Auwalu, B.M. and Muhamman, M.A. (2009). Seedling performance of sweet pepper (*Capsicum annuum L.*) as influenced by growth media and fertilizer sources in Northern Guinea Savanna Zone of Nigeria. Bayero University Kano. *Nigerian Journal of Biology and Environmental Science*, 6(3), 109–112.

Abbasi, N. A., Chaudhary, M.A., Ali, M.I., Hussain, A. and Ali, I. (2014). On tree fruit, bagging influences the quality of guava harvested at different maturity stages during summer. *International Journal Agriculture and Biology*, 16(3), 543–549.

ACIAR (Australian Center for International Agricultural Research) (2013). Tomato, capsicum, chili, and eggplant. A field guide for the identification of insect pests, beneficial, diseases, and disorders in Australia and Cambodia. 236.

Ahmad, M., Arif, M.I. and Ahmad, M. (2007). Occurrence of insecticide resistance in field populations of *Spodoptera litura* (Lepidoptera: Noctuidae) in Pakistan. *Crop Protection*, 26(6), 809–817. DOI: https://doi.org/10.1016/j.cropro.2006.07.006.

Ahmed, T., Hasan, M.M., Hasan, K., Ahmed, J.D., Ahmed, K.S.D., Azam, A. and Mondal, M.F. (2021). Fruit bagging of custard apple (*Annona reticulata*) as an eco-friendly protection approach against mealybug (*Phenacoccus solenopsis*) infestation in north-eastern Bangladesh. *International Journal of Tropical Insect Science*, 42, 723–732. DOI: https://doi.org/10.1007/s42690-021-00596-3.

Aliyu L. (2000). The effects of organic and mineral fertilizer on growth, yield, and composition of pepper. *Biology Agriculture and Horticulture*, 18(1), 29–36. DOI: https://doi.org/10.1080/01448765.2000.9754862.

BAMIS (Bangladesh Agro-Meteorological Information Systems). (2020). Bangladesh Agro-Meteorological Information Portal, Agro-Meteorological Information Systems Development Project, Department of Agricultural Extension (DAE), Farmgate, Dhaka-1215. https://www.bamis.gov.bd/home/.

Berke, T.G., Black, L.L., Green, S.K., Morris, R.A., Talekar, N.S. and Wang, J.F. (1999). Suggested cultural practices for field cultivation of sweet pepper. *Int. Cooperator's Guide. AVRDC, Pub. No. 99-497*. AVRDC. P.O. Box 42, Shanhua, Taiwan 741, ROC. https://worldveg.tind.io/record/66462/.

Bhatt, R.M., Rao, N.K.S. and Anand, N. (1999). Response of bell pepper to irradiance-photosynthesis, reproductive attributes, and yield. *Indian Journal of Horticulture*, 56(1), 62–66. Available at: https://www.indianjournals.com/ijor.aspx?target=ijor:ijh&volume=56&issue=1&article=012.

Chapman, A.V., Kuhar, T.P., Schultz, P.B., Leslie, T.W., Fleischer, S.J., Dively, G.P. and Whalen, J. (2009). Integrating chemical and biological control of European corn borer in bell pepper. *Journal of Economic Entomology*, 102(1), 287–295. DOI: https://doi.org/10.1603/029.102.0138.

Chouinard, G., Firlej, A. and Cormier, D. (2016). Going beyond sprays and killing agents: exclusion, sterilization, and disruption for insect pest control in pome and stone fruit orchards. *Scientia Horticulturae*, 208, 13–27. DOI: https://doi.org/10.1016/J.SCIENTA.2016.03.014.

Dar, J.A., Wani, A.A., Ahmed, M., Nazir, R., Zargar, S.M. and Javaid, K. (2019). Peel color in apple (*Malus* × *domestica Borkh.*): An economic quality parameter in fruit market. *Scientia Horticulturae*, 244(6), 50–60. DOI: https://doi.org/10.1016/j.scienta.2018.09.029.

Diabate, S., Martin, T., Murungi, L.K., Fiaboe, K.K.M., Wesonga, J., Kimani, J.M. and Deletre, E. (2020). Push-pull strategy combined with net houses for controlling cowpea insect pests and enhancing crop yields. *Crop Protection*, 105480. DOI: https://doi.org/10.1016/j.cropro.2020.105480.

Edison, S. (1995). Heat tolerance in sweet pepper (*Capsicum annuum L.*). Cited from the Ph.D. Thesis of Saha, S. R. 2001 submitted to the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh, 141.

Gethe, A.S., Hiray, S.A., Pujari, C.V., Patil, R.V. and Lalge, P.M. (2021). Effect of pre-harvest bagging on fruit yield, physiological disorders, pest and diseases in pomegranate. *Journal of Entomology and Zoology Study*, 9(1), 1543–1549. Available at https://www.entomoljournal.com/archives/2021/vol9issue1/PartV/9-1-185-159.pdf.

Gogo, E.O., Saidi, M., Itulya, F.M., Martin, T. and Ngouajio, M. (2014). Eco-friendly nets and floating row covers reduce pest infestation and improve tomato (*Solanum lycopersicum L.*) yields for smallholder farmers in Kenya. *Agronomy*, 4(1), 1–12. DOI: https://doi.org/10.3390/agronomy4010001.

Hasanuzzaman, S.M. (1999). Effect of hormone on yield of bell pepper (*Capsicum annuum L.*). MS Thesis submitted to the Department of Horticulture, Bangladesh Agricultural University, Mymensingh.

Karar, H., Ahmad, M., Ullah, H., Wajid, M., Zubair, M. and Raza, H. (2019). Effectiveness of Fruit Bagging for the Control of Insect-Pests Complex and its Impact on Quality of Mango Fruits. *Journal of Horticultural Science and Technology*, 2(2), 45–48. https://www.pshsciences.org/wp-content/uploads/2019/09/JHST2019-045.pdf.

Kaur, A., Kang, B.K. and Singh, B. (2007). Toxicity of different insecticides against *Spodoptera litura* (Fabricius) in Punjab, India. *Pesticide Research Journal*, 19(1), 47–50.

Kelley, W.T. and Boyhan, G. (2009). Commercial pepper production handbook. The University of Georgia, Cooperative Extension. Available at: http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1309.pdf.

Khan, A.U., Choudhury, M.A.R., Tarapder, S.A., Maukeeb, A.R.M. and Ema, I.J. (2020). Status of Mango Fruit Infestation at Home Garden in Mymensingh, Bangladesh. *Current Research in Agriculture and Farming*, 1(4), 35–42. DOI: http://dx.doi.org/10.18782/2582-7146.119.

Khorsheduzzaman, A.K.M. and Nesa J. (2013). A booklet on ‘Nature of damage of banana insect and mite and safe banana management technique for poison-free and blemish-free banana production’ (in Bengali). Published by Entomology Section, Horticulture Research Centre, BARI, Gazipur-1701.

Lamichhane, J.R. (2017). Pesticide use and risk reduction in European farming systems with IPM: An introduction to the special issue. *Crop Protection*, 97, 1–6. DOI: https://doi.org/10.1016/j.cropro.2017.01.017.

Leite, G.L.D., Fialho, A., Zanuncio, J.C., Júnior, R.R. and Costa, C.A.D. (2014). Bagging tomato fruits: A viable and economical method of preventing diseases and insect damage in organic production. *Florida Entomologist*, 97(1), 50–60. DOI: https://doi.org/10.1653/024.097.0106.

Lopez, A.J.P., Amor, F.M., Fortea, M.I. and Delicado, E.N. (2007). Influence of agricultural practices on the quality of sweet pepper fruits as affected by the maturity stage. *Journal of the Science of Food and Agriculture*, 87(11), 2075–2080. DOI: https://doi.org/10.1002/jsfa.2966.

Mondal, C.K., Garain, P.K., Maitra, J.N. and Maji, A. (2015). Bio-friendly management of guava fruit fly (*Bactrocera correcta*, Bezzi) through wrapping technique. *Journal of Applied and Natural Science*, 7(1), 358–363. DOI: https://doi.org/10.31018/jans.v7i1.616.

Muqtadir, M.A., Islam, M.A., Haque, T. and Nahar, A. (2019). Growth and yield of okra are influenced by different types of fertilizers and netting. *Progressive Agriculture*, 30, 1–9. DOI: https://doi.org/10.3329/pa.v30i0.41550.

Murthy, S.M., Thippaia, M. and Kitturmmath, M.S. (2006). Effect of neem formulations on larvae of tobacco cutworm, *Spodoptera litura* (Fab.). *Insect Environment*, 12, 84–85.

Nandi, M., Maleque, M.A., Muqit, A., Dash, C.K. and Khan, U.H.S. (2021). Comparative evaluation of three biopesticides and a synthetic chemical insecticide against citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) of Jara lemon in the north-eastern region of Bangladesh. *Biopesticides International*, 17(1), 51–57. https://connectjournals.com/file_html_pdf/3389201H_05_BI_455_51-57a.pdf.

Paul, T.K. (2009). The technology of sweet pepper production in Bangladesh. PhD Thesis. Dept. of Horticulture, BSMRAU, Salna, Gazipur. 225.

Rahman, A.K.M.Z., Maleque, M.A., Alam, S.N., Miah, M.R.U. and Sarkar, M.A. (2006). Development of environment-friendly management approaches against the litchi fruit borer (*Argyroploce illepida* Butler). *Bangladesh Journal of Entomology*, 16(1), 91–99.

Rahman, A.K.M.Z., Ferdous, A.K.M.R.H., Sarker, D., Mahmudunnabi, M. and Alam, S.N. (2013). Development of bio-rational based integrated management packages for the major insect pests of cabbage. Gazipur (Bangladesh): Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701, Bangladesh.

R. Core Team. (2017). "Kite-Eating Tree"-A language and environment for statistical computing. Vienna, Austria: The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 (64-bit). Available from: https://www.R-project.org/.

Rajan, R., Ahmad, M.F., Pandey, K. and Solankey, S.S. (2020). Bagging of fruit crops: a low-cost sustainable technology for quality fruit production. In: *Farmers' Prosperity through Improved Agricultural Technologies*, (Singh H.K., Solankey S.S., Roy M.K.), Jaya Publishing House, Delhi, India. 121–140pp.

Roy, J.R., Maleque, M.A., Mondal, M.F. and Khan, U.H.S. (2018). Management of insect and mite pests on bell peppers using a net barrier. *Journal of Sylhet Agricultural University*, 5(2), 151–157. https://jsau.sau.ac.bd/management-of-insect-and-mite-pest-on-bell-pepper-using-net-barrier.

Sharma, R.R., Reddy, S.V.R. and Jhalegar, M.J. (2014). Pre-harvest fruit bagging: a useful approach for plant protection and improved post-harvest fruit quality–a review. *The Journal of Horticultural Science and Biotechnology*, 89(2), 101–113. DOI: https://doi.org/10.1080/14620316.2014.11513055.

Simon, S., Komlan, F.A., Adjaïto, L., Mensah, A., Coffi, H.K., Ngouajio, M. and Martin, T. (2014). The efficacy of insect nets for cabbage production and pest management depends on the net removal frequency and microclimate. *International Journal of Pest Management*, 60(3), 208–216. DOI: https://doi.org/10.1080/09670874.2014.956844.

Singh, B., Singh, A.K. and Tomar, B.S. (2010). In peri-urban areas protected cultivation Technology to bring prosperity. *Indian Horticulture*, 55(4), 31–37.

SRDI (Soil Resources Development Institute). (2018). Sylhet By-pass Road, Chandipool Point, Pirijpur, Sylhet-3100, Bangladesh.

Shoemaker, J.S., and Teskey, B.J.E. (1955). *Practical Horticulture*. John Willey and Sons, Inc. New York. 371. https://www.abebooks.com/first-edition/PRACTICAL-HORTICULTURE-Shoemaker-James-Teskey-Benjamin/30277446944/bd.

Stockton, D.G., Hesler, S.P., Wallingford, A.K., Leskey, T.C., McDermott, L., Elsensohn, J.E. and Loeb, G.M. (2020). Factors affecting the implementation of exclusion netting to control *Drosophila suzukii* on primocane raspberry. *Crop Protection*, 135, 105191. DOI: https://doi.org/10.1016/j.cropro.2020.105191.

Uddin, M.A., Waliullah, M.H., Alam, K.H. and Islam, M.S. (2017a). Efficacy of different types of bagging for management of oriental fruit fly (*Bactrocera dorsalis*) attacking guava. In: *Annual Report 2017–18*, Entomology Division, BARI, Joydebpur-1701, Bangladesh.

Uddin, M.A., Waliullah, M.H., Alam, K.H. and Islam, M.S. (2017b). Efficacy of different types of bags for management of mango fruit fly *Bactrocera dorsalis* attacking mango. In: *Annual Report 2017–18*, Entomology Division, BARI, Joydebpur-1701, Bangladesh.

Wang, Y., Song, Q., Wang, F., Tang, S., Pan, T., Zhang, Y. and Hu, D. (2020). Bagging and non-bagging treatment on the dissipation and residue of four mixed application pesticides on banana fruit. *Journal of the Science of Food and Agriculture*, 101(8), 3472–3480. DOI: https://doi.org/10.1002/jsfa.10978.

Zhai, H., Ren, C., Li, E.M., Shi, D.C., Lin, G.Y. and Liu, X.Y. (2006). The effect of different bagging periods on the quality of red Fuji apples in Weibei dry land. *Journal of Northwestern University*, 20, 188–120. https://api.semanticscholar.org/CorpusID:131785982.

SUPPLEMENTARY INFORMATION

Table Appendix 1: Weather data of Sylhet from September 2018 to April 2019

Month/Year	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	Relative humidity (%)	Sunshine (hours)
Sep/2018	32.90	25.44	452.00	85.00	3.48
Oct/2018	31.21	22.27	139.00	81.16	6.22
Nov/2018	29.56	18.30	39.00	77.37	7.81
Dec/2018	27.00	15.21	29.00	76.39	6.50
Jan/2019	27.90	13.80	0.00	57.00	7.90
Feb/2019	28.30	15.70	45.00	57.00	6.70
Mar/2019	31.10	19.10	47.00	55.00	6.65
Apr/2019	32.40	21.40	326.00	63.00	6.52