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EXOGENOUS APPLICATION OF ANTIOXIDANTS ON LEAF CHLOROPHYLL, YIELD DYNAMICS AND BERRY QUALITY OF SWEET PEPPER (*Capsicum annuum* L.)

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ABSTRACT

An experiment was carried out to investigate the influences of seven levels of antioxidants on BARI Mistimorich-1 and BARI Mistimorich-2 varieties of sweet pepper at the Central Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Antioxidants were applied to sweet pepper varieties which had a significant effect on physiology, yield and quality of sweet pepper. Among those treatments, ascorbic acid (AA) at 200 ppm with salicylic acid (SA) at 200 ppm was more potential to enhance chlorophyll a (30%), chlorophyll b (39.39%), total chlorophyll (33.73%), number of flower plant-1 (17.63%), number of fruits plants-1 (56.73%), fruit yield plant-1 (43.61%), total soluble sugar (28.67%) and vitamin C (22.75%) compare to control. The variety of BARI Mistimorich-2 produces 4.55% higher fruit yield than BARI Mistimorich-1. Among those antioxidants, AA at 200 ppm with SA at 200 ppm demonstrate the best potentiality to solved flower and fruit dropping problems and ultimately lead to higher production of sweet pepper.

Contribution/Originality: This study is one of very few studies which have investigated the sweet pepper responses to antioxidants in robi season and their role in mitigating the possible constrain during the production.

1. INTRODUCTION

Species are vital for the agricultural economy, especially for domestic consumption and exchange earnings. It provides vitamin a, c and e and supply of thiamine, beta carotene, folic acid and vitamin B6. It's used in numerous shapes like green, condiments, spices, pickles and sauces. Sweet pepper (*Capsicum annuum* L.) Is also a promising farming crop in Bangladesh? It is a recently introduced crop in our country usually acquainted as capsicum or bell pepper, belongs to the Solanaceae family. Pepper may be a crucial agricultural crop, not only contribute to its economic importance but also for the nutritional value of its fruits, it is an excellent supply of natural colors and inhibitor compounds vital for human health (Howard, Talcott, Brenes, & Villalon, 2000). It's medicinal properties and used form of a vegetable that can be consumed as raw as a dish or fried. It is also often supplemental to soups, omelets, stews, brochettes, rice, pasta and pizza.

Ascorbic acid (AA) is taken into consideration as one of the universal non-enzymatic antioxidants molecules that play a task in the detoxification of ROS and intermediating many vital functions in plants each under stress and traditional conditions. However, its physiologically active type is ascorbate that cited as a very important soluble antioxidant molecule throughout a biological system (Akram, Shafiq, & Ashraf, 2011; Qian et al., 2014). Exogenous foliar application of AA is also effective against lipids and protein protection below abiotic stresses-induced oxidative adversaries (Naz, Akram, & Ashraf, 2016). El-Hifny and El-Sayed (2011) observed that AA spraying enriches the macronutrient contents of sweet pepper fruits. Different investigators found similar results on the stimulatory effects of AA on different plants like eggplant (Ei-Tohamy, Ei-Abagy, & Ei-Greadly, 2008) and lettuce (Shafeek, Helmy, Marzauk, & Magda).

Salicylic acid (SA) is known as a phenoplast compound made inside the regulation of plant growth and improvement and its response to biotic and abiotic stress factors (Miura & Tada, 2014) SA is engaged in the regulation of most plant biological processes like a chemical process, proline metabolism, nitrogen metabolism, antioxidant defense system and protects against abiotic stresses (Khan, Fatma, Per, Anjum, & Khan, 2015). El-Al and Faten (2009) found that the foliar application of salicylic acid plays a significant role in raising the productivity of sweet pepper. The non-enzymatic antioxidative system consists of compounds as ascorbic acid (vitamin c), salicylic acid, ά- e, carotenoids, and flavonoids, whereas the catalyst antioxidative system consists SOD, ascorbate peroxidase (APX), glutathione catalase (GR), enzyme (CAT), peroxidase (POD) and polyphenol oxidase (PPO), etc. Scavenge the reactive oxygen species (ROS) produced in plant cells throughout oxidative stress inside the most role of the inhibitor system and therefore facilitate the plants to beat such stress conditions (Mandal, Yadav, Yadav, & Nema, 2009).

However, the production of sweet pepper is decreased due to flower and fruit drop that is caused by a physiological and hormonal imbalance inside the plants particularly below unfavorable environments (Erickson & Markhart, 2001). There is plenty of research data on the application of varied technologies on sweet pepper that are obtainable in different countries, however very little or no is documented on the comparative study of foliar application of antioxidants with different sweet pepper verities in Bangladesh. Considering the above-named facts, a pot experiment has been designed to assess the optimum concentration of antioxidants i.e. ascorbic and salicylic acids and their impact on the growth, morphology, yield and quality of sweet pepper.

2. MATERIAL AND METHODS

2.1. Experimental Area

A pot experiment was conducted at the central research Field of Sher-e-Bangla Agricultural University, Dhaka-1207 from Nov, 2019 to May, 2020. The soil of the experimental pot belongs to the overall soil category, shallow red-brown terrace soil with silty clay. Soil hydrogen ion concentration was 5.6 and has organic carbon 0.45%.

2.2. Treatment and Experimental Layout

Sweet pepper was used as the check crop during this experiment. The experiment comprised two factors viz. variety: BARI Mistimorich-1 and BARI Mistimorich-2 and antioxidant concentrations: control, AA@100 ppm, AA@200 ppm, SA@100 ppm, SA@200 ppm, AA@100 ppm + SA@100 ppm and AA@200 ppm + SA@200 ppm. The randomized complete block design (RCBD) was followed within the experiment includes 3 replications. There were 14 pots for each replication resulting in 42 pots containing 24 kg of soil in each pot.

2.3. Crop Husbandry

Seeds (0.23 g m^{-2}) were sown in the seedbed for healthy seedlings. The fertilizers were applied 10-ton cowdung ha^{-1}, 250 kg carbamide ha^{-1}, 350 kg TSP ha^{-1}, 250 kg MP ha^{-1}, 110 kg gypsum $ha^{-1}$and 5 kg zinc sulfate ha^{-1} as a supply of NPKSZn. The half quantity of cowdung was applied before the final preparation of pots and the rest ½ quantity of cowdung, TSP, MoP, gypsum, zinc sulfate and 1/3rd of urea were applied inside 2 installments after 25 and 50 days after transplanting. Intercultural operations were done to make sure the general growth of the crop. Plant protection measures were followed as and once necessary.

2.4. Application of Antioxidants

In this experiment, the ascorbic acid and salicylic acid solution were applied in 3 installments. The 1st, 2nd and 3rd sprays were done at 25, 45 and 65 DAT with a hand sprayer.

2.5. Data Collection

Plants were chosen haphazardly from every pot. Data on the subsequent parameters were recorded throughout the experiment such as:- chlorophyll a (mg l^{-1}), chlorophyll b (mg l^{-1}), Total chlorophyll (mg l^{-1}), number of flower $plant^{-1}$, number of fruits $plants^{-1}$, Fruit yield $plant^{-1}$ (g), total soluble sugar (%) and vitamin c (mg/100g).

2.6. Statistical Analysis

The data obtained from different parameters were statistically analyzed following the computer-based package Statistix 10 and mean separation were done by LSD at 5% level of significance (Gomez & Gomez, 1984).

3. RESULTS

3.1. Chlorophyll Content

The varieties (except chlorophyll a), antioxidants and their interaction positively responded to the different photosynthetic pigments like chlorophyll a, chlorophyll b and total chlorophyll Figure 1, Figure 2 and Table 1, respectively. Among the varieties, treatments and interactions, BARI Mistimorich-2, T_6 (AA@200+SA@200) and combination of BARI Mistimorich-2 with T_6 (AA@200+SA@200) exhibit the highest content of chlorophyll a, chlorophyll b and total chlorophyll, respectively. On the contrary, BARI Mistimorich-1, T_0 (control) and combination of BARI Mistimorich-1 with T_0 (control) exhibit the lowest content of chlorophyll a, chlorophyll b and total chlorophyll, respectively.

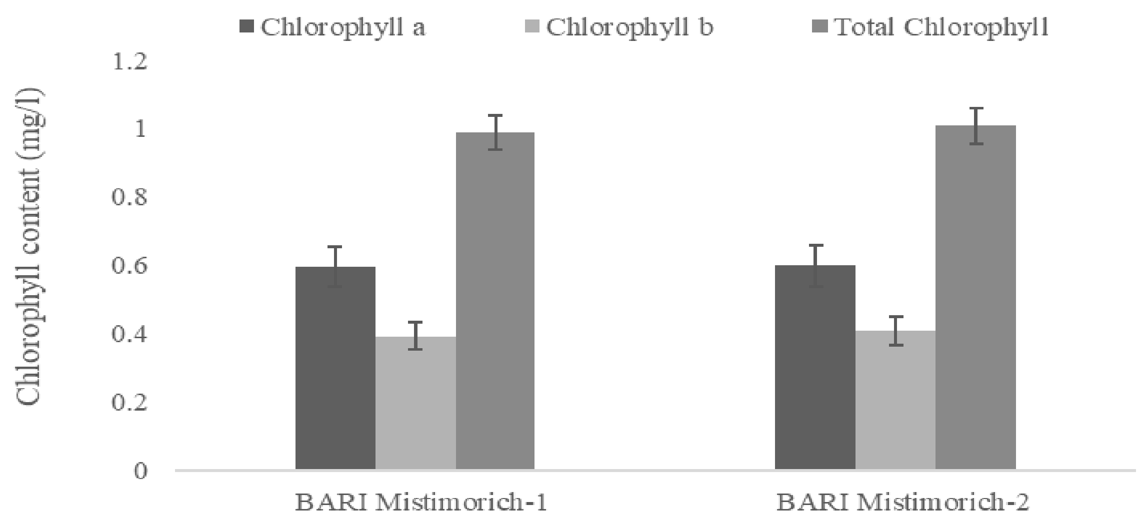

Figure-1. Effect of varieties on chlorophyll content of sweet pepper.

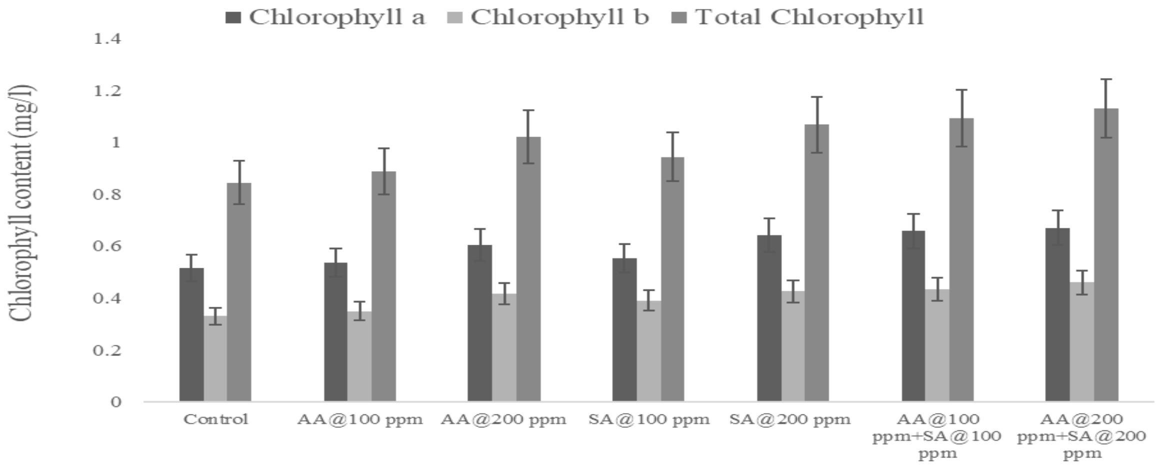

Figure-2. Effect of antioxidants on chlorophyll content of sweet pepper.

Table-1. Interaction effect of varieties and antioxidants on chlorophyll contents of sweet pepper.

Varieties × antioxidants	Chl a (mg/l)	Chl b (mg/l)	Total Chlorophyll (mg/l)
BARI Mistimorich-1 ×			
Control	0.52g	0.33g	0.84i
AA@100	0.53fg	0.34g	0.87hi
AA@200	0.59e	0.42de	1.01e
SA@100	0.55fg	0.37f	0.92g
SA@200	0.64cd	0.42cde	1.06cd
AA@100+SA@100	0.68ab	0.43cde	1.10b
AA@200+SA@200	0.66abc	0.45ab	1.11ab
BARI Mistimorich-2 ×			
Control	0.51g	0.33g	0.85i
AA@100	0.54fg	0.36f	0.90gh
AA@200	0.61de	0.42de	1.03de
SA@100	0.56f	0.41e	0.97f
SA@200	0.64bcd	0.43bcd	1.07bc
AA@100+SA@100	0.64cd	0.44bc	1.08bc
AA@200+SA@200	0.68a	0.47a	1.15a
$LSD_{(0.05)}$	0.034	0.022	0.427
CV (%)	3.4	3.25	2.55

Note: Values followed by the same letter(s) did not differ significantly at 5% level of probability.

3.2. Number of Flowers Plant^{-1}

The flower number plant^{-1} differed remarkedly among varieties, antioxidants and their interaction effect. Out of varieties, BARI Mistimorich-2 gave a higher flower number than BARI Mistimorich-1 Table 2. Among the treatment variations, T_6 (AA@200+SA@200) showed the highest flower number than other treatments whereas, T_0 (control) showed the lowest flower number Table 3. In their combinations, BARI Mistimorich-2 with T_6 (AA@200+SA@200) treatment exhibits the highest flower number whereas, the BARI Mistimorich-1 with T_0 (control) exhibits the lowest flower number Table 4.

3.3. Number of Fruits Plant^{-1}

The fruits number plant^{-1} varied notably among antioxidants and their interaction effect except varieties. Among the varieties, BARI Mistimorich-2 showed a statistically higher fruit number than BARI Mistimorich-1 Table 2. In between treatment variations, T_6 (AA@200+SA@200) exhibits the maximum fruit number than other treatments whereas, the T_0 (control) showed the minimum fruit number Table 3. In their combinations, BARI Mistimorich-2 with T_6 (AA@200+SA@200) treatment indicates the highest fruit number whereas, the BARI Mistimorich-1 with T_0 (control) indicates the lowest fruit number Table 4.

3.4. Fruit Yield Plant^{-1} (g)

The application of antioxidants significantly increased the fruit yield of plants. Among the varieties, BARI Mistimorich-2 gave a higher fruit yield than BARI Mistimorich-1 Table 2. In between treatment variations, T_6 (AA@200+SA@200) exhibits the maximum fruit yield than other treatments whereas, the T_0 (control) showed the minimum fruit yield Table 3.

In their combinations, BARI Mistimorich-2 with T_6 (AA@200+SA@200) treatment indicates the highest fruit yield whereas, the BARI Mistimorich-1 with T_0 (control) indicates the lowest fruit yield Table 4.

3.5. Total Soluble Sugar (%)

Total soluble sugar differed significantly by the application of different antioxidants except for varieties Table 2, Table 3 and Table 4, respectively.

Among the varieties, treatments and interactions, BARI Mistimorich-2, T_6 (AA@100+SA@100) treatment and combination of BARI Mistimorich-2 with T_6 (AA@200+SA@200) treatment showed the maximum soluble sugar, respectively. On the other hand, BARI Mistimorich-1, T_0 (control) treatment and combination of BARI Mistimorich-1 with T_0 (control) treatment showed the minimum soluble sugar, respectively.

3.6. Vitamin C (mg/100g)

Vitamin C varied considerably by the application of different antioxidants except for varieties Table 2, Table 3 and Table 4, respectively.

Among the varieties, treatments and interactions, BARI Mistimorich-2, T_6 (AA@100+SA@100) treatment and combination of BARI Mistimorich-2 with T_6 (AA@200+SA@200) treatment exhibit the maximal vitamin c, respectively. On the other hand, BARI Mistimorich-1, T_0 (control) treatment and combination of BARI Mistimorich-1 with T_0 (control) treatment exhibit minimal vitamin c, respectively.

Table-2. Effect of variety on yield dynamics and berry quality of sweet pepper.

Variety	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruits yield plant^{-1} (g)	TSS (%)	Vitamin c (mg/100g)
BARI Mistimorich-1	31.33b	7.81a	387.62b	3.39a	119.48a
BARI Mistimorich-2	32.38a	8.09a	405.24a	3.54a	122.29a
$LSD_{(0.05)}$	0.85	ns	14.88	0.19	3.12
CV (%)	4.19	6.52	5.92	8.99	4.07

Note: Values followed by the same letter(s) did not differ significantly at 5% level of probability.

Table-3. Effect of treatments on yield dynamics and berry quality of sweet pepper.

Treatments	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruits yield plant^{-1} (g)	TSS (%)	Vitamin c (mg/100g)
Control	29.333e	6.17d	305.00d	3.00c	107.83d
AA@100	30.17de	7.33c	370.00c	3.20bc	111.50d
AA@200	31.33cd	8.33b	413.33ab	3.57ab	124.17b
SA@100	31.50cd	7.33c	391.67bc	3.25bc	118.17c
SA@200	32.83bc	8.33b	425.00a	3.64a	124.17b
AA@100+SA@100	33.33ab	8.50b	431.67a	3.72a	128.50ab
AA@200+SA@200	34.50a	9.67a	438.00a	3.86a	131.83a
$LSD_{(0.05)}$	1.58	0.62	27.83	0.37	5.84
CV (%)	4.19	6.52	5.92	8.99	4.07

Note: Values followed by the same letter(s) did not differ significantly at 5% level of probability.

Table-4. Interaction effect of varieties and antioxidants on yield dynamics and berry quality of sweet pepper.

Varieties × antioxidants	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Fruits yield plant^{-1} (g)	TSS (%)	Vitamin c (mg/100g)
BARI Mistimorich-1 ×					
Control	28.60g	6.00e	293.33f	2.90f	106.67e
AA@100	29.67fg	7.33d	353.33de	3.03ef	109.67e
AA@200	31.00def	8.00cd	406.67abc	3.50abcde	123.33bc
SA@100	31.00def	7.33d	383.33d	3.20cdef	114.67de
SA@200	32.00bcde	8.33c	416.67abc	3.60abcd	123.33bc
AA@100+SA@100	32.67abcd	8.33c	426.67ab	3.70abc	128.33abc
AA@200+SA@200	34.33a	9.33bc	433.33ab	3.78ab	130.33ab
BARI Mistimorich-2 ×					
Control	30.00efg	6.33e	316.67ef	3.10def	109.00e
AA@100	30.67defg	7.33d	386.67cd	3.37bcdef	113.33e
AA@200	31.67cdef	8.67bc	420.00abc	3.63abc	125.00bc
SA@100	32.00bcde	7.33d	400.00bc	3.30bcdef	121.67cd
SA@200	33.67abc	8.33c	433.33ab	3.68abc	125.00bc
AA@100+SA@100	34.00ab	8.67bc	436.67ab	3.73ab	128.67abc
AA@200+SA@200	34.67a	10.00a	443.33a	3.93a	133.33a
$LSD_{(0.05)}$	2.24	0.87	39.36	0.52	8.26
CV (%)	4.19	6.52	5.92	8.99	4.07

Note: Values followed by the same letter(s) did not differ significantly at 5% level of probability.

4. DISCUSSION

Antioxidants particularly ascorbic acid and salicylic acid play a possible role in enhancing the physiological method that overcomes the environmental stresses leading to optimum yield.

The effect of antioxidants on plant growth may be because of the plant hormone action of antioxidants also as, its improved role in several metabolic and physiological processes and enhancing the synthesis of carbohydrates (Wassel, Hameed, Gobara, & Attia, 2007). SA application multiplied chlorophyll a and b in plants (Zaki & Radwan, 2011). El Bassiouny, Gobarah, and Ramadan (2005) reportable that foliar spray with antioxidant (vitamin E) on bean plants elicited increments in chlorophyll a and b content. Within the same respect, the prevalence of spraying salicylic acid and vitamin e these results is also because of the role of antioxidants in enhancing some physiological and organic chemistry aspects (Maity & Bera, 2009) or increasing N,P,K and Ca content, activity in inhibitor enzymes and glutathione content (Khan et al., 2009) on the leguminous plant.

The application of antioxidants increased flower production, reduced flower abscission that contributed to the most varieties of flowers per plant. This results in agreement with the findings of Choudhury., Islam, Sarkar, and Ali (2013) who found that the best range of flowers per plant was obtained in combined application 4-CPA and GA_3 within the summer tomato. It was noticed that the application of NAA increased flower production, reduced flower abscission that contributed to the utmost number of flowers per plant compared to plants that were treated with other hormones and management (Chaudhary, Sharma, Shakya, & Gautam, 2006).

The application of antioxidants increased fruit production, reduced fruit abscission that contributed to the most variety of fruits per plant compared to plants treated with different antioxidants and management. Sarkar, Jahan, Kabir, Kabir, and Rojoni (2014) additionally reported that plant growth regulators have nice potential to facilitate the flower and fruit set also because of the yield of summer tomato. Deb, Suresh, Saha, and Das (2009) found a major response of NAA regarding the number of fruits per plant. It was noticed that the application of 4-CPA enhances fruit set by reducing fruit abscission that contributed to a better range of fruit plant^{-1} (Das, Sarkar, Alam, Robbani, & Kabir, 2015).

The increments in flowering and fruit yield because of treating the plants with ascorbic acid and salicylic acid treatments might be connected with their impact on increasing the vegetative growth parameters and photosynthetic pigments that affect plant growth and successively enhanced its productivity. Nour, Mansour, and Eisa (2012) reported that yield and its components of pods were remarkably affected by different antioxidants in snap bean. Hosain, Kamrunnahar., Munshi, and Rahman (2020) observed that SA greatly influenced the grains yield of rice by the phenomenal reduction of stress. Bhalekar, Kadam, Shinde, Patil, and Asane (2009) where he disclosed that spraying of NAA recorded higher fruit yield compared to control. Sarkar et al. (2014) proclaimed that plant growth regulators have significant potential to facilitate the flower and fruit set additionally as the yield of summer tomato.

The increment in fruit parameters due to ascorbic acid and salicylic acid may be attributed to increasing vegetative growth, chemical pigments and uptake of nutrients. similar findings nearly were attained for SA in tomato (Fathy, Farid, & El-Desouky, 2000) and bean (Zaghlool, Ibrahim, Sharaf, & Eldeen, 2001). In this respect, Hayat and Ahmad (2007) found that hydroxy acid may be a plant hormone that increased plant bio productivity. The application of SA raised total soluble solids, total sugars, and antioxidants in sweet pepper fruit (Mahmood, Abbasi, Hafiz, & Zakia, 2017).

The antioxidants (ascorbic acid and salicylic acid) incorporate a positive role to extend vitamin c content within the fruits. Ascorbic acid includes a well-documented role in several aspects of radix management and inhibitor activity within the plant cell, this biological science making known to highlight recent development in another facet of antioxidant metabolism (Seth, Melino, & Ford, 2007). Vitamin c was also enhanced in 'California Wonder' sweet pepper fruit in response to hydroxy acid treatment at 0.1 g L^{-1} (El-Yazeid, 2011). Ascorbic acid content was found superior in the tomato plant by the applying of PGR (GA_3) (Rahman, Saki, Hosain, & Rashid, 2019).

5. CONCLUSIONS

In conclusion, long-run exposure to cold prolonged cell cycle duration and resulted in reduced plant growth. The foliar application of antioxidants (ascorbic acid and salicylic acid) treatments were typically effective in alleviating the injury caused by cold through stimulating the vegetative growth, photosynthetic pigments, and bioconstituents activities that could be reflected on the yield and quality of sweet pepper fruit. Foliar spraying with ascorbic acid at 200 ppm combined with salicylic acid at 200 ppm being the most effective. It is postulated that the foliar spraying with ascorbic acid and salicylic acid at low temperatures may positively regulate the pepper growth and therefore improved productivity.

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