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RESEARCH ARTICLE

Edible Bell Under Shade: The Phenological Characterization of Bell Pepper (Capsicum annum) Under Different Photoperiod

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Abstract

The study was conducted to evaluate the growth, inflorescence development, and yield response of the bell pepper to the different photoperiods (shading). The study was conducted from March 21 to May 15, 2021 at the DEBESMSCAT-Crop Science experimental area, Cabitan, Mandaon, and Masbate. The study used 15 experimental plots, and each plot contained 20 plants of bell pepper. The study used a total of 300 plants in 15 plots. The plant spacing was 40 cm between hills and 60 cm between rows. The study used a Randomized Complete Block Design (RCBD) with 5 treatments and 3 replications. The treatments used were different photoperiods (shading). Treatment A used shading starting from 6:00 A.M. – 9:00 A.M., Treatment B used shading from 9:00 A.M – 12:00 P.M., Treatment C used shading from 12:00 P.M – 3:00 P.M., Treatment D used shading from 3:00 P.M. – 6:00 P.M., and Treatment E (control) used no shading. The study used 10 experimental plants, randomly selected for each plot in every treatment. The data gathering started 7 days after transplanting and was conducted every 5 days. The results of the study revealed that the different photoperiods (times of shading) have no significant effect on growth in terms of plant height, number of leaves, leaf width and length, and stem diameter. Moreover, on the inflorescence development of bell peppers in terms of number of flowers, length of stalks, and size of flowers (diameter). The results on fruiting in terms of number of fruits, sizes (length and diameter), and weight also revealed that the different photoperiods have no significant effect. However, the results of the study on the number of fruits per plant and per plot revealed significant differences among each treatment.

KEYWORDS:
Bell pepper (Capsicum annum), Phenological Characterization, Photoperiod, Inflorescence Development

1 | INTRODUCTION

Bell pepper (Capsicum annum), also known as sweet pepper, kampana or lara, is grown for its fruits, which usually come in various colors such as red, green, yellow, brown, and orange. It is also known as capsicum, pepper, chili, chile, chilli, or paprika. It is a good source of vitamin A, C, and potassium. It is thought that all species of capsicum are from America. When America was discovered, peppers were immediately adopted and their use became worldwide (Mariano, J. S., Jimenez, E. F., 2006).

Bell peppers are being produced in limited quantities. The major producers of bell pepper are in the Cordillera Administrative Region (45%), Northern Mindanao (17%), and the Ilocos Region (13%). Agri-Business (2018). Pepper is a tender, warm-season

crop. They resist most pests and offer something for everyone: spicy, sweet, or hot, and a variety of colors, shapes, and sizes (Pinoynegosyo, 2018). Bell pepper require high temperatures (65 to 95°F) for their growth. Hence, the hot weather and sunny days are very beneficial for bell pepper production. However, the bell pepper fruit is very susceptible to sunscald under conditions of high irradiance. The bell pepper fruit exposed to the sun becomes very hot, in contrast to fruit protected by a dense canopy. The combination of hot weather conditions and rainfall events increased the rate of fruit expansion, making fruit even more susceptible to sunburn (Ngouajio, 2011).

Plants capture both short-wave and long-wave radiation. If the radiation accumulates, it will increase the temperature in the plant tissue. In most plant species, photosynthesis increases when carbon dioxide and water are available as plant temperatures rise. This accelerates photosynthesis to stabilize the plant temperature by diverting light energy to a photosynthetic pathway that makes chemical energy. However, if the leaves and fruits are exposed to severe ultraviolet radiation or if they accumulate too much light radiation, damage occurs in plant cells and tissues. If the plant cannot repair, the damage, the tissues eventually leads to cell or tissue death. This is a very common plant disorder (Maughan et al., 2017).

Photoperiod, from the Greek roots, combines light and the duration of daylight, or the number of hours of light in a 24-hour period. The number of hours of light during a day is referred to as the photoperiod. In the broadest sense, the photoperiodic response is to either increasing or decreasing day length. The important point is that the photoperiod response is not to some arbitrary long or short day but to increasing or decreasing day length (Green, 1984).

Photoperiod controls many evolving responses in animals, plants, and even fungi. The response of plants to photoperiod has changed because the day length has become a reliable indicator of the time of year. This enables developmental actions to be scheduled to match with a particular environmental condition.

Flowering, tuberization, and bud formation are just a few of the many different responses in plant growth that are under photoperiodic control (Jackson, 2008). The shade levels affect the fruit yield, quality, and postharvest attributes. Bell pepper yield increased with increasing shade level up to a maximum of 35% shade and then decreased with further increments in shade level (Pérez, 2014). The sunlight intensity under shade is 70.02 Wm2. Shade decreases 32% of the light intensity compared without shade. The use of shade decreased the air temperature and soil temperature by up to 2.06°C. However, the use of shading increases the air humidity by up to 4.23% compared with without shade. Furthermore, the use of shading increases the plant height and leaf surface area index of the plant (Hamdani et al., 2018).

The study evaluated the effects of different photoperiods on phenological characteristics (growth, flowering development, fruiting, and yield) of bell pepper. Specifically, it aimed to evaluate the growth in terms of plant height, number of leaves, leaf width and length, and stem diameter; evaluate the inflorescence development in terms of number of flowers, length of stalks, and size of flowers (diameter); evaluate the fruiting of bell peppers in terms of number of fruits, size (length and diameter), and weight of fruits; and evaluate the yield per plant and per plot.

2 | MATERIALS AND RESEARCH METHODS

2.1 | Research Design and Experimental Unit

The study was conducted at Dr. Emilio B. Espinosa Sr. Memorial State College of Agriculture and Technology (DEBESMSCAT)-College of Agriculture Crop Science experimental area, Masbate, Philippines. The study was conducted from March to May 2021 in three (3) months, or a cultural period. The experimental unit that was used in this study was a Randomized Complete Block Design (RCBD) with five (5) treatments and was replicated three (3) times. Treatment A (6:00 a.m. to 9:00 a.m.) shading, Treatment B (9:00 a.m. to 12:00 p.m.) morning shading, Treatment C (from 12:00 p.m. to 3:00 p.m.), Treatment D (3:00 p.m. to 6:00 p.m.), and Treatment E (no shading). The study used 15 experimental plots, and each plot was composed of 20 plants of bell pepper. Overall, the study used 300 plants of bell pepper.

2.2 | Materials and Procedure of the Study

The materials used in the study were plastic canvas, bamboo poles and slats, sharp bolo, cutter knife, nails, tie wire, used styro cups, polyethylene (PE) plastic, caliper, meter stick, and seeds of bell pepper.

2.2.1 | Preparation Area

Thorough land preparation was done in the area. The field was ploughed and harrowed until the soil was well pulverized. Then, a plot of fifteen was made. The width of each plot was 2.0 meters (m), the length was 3.0 m, and the width of the canal was 50 centimeters (cm). The total area of the field was 144 square meters.

The construction of the collapsible shed for bell peppers was done using bamboo poles and slats. A height of 1.5 m by 2.0 m width and 3.0 m length shading frames were made based on the plot dimensions and treatments.

2.2.2 | Seedling Preparation and Transplanting

The study used a soil medium made from decomposed rice straw mixed with garden soil. The soil media is potted in 4.0 cm by 5.0 cm polyethylene plastic. The seeds of bell pepper were sown at the top of the pot to a depth of 5 millimeters. Watering of potted seeds was done every day until they grew to a height of 15.0 cm–20 cm.The transplanting of the bell pepper was done 30 days after sowing. Each plot was planted with twenty-five bell pepper seedlings. The planting distance was 40 cm between hills and 60 cm between rows, following the recommended planting distance for bell peppers.

2.2.3 | Preparation and Application of Treatments

A removable shade made of plastic canvas with a frame was constructed for the study as a treatment to shorten the photoperiod. The treatments were applied every day. A Treatment A: Plant shading from 6:00 a.m. to 9:00 a.m.; Treatment B: Plant shading from 9:00 a.m. to 12:00 p.m.; Treatment C: Plant shading from 12:00 p.m. to 3:00 p.m.; and Treatment D: Plant shading from 3:00 p.m. to 6:00 p.m. The treatment E is the control (no shading)

2.2.4 | Cultural Management

The weeding and cultivation were done every 5 days. The study used rice straw as mulch to control the weeds and preserve soil moisture.

Water the plants early in the morning and late in the afternoon every day using a sprinkler. Different pest and disease control methods were also applied in this study to protect the plants. The study used organic fertilizer.

2.3 | Data Gathering

The following parameters were gathered during the study:

2.3.1 | Growth of Bell Pepper

- Plant Height The 10 plants that were randomly selected per plot in every treatment were measured every 5 days. The height of the plant was measured in centimeters (cm) using a meter stick from the base to the apex of the plant. The data gathering was done 7 days after transplanting.
- Number of Leaves. The number of leaves from ten randomly selected plants per plot in every treatment was counted every 5 days up to the first flowering.
- Size of Leaves. The width and length of leaves from 10 experimental plants were measured every 5 days and were expressed in centimeters. The measurement was done using a plastic caliper.
- Stem diameter. The stem diameter was measured 7 days after transplanting using a caliper and was expressed in centimeters. The measurement of stem diameter was also done every 5 days.

2.3.2 | Florescence Development

- Number of flowers Every 5 days, the number of flowers developed per plant was counted. This was taken from 10 experimental plants randomly selected per plot in every treatment.
- Length of Stalk. The length of the stalks of flowers from 10 experimental plants was measured using calipers and was expressed in terms of centimeters.

- Size of Flowers. The diameter of the flower was also measured in this study. The flowers of 10 experimental plants per plot in every treatment were measured in terms of centimeters using the caliper. This was also done every 5 days.

2.3.3 | Fruiting of Bell Pepper

- Number of Fruits. The fruiting of bell pepper in terms of number of the fruits was observed in this study. The harvested fruits of 10 experimental plants per plots in every treatment were counted. This was done up to third harvest.
- Size of Fruits. The size of harvested fruits from 10 experimental plants per plot in every treatment was measured. The fruit size was measured in terms of length and diameter. The diameter was measured in the middle part of the fruit and expressed in terms of centimeters.
- Weight of Fruits. The weight of the fruit was measured using a weighing scale and expressed in terms of grams. The fruits measured were taken from experimental plants per plot and per treatment.

2.4 | Data Analysis

A Randomized Complete Block Design (RCBD) was used in the study to describe the effects of different photoperiods (shading times) on growth, inflorescence development, fruiting, and yield of bell pepper. The data was analyzed using univariate analysis. The data analysis was done using the statistical software SPSS version 25.

3 | RESULTS AND DISCUSSION

3.1 | Growth of Bell Pepper

3.1.1 | Increase in plant height

The result of the study on the increase in plant height found that the average height ranges from 4.29 to 5.73 cm at a 5 day interval. Treatment B (9:00–12:00 P.M) had the highest rate of increase with 5.73 cm compared to the other treatments. This was followed by treatment A (6:00–9:00 A.M.) with an average mean of 5.62 cm. Then, followed by treatment C (1:00–3:00 P.M) with 4.68 cm, followed by treatment D (3:00–6:00 P.M) with 4.45 cm, and last was treatment E (control) with 4.29 cm. The results manifest that the plants still need sunlight from 9:00 a.m. to 12:00 p.m. In response, the plants produced longer stems and branches compared to those plants in other treatments. The results of the analysis of the increase in plant height revealed no significant differences among each treatment. Figure 1 shows the graph of the increase in height of the bell pepper.

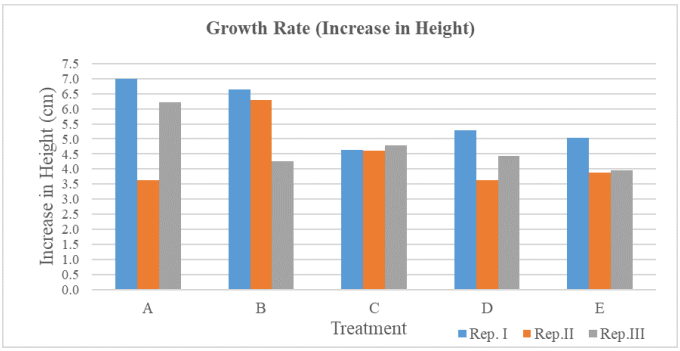

FIGURE 1 Increase in height of Bell Pepper.

3.1.2 | Overall Plant Height

The result of the study on the overall height of the plant found that the average height ranges from 51.50 cm to 62.35 cm. Treatment B had the highest plant height with 62.35 cm, compared to treatment A with about 61.64 cm, treatment C with 55.00

cm, treatment D with 54.00 cm, and treatment E with 51.50 cm. The results of the rate of increase in plant height proved the results in overall plant height. Based on the observation, the bell pepper produced longer stems and branches in response to the shading from 9:00 A.M. to 12:00 P.M. These non-photosynthesis-related responses allow plants to adjust to their environment and optimize growth. These results revealed that shading from 9:00 A.M. to 12:00 P.M enhances the growth of bell peppers in terms of plant height. Results of analysis of plant height revealed no significant differences among each treatment.Figure 2 shows the graph of the overall height of the bell pepper per replication and per treatment.

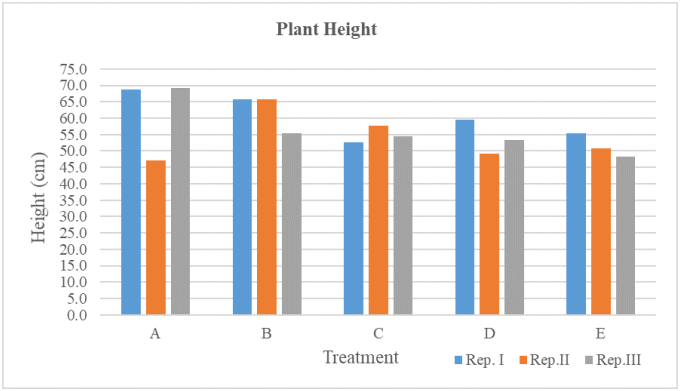

FIGURE 2 Overall height of Bell Pepper.

3.2 | Leaves of Bell Pepper

3.2.1 | Number of Leaves

The result of the study on the number of leaves found that the average ranges from 12 to 14. Treatment A and treatment C were the highest among other treatment with 14 leaves, this was followed by treatment E (control) and treatment D with an average of 13 leaves per plant. The last was the treatment B with an average of 12 leaves per plant before first flowering. The results of analysis on the number of leaves revealed no significant differences among each treatment. The results manifest that the different photo period or time of shading had no effect on bell pepper response in term of number of leaves. The Figure 3 shows the graph of number of leaves of Bell Pepper.

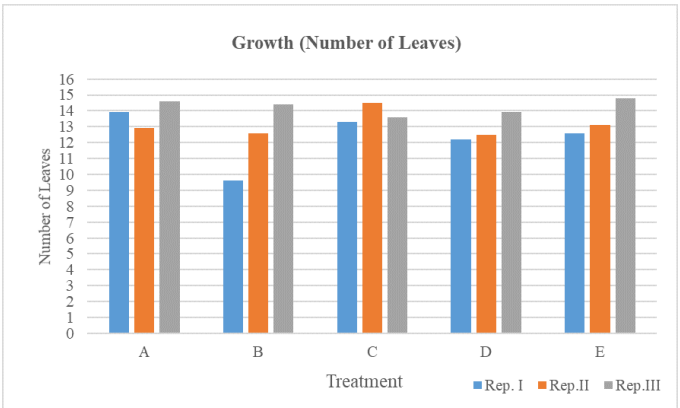

FIGURE 3 Number of leaves of Bell pepper.

3.2.2 | Width of Leaves

The results of a study on the width of leaves of bell pepper range from 5.23 cm to 5.68 cm. Treatment C had the highest mean among the other treatments, with 5.68 cm width of the leaves. This was followed by treatment E (Control) with 5.46 cm width. Next was treatment D with 5.37 cm, and the last was treatment A (6:00–9:00 AM) with 5.25 cm, and the last was treatment B with 5.23 cm. The results show that the plants shaded during the sun's peak hours produce wider leaves than those shaded at other times of the day, while those shaded from 9:00–12:00 PM produce narrower leaves. This might be due to the active photosynthetic activity of plants when exposed to higher solar radiation. The outcomes confirmed the results on overall plant height, that the plants in treatment B grow taller to search for sunlight. This result showed that sunlight from 9:00 AM to 12:00 PM is very essential for bell pepper growth in terms of the width of the leaves. The results of the analysis on the width of leaves revealed no significant differences among each treatment. Figure 4 shows the graph of the average width of the leaves of a bell pepper.

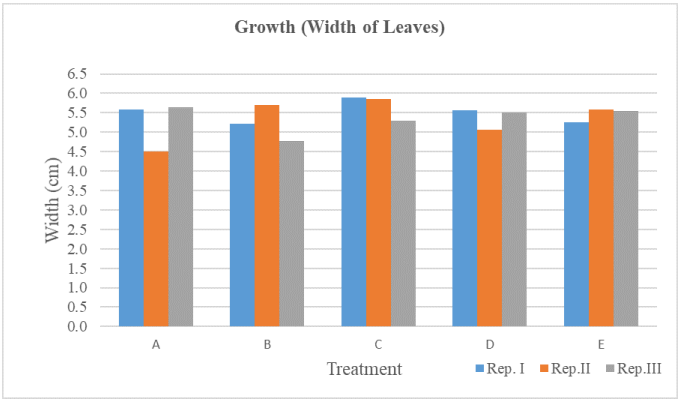

FIGURE 4 Width of leave of Bell pepper.

3.2.3 | Length of Leaves

The result on the length of leaves found that the average length ranged from 9.57 cm to 10.58 cm. Treatment C was the highest mean among other treatments that produced 10.58 cm of length of leaves compared to treatment E (control) with 10.55 cm, treatment A with 10.15 cm, treatment D with 9.85 cm, and treatment B with 9.57 cm. The results manifested that the plants exposed to peak sun hours produced larger leaves. It might be due to the higher solar radiation the bell pepper received that resulted in the active photosynthetic activity of plants. The results of the analysis on the length of leaves revealed no significant difference among each treatment. Figure 5 shows the average length of the leaves of a bell pepper.

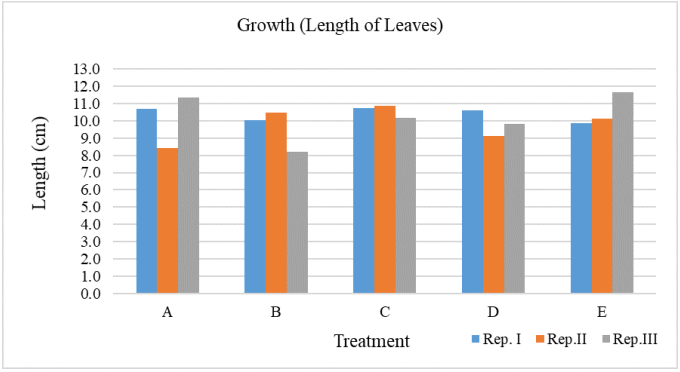

FIGURE 5 Length of leaves of Bell pepper.

3.2.4 | Stem Diameter

The result of the study on stem diameter found that the average diameter ranges from 0.90 cm to 1.15 cm. Treatment A (shaded from 6:00 AM to 9:00 AM) produced a larger stem diameter of 1.15 cm compared to the other treatments. This was followed by treatment C, with a 1.01cm stem diameter. Next was the treatment B and E (control) with a 0.97 cm diameter, and the last was the treatment D with a 0.90 cm stem diameter. The results indicated that bell peppers shaded after sun peak hour produced smaller stem diameters and bell peppers shaded in the early morning produced larger stem diameters. The results of the analysis on stem diameter revealed no significant difference among each treatment. Figure 6 shows the graph of the average stem diameter of bell peppers.

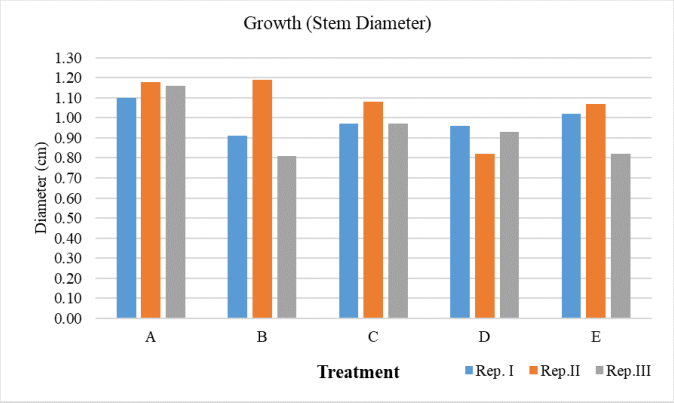

FIGURE 6 Stem diameter of Bell pepper.

3.3 | Inflorescence Development

3.3.1 | Length of Stalks

The results of a study on the length of the stalk of flowers range from 1.19 cm to 1.37 cm. Treatment D had the highest mean among the other treatments, with 1.37 cm, compared to treatments C and E (control), both of which had 1.27 cm. Then, followed by treatment A with 1.24 cm and last was treatment B with 1.19 cm of the stalks. The study showed the bell pepper shaded in the late afternoon generated longer stalks than at other times of shading. This might be due to cooler temperatures when shaded and prolonged nighttime hours. The results of the analysis on the length of stalks revealed no significant differences among each treatment. Figure 7 shows the graph of the average length of the stalks of bell peppers.

3.3.2 | Size of flower

The result of the study on the size of flowers found that the average ranges from 1.19 cm to 1.25 cm. Treatment D produced the largest size of a flower with a 1.25 cm diameter. Treatment D had the highest mean among other treatments. This was followed by treatment E (control) with 1.22 cm. Next was treatment C with 1.21 cm, followed by treatment A with 1.19 cm, and last was treatment B with 1.17 cm of flower diameter. The results showed that bell peppers shaded in the late afternoon produced a larger flower. This might be due to shortened daylight and protracted night time hours. The results of the analysis on the size of the flowers of bell pepper revealed no significant differences among each treatment. This means that the different times of shading had no significant effect on the flower size of a bell pepper. Figure 8 shows the graph of the average diameter of flowers.

3.4 | Fruiting of Bell Pepper

3.4.1 | Length of Fruit

The results of the study on the length of the fruit of bell pepper found that the average ranges from 6.28 cm to 6.72 cm. Treatment B, with 6.72 cm, had the highest mean among other treatments, followed by treatment E (control), with 6.62 cm. Next was

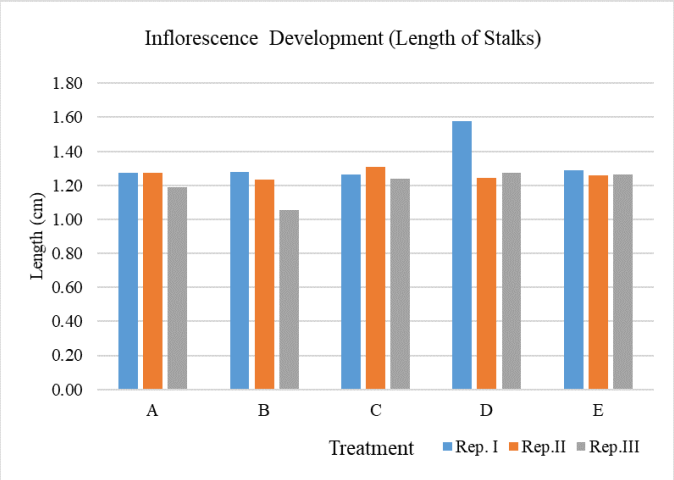

FIGURE 7 Length of stalk of flowers.

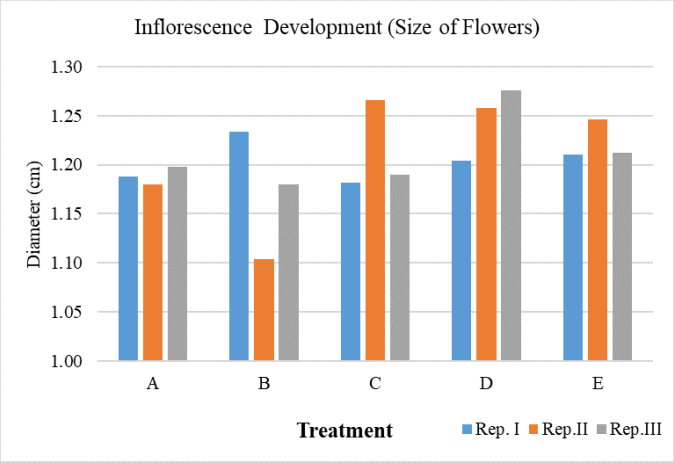

FIGURE 8 Diameter of flowers.

treatment D with a 6.47cm length, followed by treatment C with a 6.44 cm and treatment A with a 6.28 cm length of the fruit, respectively. The results indicated that the bell pepper shaded from 9:00 AM – 12:00 PM produced longer fruits compared to plants shaded at different times. The results of the analysis on the length of bell pepper fruits revealed no significant differences among each treatment. Figure 9 shows the graph of average length of fruit.

3.4.2 | Diameter of Fruit

The results of the study on the size of the fruit (diameter) of bell pepper found that the average ranges from 37.49 cm to 44.57 cm. Treatment C produced the highest mean among other treatments, with a 44.57 cm diameter of fruit, followed by treatment E (control) with a 43.49 cm diameter. The next was the treatment A with a 43.01cm diameter, followed by treatment D with 42.17 cm, and last was the treatment B with a 37.49 cm diameter of the fruit. The results showed that the bell pepper shaded during sun peak hours produces larger fruits. This might be due to a decrease in solar radiation and temperature. The shading reduces the soil and air temperatures, which greatly affects the soil moisture depletion. The results of the analysis on the average size of the fruit of bell pepper revealed no significant differences among each treatment. Figure 10 shows the graph of the average fruit size of bell peppers.

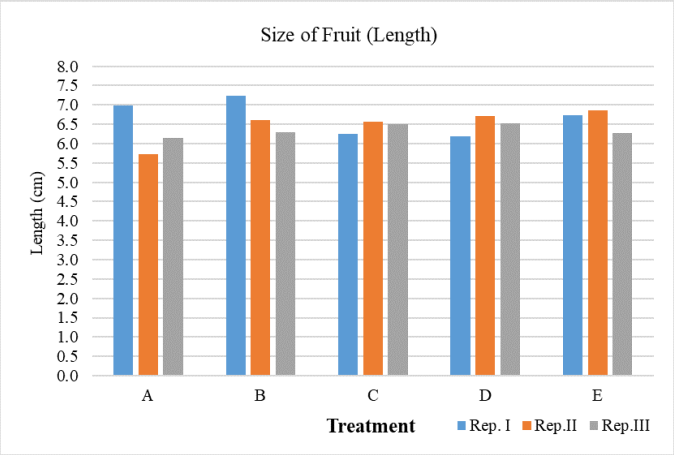

FIGURE 9 Length of fruits of Bell pepper.

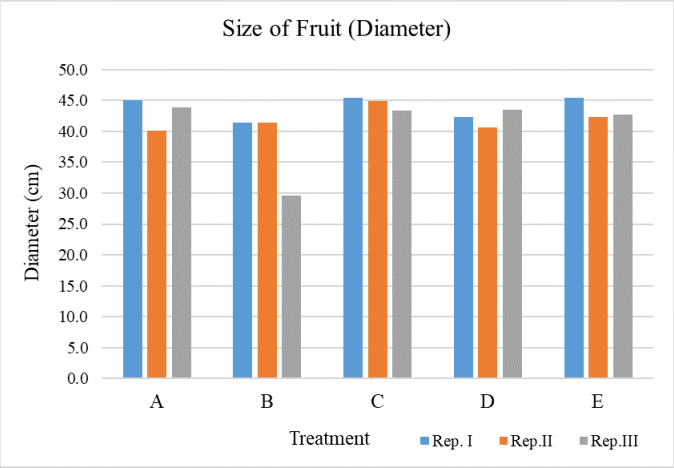

FIGURE 10 Diameter of fruits of Bell pepper.

3.4.3 | Weight of Fruit

The result of a study on the weight of fruits found that the weight ranged from 32.05 grams to 35.91 grams. Treatment C produced the highest mean, among other treatments, with 35.91 grams, followed by treatment D with 35.41 grams, and the next was treatment E (control) with 34.46cm. Then, followed by treatment A at 33.02 cm, and last was treatment B with a 32.05-gram fruit weight. The results showed that the bell pepper shaded during 12:00 PM–3:00 PM or sun peak hours produced heavier fruits than other shades. This might be due to the preserved soil moisture from shading and cooler temperatures. At this time of shading, the volumetric soil-water content was less. The volumetric soil water increased as the shade levels increased (Kabir and Pérez, 2020). The results of the analysis of the weight of fruits revealed no significant differences among each treatment. Figure 11 shows the graph of average fruit weight per replication in 5 different treatments.

3.4.4 | Yield per Plant

The results in the weight of fruits per plant range from 126.67 grams to 365.67 grams. Treatment C produced the highest yield among other treatments, with 365.67 grams, followed by treatment E (control), with a 352.22 gram yield. The next was treatment A, which produced 290.06 grams of yield per plant, followed by treatment D with 258.89 grams, and the lowest was treatment B, with 126.67 grams of yield per plant. The results show that treatment C with heavier fruits had the highest yield of the treatments. This might be due to the fact that bell peppers produce more fruit when shaded during peak sun hours. This indicated that shading the bell pepper from 12:00 PM to 3:00 PM reduced the flower droppings. The results of the analysis on

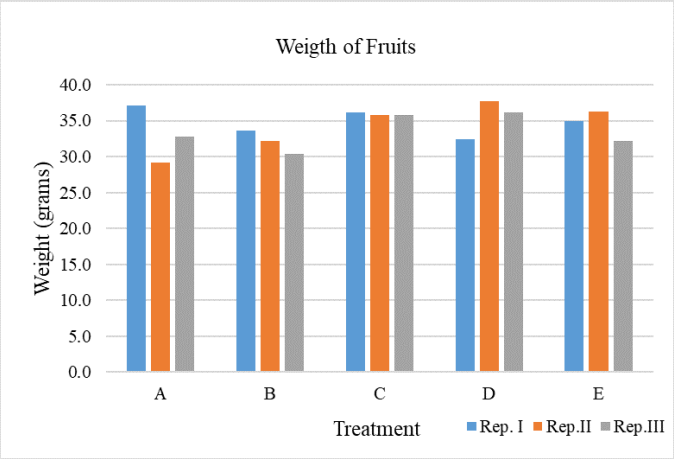

FIGURE 11 Weight of fruits of Bell pepper.

the average weight of fruits per plant of bell revealed significant differences among each treatment. Figure 12 shows the graph of the yield in terms of the weight of fruits per plant.

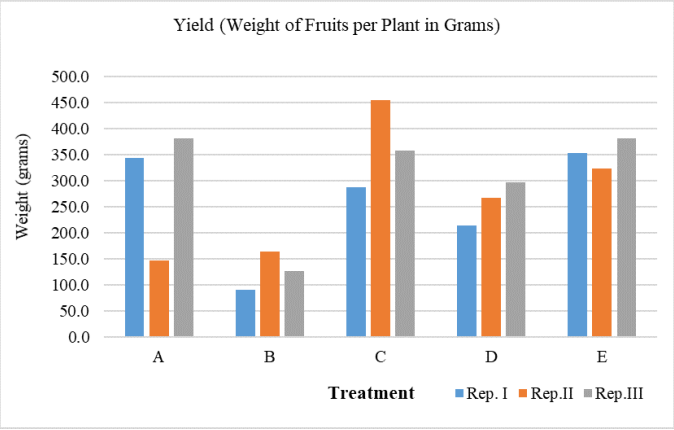

FIGURE 12 Weight of fruits per plant.

3.4.5 | Yield per Plot

The results of the study on the yield per plot found that the average ranged from 163.33 grams to 624.44 grams. Treatment C produced the highest yield among the treatments, with 624.44 grams. This was followed by treatment E (control), with 483.33 grams. Then, followed by treatment A with 476.67 grams, treatment D with 405.56 grams, and treatment B with 163.33 grams, respectively. The results revealed that most of the plants shaded from 12:00 PM to 3:00 PM developed more flowers, produced heavier fruits, and had a greater yield per plant. These results showed that shading the bell pepper during peak sun hours (12:00 PM–3:00 PM) produces more yield and the solar radiation in the morning is very important to plants. The results of the analysis on the average yield of bell pepper per plot revealed significant differences among each treatment. Figure 13 shows the graph of the yield per plot.

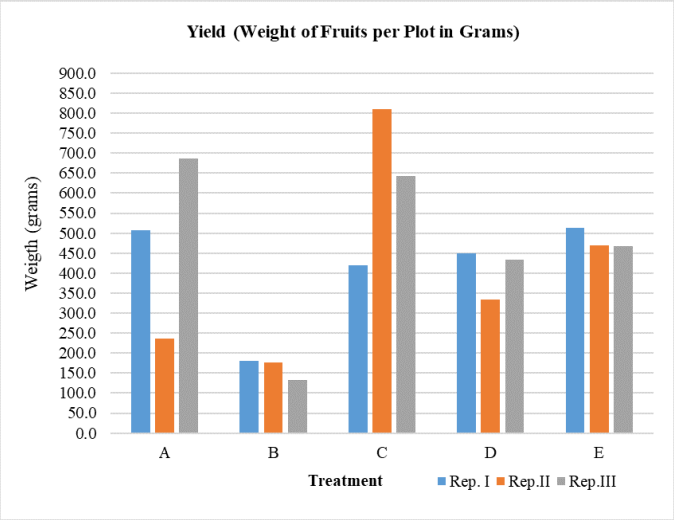

FIGURE 13 Weight of fruits per plot.

4 | CONCLUSION

A total of 300 seedlings were transplanted and arranged for treatments and replications. The treatment applied the shading starting from 6:00 A.M to 9:00 A.M; 9:00 A.M to 12:00 P.M; 12:00 P.M to 3:00 P.M; 3:00 P.M to 6:00 P.M and control (no shading). Based on the results of the study, the different photoperiods (time of shading) had no significant effect on growth, inflorescence development, and fruiting of bell pepper. The yield of bell pepper in terms of the number of fruits per plant and per treatment was significantly affected by different photoperiods. Shading the bell pepper from 1:00 P.M. to 3:00 P.M. reduces the drop of flowers and stress.

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