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Horticultural Qualities and Survival of Bell pepper (*Capsicum annuum* L.) as Influenced by Hydrogen Peroxide and Salicylic Acid

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Abstract

Bell pepper (Capsicum annuum L.) is widely recognized for its potent antioxidant properties and high levels of bioactive compounds. The cultivation of bell peppers has been proven successful. However, production remains low due to disease infestations, particularly bacterial wilt (BW), and efforts have been made to help farmers protect their plants. Currently, no commercial bactericide is available to control BW disease. This experiment was designed to evaluate the effects of hydrogen peroxide and salicylic acid concentrations on yield, fruit quality, and disease suppression in bell peppers. The experiment was conducted using a single-factor experiment design, arranged in a Randomized Complete Block Design (RCBD) with seven treatments. Results revealed that hydrogen peroxide and salicylic acid at different concentrations significantly influenced specific horticultural characteristics, flowering, yield, and plant survival rate. The increasing salicylic acid concentration (276 ppm) resulted in a corresponding delay in both bell pepper flowering (17.83 days) and harvesting (68.44 days). In contrast, the number and weight of both marketable and total yield plant $^{-1}$ were greatest and heaviest at higher concentrations of hydrogen peroxide, with an effect comparable to that of lower concentrations of salicylic acid. Higher hydrogen peroxide (H_2O_2) levels and lower salicylic acid (SA) levels enhanced bell pepper growth, yield, and disease resistance. Specifically, 150 ppm H_2O_2 combined with the lowest SA concentration produced the most fruits, the greatest yield per plant, the best bacterial wilt suppression, and the highest net income. In contrast, higher SA concentrations delayed flowering and harvest.

***Keywords**:* bacterial wilt, bell pepper, hydrogen peroxide, percent survival, salicylic acid

1. Introduction

Bell pepper, scientifically known as (*Capsicum annum* L.), is the second-most popular vegetable in the world. It is distinguished by its high levels of calcium, provitamin A (carotene), and vitamin C (ascorbic acid) content. It is renowned for its high concentration of bioactive compounds and a potent antioxidant system. Due to their unique blend of color, flavor, and nutritional content, bell peppers are among the most commonly consumed fresh veggies worldwide (Blanco-Rios *et al*., 2013). It contains β-carotene, vitamin C, lycopene, and specific flavonoids and neutral phenolic compounds, including lutein, capsaicinoids, and quercetin, which have been demonstrated to be efficient free-radical scavengers (Deepa *et al*., 2006). According to Deepa *et al*. (2006), these substances also give bell peppers their color. The phytochemicals in bell peppers are considered a primary source of health benefits for humans. According to Andrews (1995), these include clearing mucus from the lungs and nose, promoting the flow of digestive juices to protect the stomach, triggering the activation of endorphins in the brain, which are naturally occurring painkillers, making your mouth water to counteract the acids that cause cavities, and using antioxidant activity to help protect the body against cancer.

Bell pepper cultivation has been proven successful and is considered a highly valued crop. However, production is lower due to pest and disease infestations and natural disasters. That is why, in 2018, the price of bell peppers and other pepper cultivars rose from PhP 150 to PhP 1,250 per kilo (Philippine Statistics Authority [PSA], 2015). Bell pepper favors highlands with cooler temperatures, like in Brgy. Cabintan, Ormoc, City, Leyte. However, the major problem for growers is the incidence of soil-borne diseases, particularly bacterial wilt (BW), which hinders bell pepper production (Salas *et al*., 2019).

The percentage of bell pepper production lost in the field due to bacterial wilt ranged from a few affected plants to 100%. Filipino farmers have the same challenges as farmers in other nations, such as China, India, the United States, and Indonesia (Wang & Lin, 2005). Although extensive studies have investigated strategies to prevent bacterial wilt, the application of appropriate cultural practices remains one of the most effective and sustainable management approaches. Crop rotation with non-host crops, such as corn, rice, beans, or cereals, disrupts the disease cycle by depriving the bacteria of a suitable host, leading to a natural decline in the soil pathogen population. Soil tillage improves soil aeration, drainage, and oxygen availability, creating conditions that are unfavorable for bacterial survival and proliferation. Proper crop management practices, including removing infected plants, disinfecting tools, and avoiding mechanical injuries, further reduce the risk of pathogen spread and infection. In addition, seed treatment using hot water, hydrogen peroxide, or biological agents helps eliminate bacterial contamination on seed surfaces, ensuring disease-free planting materials. Collectively, these integrated cultural management practices minimize the incidence of bacterial wilt and prevent severe yield losses or total crop failure (Yuliar *et al.,* 2015).

Efforts have been made to assist farmers in safeguarding their plants from BW, no commercial bactericide is now available to combat the latter. Yuliar *et al.* (2015) used a novel method of exogenously applying salicylic acid (SA) to control BW in tomatoes and found that SA pretreatment delays BW symptoms and reduces their severity by activating defenses such as PR-1a. Exogenous SA inhibits *R. solanacearum* growth and induces stress responses in the pathogen. When used in modest amounts as a phytohormone, (SA) promotes cell division while suppressing cell growth. However, it causes cell apoptosis at greater dosages. It is an all-purpose inducer of plant resistance to a range of pathogen infections and stressors. It is linked to the activation of Systemic Acquired Resistance (SAR) in plants, which protects them from bacteria, viruses, and fungal phytopathogens.

Martin and Rozalska (2019) found another method of controlling pathogens and diseases using hydrogen peroxide: *Leptosphaeria maculans* in Chinese cabbage, Nováková *et al*. (2015) on the resistance in *Nicotiana benthamiana,* and Deng *et al*. (2016) to systemic virus and resistance against root-knot nematode, BW by Song *et al*. (2018). Hydrogen peroxide is an environmentally friendly substance, and Vegetable pathogens were successfully managed during storage with its use. According to Mohamed *et al*. (2019), it is an important signaling molecule that plays a key role in several physiological and biochemical functions in plants. These technologies could be a potential breakthrough in bell pepper production in the Philippines, specifically in Brgy. Cabintan, Ormoc, City, Leyte. Moreover, there have been no previous studies and limited information in comparing the effects of hydrogen peroxide and SA treatments on bell peppers. Hence, the study evaluates the efficacy of H_2O_2 and SA on the horticultural qualities and percent survival of bell peppers.

2. Methodology

2.1 Land Preparation

An area of 264 m^2 under the tunnel structure was used in this study. It was plowed and harrowed twice a week to break up large clods, level the ground, and remove debris. After the last harrowing, 21 plots, each measuring 1 m × 5 m per plot and separated by 0.5 m alleyways, were constructed.

2.2 Seedling Preparation and Field Planting

The seeds of the Sondela bell pepper variety were planted in seedling trays filled with a 1:1:1 mixture of river sand, coco coir, and vermicast. To acclimate seedlings to field conditions, they were gradually exposed to direct sunlight, and water was withheld for 1 week before transplanting. The seedlings were moved into the experimental area after hardening and planted at a spacing of 0.5 m × 0.5 m.

2.3 Experimental Design and Treatments

The study was arranged in a Randomized Complete Block Design with seven treatments and three replications, consisting of twenty-one treatment plots with ten samples per treatment.

Treatments:
T_1 - (control)
T_2 – 50 ppm H_2O_2 (0.05 $mL/^{-1}$)
T_3 – 100 ppm H_2O_2 (0.1 $mL/^{-1}$)
T_4 – 150 ppm H_2O_2 (0.15 $mL/^{-1}$)
T_5 – 138 ppm salicylic acid (138 $mg/^{-1}$)
T_6 – 207 ppm salicylic acid (207 $mg/^{-1}$)
T_7 – 276 ppm salicylic acid (276 $mg/^{-1}$)

The concentrations in this study were 1 ppm Hydrogen peroxide (H_2O_2), equivalent to 0.001 mL/L, and 1 ppm salicylic acid (SA), equivalent to 1 mg/L. Each amount of salicylic acid was diluted to 1 L with water (Martin & Rozalska, 2019).

2.4 Treatment Preparations

To obtain a 1 ppm (RHEA 20 volumes) hydrogen peroxide, 0.001 mL was diluted to 1 liter of water and stirred using a stirrer. The concentration was based on the equivalent of 1 ppm hydrogen peroxide, or 0.001 mL diluted to 1 liter of water, multiplied by 50, 100, and 150 ppm. For SA concentrations, 1 mg of salicylic acid powder was dissolved in 5 drops of ethanol in a beaker, then agitated until dissolved using a magnetic stirrer. Then mixed with 1 liter of water and diluted to 138, 207, and 276 ppm salicylic acid.

2.5 Application of Treatments to Transplanted Seedlings

Different concentrations of hydrogen peroxide and salicylic acid were prepared. Each concentration was mixed with 1 liter of tap water and diluted 20-fold to create 20-liter dilutions for each treatment, and each seedling was drenched with 1 liter of the diluted solution. The application was done at two-week intervals and stopped at the first harvesting.

2.6 Fertilizer Application

For fertilizer application, 10 g of 18-46-0 fertilizer per hill was applied basally at planting, and weekly drenching was carried out at the rate indicated in Table 1. A total of 150 mL of the suggested fertilizer was administered to each plant after it was dissolved in 100 liters of water.

Table 1. Fertilization scheme of Bell pepper

Stage	Number of Weeks	Fertilizer	GM/WEEK/264 SQM
Seedling stage	2	DAP (basal)	342.7
		Urea	393.1
		MOP	342.7
Vegetative stage	2	SSP	688.0
		Urea	1056.5
		MOP	1351.4
Flowering fruit-stage	5	SSP	688.0
		Urea	1991.8
		MOP	1695.3
Fruit-set to harvest stage	10	SSP	688.0
		Urea	1326.8
		MOP	1351.4

Legend: DAP (Diammonium phosphate), MOP (Muriate of potash), and SSP (Single superphosphate)
Source: (Haifa- group, 2018).

2.7 Trellising and Pruning

A trellis was constructed three weeks after transplanting. Twine string served as a post and was placed in line in each row of growing bell peppers. Tie wire was tied along each row from post to post to secure the plants by tying it to the tie wire using lacing tapes. Pruning starts as soon as the plants develop three to four laterals stem using sharp pruning shears. According to Holland and Trouillas (2020) recommended avoiding pruning before rain to protect fresh wounds from fungal pathogens.

2.8 Weeding and Irrigation

Hand weeding was done weekly until the end of the study. A drip irrigation system was installed in the experimental area. A drip hose with minute holes spaced 0.5 m apart was set to deliver a single drip to supply adequate water to the plant.

2.9 Insect Pests and Diseases Control

The plants were monitored for any pest infestation, and the appropriate physical and mechanical control methods were implemented by manually handpicking visible insect pests or their egg masses from the plants to reduce their population, and by using pheromone traps that attracted and captured male insects, thereby disrupting their mating cycle and lowering pest infestation levels. To stop and manage insect pest infestations and disease infections, sick plants were routinely pruned, and cleanliness measures were implemented.

2.10 Harvesting

Fifty-nine days after transplantation, the fruits were harvested manually at the mature green stage using pruning shears to ensure that the fruits remained intact and of marketable quality. Mature green fruits were carefully selected and cut approximately 1 to 2 centimeters above the calyx to prevent damage to the plant and reduce the risk of detaching immature fruits. After harvesting, the fruits were gently placed in clean plastic crates to minimize bruising and mechanical injury during handling and transport. The fruits were divided into marketable and non-marketable categories after harvest. Marketable fruits are those that are fully ripe, have conventional polar and equatorial sizes (2.5”–2.5”), and are free from insect damage, and mechanical injuries (Salinas-

Romero *et al*., 2023). The tiny fruits that were harmed by pests or mechanical damage were considered non-marketable.

2.11. Data Gathered

2.11.1 Horticultural Characteristics

Plant height was determined using a meter stick by measuring the stem from the lowest point of the plant to the terminal end of the highest portion. Stem girth was measured weekly with a caliper until the final harvest of bell peppers. The number of leaves on bell peppers was determined by counting the leaves of five sampled plants at the first harvest. The leaf length and width were determined by measuring the longest and widest leaf distances across the middle portion of the leaf at first harvest. Root length and weight were determined by measuring the longest roots and weighing the roots at the end of the study. Herbage yield was determined by weighing the upper biomass of plants at the end of the study. The number of days from transplanting to the first flower formation was also recorded, as well as the number of days from transplanting to the first harvest.

2.11.2 Yield and Yield Components

Using a Vernier caliper, the polar and equatorial diameters of six harvested fruits from each treatment plot during the second, third, fourth, and fifth harvests were measured to assess the size of the fruit. The weight and number of fruits from the first to the last harvest were used to determine the weight and number of marketable and non-marketable fruits. The results were summed up and expressed per plot/treatment using the following criteria: fruits free of diseases, insects, and physical damage or mechanical damage were classified as marketable, while fruits that were infected, physically damaged, very small, or unappealing to consumers were classified as non-marketable. To determine the total yield (kg/264 m^2), the total weight of non-marketable and marketable fruits per treatment plot was multiplied by 264 m2/plot area.

2.11.3 Plant Survival (%) and Disease Incidence (bacterial wilt)

Every month until the study's termination, the percentage of plants that survived was calculated getting the quotient of the total number of plants planted to the number of plants that survived x100. The incidence of bacterial wilt was calculated by counting the number of affected plants and expressing it as a (%) percentage of the total number of plants.

2.11.4 Meteorological Data

The data on average weekly in and out temperatures under protective structure were monitored using a thermometer. Weekly relative humidity (%) was taken using a hygrometer.

2.11.5 Statistical Analysis

STAR software or (Statistical Tool for Agricultural Research), a computer program, was used to statistically analyze the parameters. Analysis of Variance (ANOVA), arranged in single factor RCBD, was used to determine whether the treatments differed significantly from one another. The Least Significant Difference (LSD) Test was used to compare treatment averages at the 5% significance level.

3. Results and Discussion

3.1 Horticultural Characteristics

The plant height of bell pepper is presented in Table 2. There were no discernible variations across the treatments in weeks 2, 4, 10, and 12, with plant height ranging from 29.11–30.66 cm, 32.11–35.29 cm, 49.23-56.62 cm, and 62.38–70.65 cm, respectively. However, plants treated with 150 ppm hydrogen peroxide (T_4) showed significant differences in plant height, which is comparable to 138ppm salicylic acid (T_5) observed from week 6 and week 8 (39.52 cm and 38.92 cm, respectively), while the shortest in height were observed from T_0 (control) with (34.42 cm and 37.39 cm, respectively). The result supported by the findings of Voxeur and Höfte (2016), who found a strong correlation between environmental factors and phytohormones cross-linked to hydrogen peroxide, particularly auxin and gibberellin via inducing ROS production, cell wall peroxidation (peroxidases class III) and NADPH oxidation to cause cell wall elongation and loosening, auxin contributes to cell growth which has the same function with gibberellin that will promote stem elongation and cell enlargement. Moreover, Lee *et al*. (2010) stated that SA increases the plant height in tobacco. SA promotes cell elongation in plants that are cross-linked to auxin and gibberellin (Raskin *et al.,* 1990).

Table 2. Plant height (cm) of bell pepper as influenced by different concentrations of hydrogen peroxide and salicylic acid

TREATMENTS	Plant height (cm) (Week)					
	2	4	6	8	10	12
T_1- Control	29.39	32.11	34.42c	37.39b	52.84	70.65
T_2- 50 ppm (H_2O_2)	27.89	32.66	34.82bc	37.55b	49.23	62.57
T_3- 100 ppm (H_2O_2)	30.66	35.29	38.24ab	42.25a	54.42	62.96
T_4- 150 ppm (H_2O_2)	30.13	35.24	39.52a	43.17a	56.52	70.59
T_5- 138 ppm (SA)	29.19	36.22	38.92a	42.68a	55.67	69.68
T_6- 207 ppm (SA)	29.11	34.29	35.36bc	40.58ab	51.72	63.65
T_7- 276 ppm (SA)	29.54	33.92	36.09bc	39.74ab	52.58	62.38
P-value	0.4104^{ns}	0.1520^{ns}	0.0331*	0.0427*	0.3935^{ns}	0.0766^{ns}
CV(%)	4.86	5.36	5.32	5.73	7.54	6.52

*At the 5% level of significance, means within the same letter column in a block that are followed by a common letter(s) are not significantly different from each other; ns – not significant, * - significant and ** - highly significant; (H_2O_2 – Hydrogen peroxide, SA – Salicylic acid)*

Table 3 shows the stem girth of bell peppers as influenced by hydrogen peroxide and salicylic acid. The results revealed that the stem diameter of bell pepper was not influenced by hydrogen peroxide and salicylic regardless of the concentration from week 2 (0.3933 cm-0.4267 cm), week 4 (0.4667 cm-0.5233 cm), week 8 (0.6967 cm-0.7733 cm), week 10 (0.8267 cm-0.9600 cm), and week 12 (1.02 cm-1.16 cm), respectively. Significant differences were observed in week 6 on the stem diameter of bell pepper. Treatment 5 has the largest diameter at 0.6567 cm, which is comparable to treatments 2, 3, 4, 6, and 7 (0.5900 cm, 0.6267 cm, 0.6467 cm, 0.6267 cm, and 0.6133 cm, respectively). This result coincided with the findings of Waszczak *et al.* (2018), who found that administering 270 ppm SA enhanced stem enlargement in tomato. SA connects the signaling pathways of multiple phytohormones, especially GA, auxin, jasmonic, ABA, and ethylene, and responds to many circumstances influencing plant growth and development that act as a second messenger. In addition to serving as a growth regulator, H_2O_2 is sometimes considered a potential phytohormone that stimulates cell growth and enlargement (Martin & Rozalka, 2019).

Table 3. Stem diameter (cm) of bell pepper as influenced by different concentrations of hydrogen peroxide and salicylic acid

Treatments	Stem diameter (cm) (Week)					
	2	4	6	8	10	12
T_1- Control	0.4200	0.4833	0.5800b	0.7300	0.9000	1.12
T_2- 50 ppm (H_2O_2)	0.3933	0.4667	0.5900a	0.6967	0.8267	1.02
T_3- 100 ppm (H_2O_2)	0.4267	0.5067	0.6267ab	0.7500	0.9400	1.04
T_4- 150 ppm (H_2O_2)	0.4200	0.5233	0.6467a	0.7700	0.9600	1.16
T_5- 138 ppm (SA)	0.4133	0.5100	0.6567a	0.7733	0.9600	1.12
T_6- 207 ppm (SA)	0.4267	0.5033	0.6267ab	0.7300	0.8900	1.02
T_7- 276 ppm (SA)	0.4267	0.4800	0.6133ab	0.7333	0.9000	1.07
P-value	0.4146 ^{ns}	0.5040 ^{ns}	0.0451*	0.3019 ^{ns}	0.3805 ^{ns}	0.2381 ^{ns}
CV (%)	4.73	7.20	4.44	5.31	8.30	7.08

*At the 5% level of significance, means within the same letter column in a block that are followed by a common letter(s) are not significantly different from each other; ns – not significant, * - significant and ** - highly significant; (H_2O_2 – Hydrogen peroxide, SA – Salicylic acid)*

3.2 Flowering Characteristics

Reproductive development of bell peppers expressed in terms of days from transplanting to first flowering and first harvesting was significantly affected by varying concentrations of hydrogen peroxide and salicylic acid (Table 4). The flowering and fruiting of tomatoes were significantly delayed by the application of varying concentrations of hydrogen peroxide and salicylic acid. Plants treated with 276 ppm salicylic acid have a longer number of days to flower and harvest with 17.83 days and 68.44 days, respectively. These results coincide with the findings of Kumar *et al.* (2013) that a higher concentration of salicylic acid delays and prolongs the flowering of strawberries which results in delayed harvesting. Recent research indicates that salicylic acid (SA) plays a complex role in regulating flowering time, with its effects depending strongly on concentration, species, and environmental conditions. Luo *et al.* (2022) emphasized that SA influences floral induction in a dose and context-dependent manner, where low levels can promote flowering while higher concentrations may inhibit or delay it. Similarly, Berková *et al.* (2023) reported that pre-flowering SA treatments affected reproductive development and reduced seed yield, implying a potential delay or suppression of floral transition when plants are exposed to elevated SA levels. Yang *et al.* (2023) further discussed that excessive SA can disturb cellular redox homeostasis, leading to oxidative stress and slowed developmental processes, which may contribute to delayed flowering under high SA accumulation. Although some species-specific studies, such as Shah *et al.* (2021) on *Malus domestica*, have demonstrated that moderate SA application improves leaf physiology and indirectly promotes flowering, most evidence suggests that excessive or prolonged SA exposure tends to inhibit or postpone reproductive development.

Table 4. Flowering and harvesting characteristics of bell pepper as influenced by hydrogen peroxide and salicylic acid

Treatment	Number of Days from Transplanting to	
	Flowering	Harvesting
T_1- Control	8.97e	60.77b
T_2- 50 ppm (H_2O_2)	9.63de	61.13b
T_3- 100 ppm (H_2O_2)	9.77de	60.05b
T_4- 150 ppm (H_2O_2)	10.57d	59.75b
T_5- 138 ppm (SA)	12.27c	62.57b
T_6- 207 ppm (SA)	13.97b	62.35b
T_7- 276 ppm (SA)	17.83a	68.44a
P-value	0.0000**	0.0023**
CV (%)	2.80	3.15

*At the 5% level of significance, means within the same letter column in a block that are followed by a common letter(s) are not significantly different from each other; ns – not significant, * - significant and ** - highly significant; (H_2O_2 – Hydrogen peroxide, SA – Salicylic acid)*

3.3 Yield and Yield Components

Different concentrations of hydrogen peroxide and salicylic acid significantly affect the yield components (Table 5). Significantly, more marketable fruits were obtained from plants applied with 150 ppm hydrogen peroxide, comparable to treatments 5, 6, and 7 (11.33, 10.67, 9.33, and 9.67, respectively). On the other hand, the heaviest weight (kg per plant) was obtained from bell pepper applied with 150 ppm hydrogen peroxide, which is commensurate with the plant applied with 138 ppm SA. Additionally, plants treated with 100 ppm hydrogen peroxide produced the highest number and weight of non-marketable fruits, while the lowest number and weight of non-marketable fruits were observed in plants treated with 150 ppm hydrogen peroxide.

These results on yield and yield components could be related with the highest percent survival (Figure 1) and minimal incidence of bacterial wilt (Figure 2). Moreover, the decrease in fruit yields of bell peppers under control and treatment with lower concentration of hydrogen peroxide was not correlated with the size of fruit but on the lesser yield of fruits produced per plot brought about by lower plant survival. Furthermore, total yield was also significantly influenced by the concentration of hydrogen peroxide and salicylic acid whereas plants applied with 150 ppm hydrogen peroxide obtained the highest yield characteristics with 1535.22 kg per 200 m^2. Khandaker *et al*. (2012) reported that wax apple treated with 100 ppm hydrogen peroxide and tomato with 1.00 mm salicylic acid showed better yield and fruit quality.

Mauseth (2014) states that the application of hydrogen peroxide either modifies cell enlargement at Phase II or significantly enhances cellular growth and development during the initial cell division at Phase I. According to Shakirova (2003), salicylic acid's beneficial effects on growth and yield may be attributable to its influence on other plant hormones that also raise yield.

Table 5. Yield components of bell pepper as influenced by hydrogen peroxide and salicylic acid

Treatments	Marketable Fruits (Kg $Plant^{-1}$)		Non-Marketable Fruits (Kg $Plant^{-1}$)		Total Yield (Kg $Plant^{-1}$)	Total Yield (Kg 264 m^2)
	Number	Weight	Number	Weight		
T_1- Control	6.33d	0.96e	2.00ab	0.1737d	1.13e	680.08c
T_2- 50 ppm (H_2O_2)	8.00cd	1.09d	2.33ab	0.1922c	1.28d	998.51b
T_3- 100 ppm (H_2O_2)	8.67bcd	1.21c	3.67a	0.2917a	1.50c	1117.60b
T_4- 150 ppm (H_2O_2)	11.33a	1.60a	1.67b	0.0898f	1.69a	1535.22a
T_5- 138 ppm (SA)	10.67ab	1.56a	2.67ab	0.1120e	1.67a	1211.04b
T_6- 207 ppm (SA)	9.33abc	1.34b	3.33ab	0.2574b	1.60b	1096.49b
T_7- 276 ppm (SA)	9.67abc	1.39b	2.67ab	0.1961c	1.59b	1146.47b
P-value	0.0004**	0.0000**	0.0156*	0.0000**	0.0000**	0.0000**
CV (%)	9.98	1.95	22.56	1.80	1.59	8.97

*At the 5% level of significance, means within the same letter column in a block that are followed by a common letter(s) are not significantly different from each other; ns – not significant, * - significant and ** - highly significant; (H_2O_2 – Hydrogen peroxide, SA – Salicylic acid)*

3.4 Percent Plant Survival

Data on the percent of survival of bell pepper were significantly affected by different hydrogen peroxide and salicylic acid concentrations from February to April, except in March (Figure 1). The highest percentage of plant survival was recorded in T_4 (150 ppm hydrogen peroxide), which is comparable to the effects on T_2 (50 ppm hydrogen peroxide), T_3 (100 ppm hydrogen peroxide),

T_5 (138 ppm salicylic acid), T_6 (207 ppm salicylic acid), and T_7 (276 ppm salicylic acid). Conceivably, the bell pepper grown without treatment (control) had the lowest percentage of survival from the start, up to the end of the experiment. This can be correlated to a higher incidence of bacterial wilt. The higher survival rates in tomatoes and sweet peppers were found to be due to the roles of H_2O_2 and SA in disease resistance, which are endogenous (SAR), in contrast to the findings of Ryals *et al.* (1996).

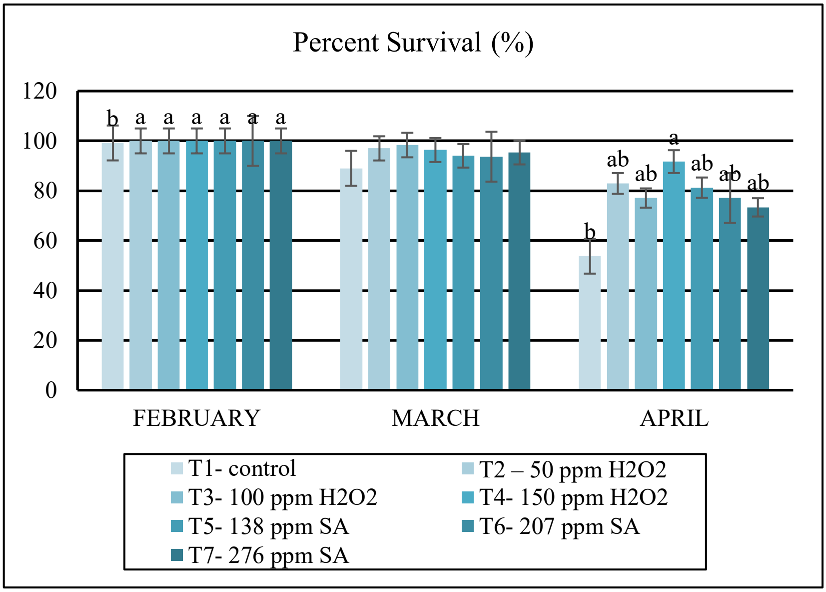

Figure 1. Percent plant survival (%) of bell pepper as influenced by hydrogen peroxide and salicylic acid. Means followed by the same letter within each hydrogen peroxide and salicylic concentrations are not significantly different at $p \leq 0.05$ based on LSD test. Error bars represent ± standard error of the mean

3.5 Bacterial Wilt Incidence

The incidence of bacterial wilt was monitored at weekly intervals (Figure 2). BW incidence was significantly affected by different concentrations of hydrogen peroxide and salicylic acid from February to April except for March. Plants under control had the highest percentage of bacterial wilt incidence and were consistent throughout the study, from the first month to the last month. Less bacterial wilt incidence was noticed in the 1st month which continued to increase until the 3rd month of the study. This result indicates that bacterial wilt was more pronounced at the fruiting stage of bell peppers. The primary mode of infection for this soil-borne disease, caused by *Ralstonia solanacearum*, is through the roots of the host plants. It enters through wounds created by lateral root emergence or injury. Plant species that are afflicted with this pathogen typically exhibit characteristic signs such as yellowing and wilting, which can progress to necrosis and eventual death.

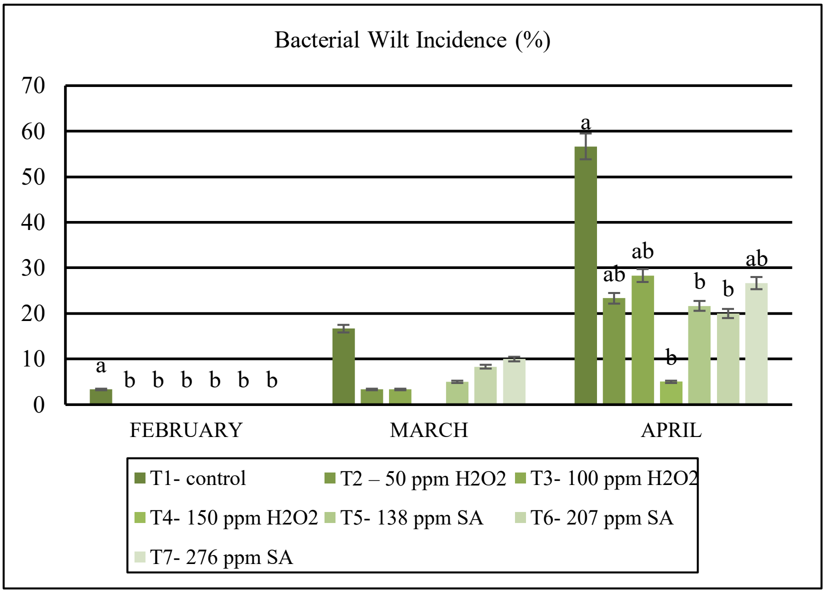

Figure 2. Percent Bacterial wilt incidence of bell pepper as influenced by hydrogen peroxide and salicylic acid. Means followed by the same letter within each hydrogen peroxide and salicylic concentrations are not significantly different at $p \leq 0.05$ based on LSD test. Error bars represent ± standard error of the mean

These results were consistent to the study of Levine *et al*. (1994) in tomato. At the site of disease infection, the administration of hydrogen peroxide has the potential to cause fast, localized cell death known as the hypersensitive sensitivity response (HR). It is a well-known feature of resistance that occurs when a pathogen or virulent pathogenic strain attacks and limits the growth of the pathogen. These results were consistent to the study of Levine *et al*. (1994) in tomato. At the site of disease infection, the application of hydrogen peroxide can cause fast, localized cell death known as the hypersensitive sensitivity response (HR). It is a well-known feature of resistance that occurs when a pathogen or virulent pathogenic strain attacks and limits the growth of the pathogen. A group of SAR genes, including pathogenesis-related (PR) proteins - becomes activated throughout the development of SAR (Ryals *et* *al*., 1996). Moreover, SA, a well-known SAR inducer, has been found to inhibit the H_2O_2 scavenging enzymes catalase and ascorbate peroxidase (Gaffney *et al*., 1993; Chen *et al.*, 1993). It was suggested that the mobile downstream signal of SA during SAR is the accumulation of H_2O_2. Additional findings showed that SA treatment increases H_2O_2 (Kauss & Jeblick, 1996) and that H_2O_2 stimulates the expression of genes associated to SAR protection (Chen *et al*., 1993). These results also demonstrate a relationship between the ability of SA analogs to inhibit ascorbate peroxidase and catalase and their capacity to activate defense-related genes and enhance resistance (Durner & Klessig, 1995; Conrath *et al*., 1995).

Furthermore, several reports have shown that SA is engaged in both HR and SAR. According to Shirasu *et al*. (1997), in soybean cell cultures, SA induced defense gene transcripts, H_2O_2 buildup, and hypersensitive cell death. According to a newer hypothesis by Anderson *et al*. (1998), SA may help regulate excessive ROS by preventing catalase inhibition at the infection site, where H_2O_2 levels are exceptionally high due to induced oxidative burst by the pathogen. However, SA may block catalase in distant, uninfected tissues with lower hydrogen peroxide concentrations. The ensuing H_2O_2 may mediate the activation of the defensive response. In addition, SA's interaction with catalase's peroxidative cycle produces SA radicals, which have the potential to start a chain reaction leading to lipid peroxidation. Lipid peroxidation products may function as a signal for initiating defense reactions. On the other hand, studies have also shown that H_2O_2 increases SA production, indicating that H_2O_2 may act prior to SA (León *et al*., 1995). When considered collectively, there is compelling evidence that H_2O_2 and SA work in an intricate tandem to activate both SAR & HR in numerous plant and pathogen interactions.

3.6 Meteorological Data

Weekly in and out temperature ranged from (28.07-35.50°C and 25.83-30.40°C, respectively). However, the lowest temperature was observed in the first month of the experiment and increased in the succeeding weeks (Figure 3). The highest temperature inside the tunnel was observed in the 5th week. Meanwhile, the highest temperature outside of the experimental area was recorded in the 8th week of the study. This can be correlated with the slower growth observed on four consecutive weeks as well as the lesser yield of bell pepper. Moreover, the recommended growing temperature for bell pepper is 21 to 26°C (Haifa-group, 2018). On the other hand, elevated temperatures impact various facets of plant physiology and development, potentially causing direct or indirect effects on fruit set. Higher ethylene production and lower concentrations of reducing sugars in flower buds and flowers have been related to reduced fruit set in pepper under high temperatures (Aloni *et al*., 1991). Elevated temperatures may also have an indirect impact on fruit set because they create vapor pressure deficits (VPDs), which can result in water deficits. Higher VPD leads to increased transpiration and evaporation from leaf surfaces (Larcher, 1995). According to Nilsen and Orcutt (1996), stomata will close, and leaf water potential will decrease if the VPD leads to a water deficit in the plant, which will consequently lower photosynthesis. Unfortunately, research on the impact of water deficiency on pepper fruit set has been scanty (Katerji *et al*., 1993).

The weekly relative humidity is presented in (Figure 3). Data shows that relative humidity was highest in the 3rd week with 70 percent (%) and the lowest was observed during week 5 of the study. Air temperature and relative humidity (RH) during anthesis, fruit set, development, and maturation, as well as plant growth, affect the size and growth of bell pepper fruits (Jovicich *et al*., 2004). Atmospheric humidity significantly influences plant growth (Hirai *et al*., 2000). The rate of leaf emergence, plant height, leaf area, leaf blade length, leaf sheath length, number of roots, total root length, and photosynthesis were all boosted by high levels of moisture during the light period (Hirai *et al*., 2000). Relative humidity (RH) is essential for plant growth and development.

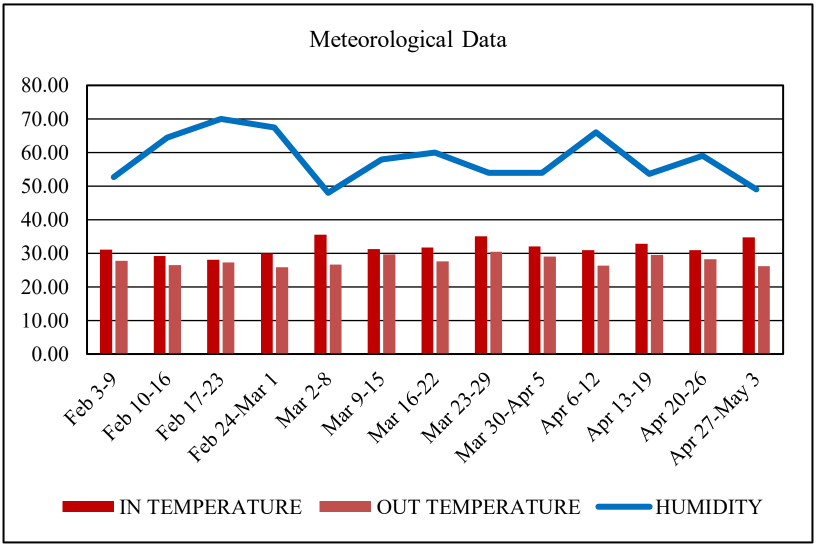

Figure 3. Weekly temperature and humidity from February 2020 to May 2020 taken from in and out thermometer at the experimental area in Brgy. Cabintan, Ormoc, City Leyte

4. Conclusion and Recommendation

Higher hydrogen peroxide (H_2O_2) concentrations combined with lower salicylic acid (SA) levels significantly improved bell pepper growth and yield. The application of 150 ppm H_2O_2 increased the number and weight of marketable fruits, enhanced total yield per plant, and effectively suppressed bacterial wilt, resulting in higher plant survival. In contrast, higher SA concentrations delayed flowering and harvesting. Moreover, the experiment was conducted under specific local climatic and soil conditions, which may limit the broader applicability of the findings to other production environments or seasonal variations. Future studies involving another trial conducted over different growing seasons or location, are recommended to enhance the robustness and generalizability of these results.

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