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Original article

Impact of plant growth regulators spray on fruit quantity and quality of pepper (*Capsicum annuum* L.) cultivars grown under plastic tunnels

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ABSTRACT

The study aims to investigate the effect of foliar spray with three plant growth regulators (PGRs) p-Chlorophenoxyacetic acid (CPA) at 20 and 40 ppm; Gibberellic acid (GA3) at 20 and 30 ppm, 1-Naphthaleneacetic acid (NAA) at 10 and 20 ppm on the response of fruit set, yield, and fruit quality of some hot pepper cultivars (Chillina, Parbirian, Shampion, and Hyffa) grown in sandy soil under plastic tunnels as compared to the control. Spraying Chillina cultivar GA3 at 30 ppm significantly increased the number of fruits/ plant and fruit set (%), yield/plant, and total yield/fad. In addition, the contents of TSS and Vit C, furthermore, maximum capsaicin content were observed in chili fruits in both seasons. However, the interaction between Chillina cultivar and spraying with GA3 at 20 ppm ranked second in yield and quality. The interaction between Parbirian cultivars and spraying with GA3 at 20 or 30 ppm increased the number of flowers/plants in both seasons. On the other hand, the interaction between Shampion cultivar and spraying with tap water (control) gave the lowest values of the number of flowers/ plants, the number of fruits/ plant and fruit set (%), yield, and its components, and fruit quality in both seasons.

1. Introduction

Hot pepper (*Capsicum annuum* L) is one of the most essential medicinal and vegetable crops cultivated in Egypt. the plant has medicinal value. It is eaten as both fresh and dried spices (Bosland and Votava, 2000). Chili Pepper is the third most popular vegetable in the world after potatoes and tomatoes in production quantity. The total cultivated area of chilies and pepper (green) in Egypt in 2020 was 102,141 Feddan (fed.), which produced 790,525 tons with an average of 7.9 tonnes/fed. (Knoema, 2020)

The active compound in chili pepper is capsaicin which had several activities. The therapeutic applications of capsaicin briefed in enhancing skin blood flow, treating rheumatism, sciatica, and pleurisy. In addition, diabetic headache and cluster headache is also used. It is an excellent source of vitamin B_2, potassium, phosphorus and calcium, besides, low calory. The pepper's high nutritional value results in high year-round demand on the market. Pepper fruits are used as a dried powder in salads, pickles, filling, sauces, and sauce (Mukul et al.,2018; Toyer, 2021).

Chili pepper production is not limited to genetic capacity, but also many environmental factors and cultivation practices. The production of chili decreases due to the decrement in flowers and fruits caused by the physiological and hormonal imbalance in plants as a result of nondurable conditions (Erickson and Markhart, 2001; Vega-Alfaro et al, 2021).

hot pepper cultivars showed significant differences for fruit setting (Chouhan et al 2017; Soreng and Kerketta 2017; Kesumawati et al., 2019). In addition to Productivity and fruit quality (Gungor and Yildirim, 2013, Chowdhury et al. 2015; Ibrahim et al. 2019).

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Plant regulators play a crucial role in various metabolic processes, such as cell division, differentiation and expansion, organogenesis, and germination and are being widely used to increase fruit quality. The quality of green pepper during harvest and post-harvest were maintained by applying gibberellic acid (GA_3) (dos Anjos et al, 2022). Spraying hot pepper with p-Chlorophenoxyacetic acid (CPA), Gibberellic acid (GA3) 1-Naphthaleneacetic acid (NAA) recorded the best results for enhancing fruit setting (Sreenivas et al. 2017; Akhter et al. 2018; Mahindre, et al. 2018). Yield (Patel et al. 2016; Shankhwar et al. 2017; Tapdiya et al. 2018) and fruit quality (Chaudhary et al. 2006; Deshmukh et al. 2010) than unsprayed plants.

The aim of this work to study the effect of GA_3, 4-CPA and NAA growth regulators foliar spray on fruit setting, productivity and fruit quality of some hot pepper cultivars grown under conditions of plastic tunnels.

2. Materials and methods

2.1. Materials

The source of chilli seeds for Chillina and Parbirian cultivars were obtained from Sand Valley Company, Shampion cultivar was from New Star Seed Company and Hyffa cultivar was from Enza zaden Company. The growth regulators (4-CPA, GA_3 and NAA) were purchased from Al Gomhouria Company, Zigzag , Sharkia , Egypt.

2.2. Chemical composition of soil

The soil was chemically analyzed according to Black (1982). The experimental soil was textured sandy, with a method of drip irrigation. The chemical analysis of soil at two seasons was organic matter, 0.07 and 0.09 %; N was 14.62 and 14.98 ppm, available P was 18.0 and 19.46 ppm, available K was 59.6 and 63.1 ppm, available pH 7.90 and 7.88 and E.C. 2.10 and 2.50 m mhos/cm, respectively.

2.3. Experimental design

During the two seasons of 2015/2016 and 2016/2017, the present study was performed at the private farm (The Experimental Farm of Sand Valley Company) at the Ismailia Governorate, Egypt. The response of flowering, yield and fruit quality of the pepper cultivars (Chillina, Parbirian, Shampion and Hyffa) affected by foliar spray of growth regulators treatments (CPA at 20 and 40 ppm, GA_3 at 20 and 30 ppm and NAA at 10 and 20 ppm were studied. Besides, unsprayed treatment (control) of hot chilli grown under tunnel plastic conditions.

This experiment included 28 treatments that were the combination of 4 cultivars and 3 plant growth regulators at two concentrations as compared to control. Such treatments were grouped with three replicates in a split plot in a complete randomized block design. Cultivars were arranged randomly in the main plots and some treatments of the growth regulators (PGRs) randomly distributed in the sub plots. Chili cultivar seeds were sown on 10th Oct. in speed trays under plastic tunnels in the 2015/2016 and 2016/2017 seasons, then were transplanted at 15th Nov. on both row with a width of 1.8 m and a length of 3.6 m with 0.4 m separation between each plant. The plot area was 6.48 m^2 which occupied by 20 plants. In both seasons, the tunnels were removed on 15th March, when temperatures were suitable for rising chili plants.

The plot was sprayed with 2L of 4-chlorophenoxyacetic acid (4-CPA), gibberellic acid (GA3); and naphthaleneacetic acid (NAA) after 20 days from sowing then weekly sprayed. The PGRs homogenized in aqueous solutions using spreading agent (reflecting material). The control plants were treated with tap water mixed with spreading agent. The following data were recorded Flowering characters: At flowering stage, the number of flowers per plant was recorded

2.4. Fruit yield

The cultivars Chillina, Parbirian, Shampion and Hyffa were harvested, respectively after 85, 88, 115 and 100 days from transplanting. Fruits were harvested at intervals of two days, at a length of 12–15 cm and the following data were recorded, Number of fruits/-plant, fruit set % was determined by divided number of fruit setting /total flower per plant, fresh weight of fruit/ plant (gm), total yield / fad. was recorded during the harvesting period and relative increases in total yield were calculated (El-Saadony et al, 2021a).

2.5. Fruit quality

The quality parameters; vitamin C (mg /100 g FW) in chili fruits were estimated according to AOAC (2000). TSS (Brix ^{o}) were mesured by using Hand Refractometer (Saad et al., 2021a). Total capsaicin content in chili fruit (mg /100 g as dry weight) during the second season (2016/2017) only was determined as Popelka et al. (2017).

2.6. Statistical analysis:

The data were statistically analysis using the COSTAT program. The differences between values means were estimated by least significant value (L.S.D.) at 0.05 level of probability according to Snedecor and Cochran (1967).

3. Results

3.1. Number of flowers, number of fruits/ plant and fruit set

3.1.1. Effect of cultivars

There were significant differences among four cultivars respecting number of flowers, number of fruits/ plant and fruit set in both seasons (Tables 1 to 3).

Parbirian cultivar recorded maximum number of flowers/plant, followed by Chillina cultivar, whereas Hyffa cultivar recorded minimum values. On the other hand, Chillina cultivar recorded maximum number of fruits/ plant and fruit set followed by Hyffa cultivar, whereas Champion cultivar recorded minimum number of fruits/ plant and fruit set (%).

3.1.2. Effect of some PGRs

Foliar spray chili plants with 4-CPA, GA_3 and NAA at different concentrations increased number of flowers / plant, number of fruits/ plant and fruit set (%) in both seasons compared to control (spraying with tap water) as shown in Tables 1-3.

Spraying with GA_3 at 30 ppm increased number of flowers / plants, and number of fruits/ plant, followed by spraying with GA_3 at 20 ppm. as for fruit set (%), spraying with 4-CPA at 40 and 20 ppm increased fruit set followed by GA_3 at 30 and 20 ppm in both seasons. Spraying NAA at 10 ppm recorded minimum values of number of flowers, number of fruits/ plant and fruit set (%) in both seasons.

3.1.3. Effect of the interaction

Data in Tables 1-3 indicate that the interaction between Parbirian cultivar and spraying with GA_3 at 30 ppm increased number of flowers / plant in both seasons. However, spraying Chillina cul-

Table 1
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on Number of flowers /plant of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA		GA_3		NAA		Mean (C)
	0.0	20	40	20	30	10	20	
	2015/2016 season							
Chillina	35.33	37.00	48.00	56.33	60.33	42.00	49.00	**46.86**
Parbirian	36.67	51.33	64.00	72.00	74.33	47.00	50.67	**56.57**
Shampion	37.67	44.33	51.33	53.67	61.67	41.67	47.00	**48.19**
Hyffa	33.00	38.33	41.33	41.67	45.67	35.67	41.00	**39.52**
Mean (PGRs)	**35.67**	**42.75**	**51.17**	**55.92**	**60.50**	**41.59**	**46.92**	
LSD at 5%	**(C) = 0.81**		**(P) = 1.52**			**(C × P) = 2.93**		
	2016/ 2017 season							
Chillina	41.33	48.33	53.67	65.00	66.67	49.67	54.33	**54.14**
Parbirian	41.67	51.67	53.67	66.33	69.67	53.00	55.67	**55.95**
Shampion	41.33	39.67	50.00	49.00	58.67	40.00	42.33	**45.86**
Hyffa	35.33	37.00	42.67	47.00	51.67	38.33	40.00	**41.71**
Mean (PGRs)	**39.92**	**44.17**	**50.00**	**56.83**	**61.67**	**45.25**	**48.08**	
LSD at 5%	**(C) = 1.23**		**(P) = 1.44**			**(C × P) = 2.92**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Table 2
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on Number of fruits /plant of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA	GA_3	NAA	Mean (C)			
	0.0	**20**	**40**	**20**	**30**	**10**	**20**	
2015/2016 season								
Chillina	24.00	23.33	25.67	29.67	33.67	23.67	26.33	**26.62**
Parbirian	10.67	18.00	23.33	22.00	24.00	15.33	18.00	**18.76**
Shampion	8.67	17.00	16.67	18.33	21.67	9.67	16.67	**15.53**
Hyffa	11.67	19.00	22.67	23.33	25.33	14.33	18.67	**19.29**
Mean (PGRs)	**13.75**	**19.33**	**22.09**	**23.33**	**26.17**	**15.75**	**19.92**	
LSD at 5%	**(C) = 0.37**	**(P) = 0.83**	**(C × P) = 1.58**					
2016/ 2017 season								
Chillina	21.00	27.00	32.33	35.33	42.67	26.33	31.33	**30.86**
Parbirian	11.33	22.00	26.00	28.00	28.33	16.00	20.67	**21.76**
Shampion	10.67	16.33	18.00	17.67	19.00	13.33	17.00	**16.00**
Hyffa	13.00	19.67	23.67	25.00	26.67	18.33	21.67	**21.14**
Mean (PGRs)	**14.00**	**21.25**	**25.00**	**26.50**	**29.17**	**18.50**	**22.67**	
LSD at 5%	**(C) = 0.91**		**(P) = 1.05**			**(C × P) = 2.13**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Table 3
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on fruit set (%)of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA		GA_3		NAA		Mean (C)
	0.0	20	40	20	30	10	20	
	2015/2016 season							
Chillina	67.97	63.07	53.49	52.64	55.86	56.36	53.87	**57.61**
Parbirian	29.21	36.07	36.50	30.57	32.28	32.72	35.56	**33.27**
Shampion	23.04	38.50	32.47	34.17	35.13	23.21	35.47	**31.71**
Hyffa	35.37	49.59	54.89	56.02	55.49	40.16	45.55	**48.15**
Mean (PGRs)	**38.90**	**46.81**	**44.34**	**43.35**	**44.69**	**38.11**	**42.61**	
LSD at 5%	**(C) = 0.77**		**(P) = 2.21**			**(C × P) = 4.16**		
	2016/ 2017 season							
Chillina	50.81	55.84	60.30	54.38	64.34	53.02	57.72	**56.63**
Parbirian	27.26	42.63	48.44	42.20	40.65	30.19	37.11	**38.35**
Shampion	25.79	41.27	36.00	36.06	32.38	33.41	40.02	**34.99**
Hyffa	36.79	53.20	55.48	53.24	51.62	47.82	54.21	**50.34**
Mean (PGRs)	**35.16**	**48.24**	**50.06**	**46.47**	**47.25**	**41.11**	**47.27**	
LSD at 5%	**(C) = 1.62**		**(P) = 2.54**			**(C × P) = 4.92**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Table 4
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on fruit yield /plant (g) of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA		GA_3		NAA		Mean (C)
	0.0	20	40	20	30	10	20	
	2015/2016 season							
Chillina	356.67	420.00	430.00	466.67	505.00	376.67	413.33	**424.05**
Parbirian	223.33	278.33	371.67	440.00	435.00	240.00	331.67	**331.43**
Shampion	83.33	106.67	101.67	118.33	140.00	96.67	93.33	**105.71**
Hyffa	186.67	263.33	316.67	335.00	383.33	221.67	265.00	**281.67**
Mean (PGRs)	**212.50**	**267.08**	**305.00**	**340.00**	**365.83**	**233.75**	**275.83**	
LSD at 5%	**(C) = 6.64**		**(P) = 11.45**			**(C × P) = 22.19**		
	2016/ 2017 season							
Chillina	420.00	453.33	520.00	540.00	596.67	440.00	470.00	**491.43**
Parbirian	233.33	265.00	356.67	450.00	473.33	273.33	360.00	**344.52**
Shampion	73.33	111.67	96.67	110.00	153.33	88.33	95.00	**104.05**
Hyffa	195.00	305.00	303.33	336.67	378.33	250.00	281.67	**292.86**
Mean (PGS)	**230.42**	**283.75**	**319.17**	**359.17**	**400.42**	**262.92**	**301.67**	
LSD at 5%	**(C) = 3.68**		**(P) = 12.58**			**(C × P) = 23.57**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

tivar with GA_3 at 30 ppm increased number of fruits/ plant in both seasons, followed by the effect of foliar spray of GA_3 (20 ppm) on Chillina. Regarding, fruit set, the interaction between Chillina treated with GA_3 spray (30 ppm) increased fruit set in the 2nd season. Moreover, the Shampion cultivar treated with tap water (control) gave the lowest values of number of flowers/ plant, number of fruits/ plant and fruit set (%) in both seasons.

3.2. Yield / plant and total yield/fad.

3.2.1. Effect of cultivars

There were significant differences among four cultivars in total fruit yield in both seasons (Tables 4-6). Chillina cultivar recorded the highest fruit yield / plant and total fruit yield /fad. followed by Parbirian cultivar, while Shampion cultivar recorded the minimum values in this respect.

The decreases in total fruit yield /fad were about 21.86 and 27.92 % for Parbirian cultivar, 75.08 and 74.38 % for Shampion cultivar and 33.6 and 15.21 % for Hyffa and Chillina cultivar in the 1st and 2nd seasons, respectively.

3.2.2. Effect of the PGRs

Spraying with some PGRs increased yield of fruits/ plant and total fruit yield /fad. compared to control (sprayed with tap water) shown in Tables 4-6. Spraying pepper cultivars with GA_3 at 30 ppm recorded maximum values of yield / plant and total fruit yield/fad. followed by GA_3 (20 ppm), whereas minimum chili yield was recorded with NAA (10 ppm) spraying followed by spraying with 4-CPA at 20 ppm in both seasons.

The increases in total fruit yield /fad. were about 72.18 and 73.79 % for GA_3 at 30 ppm , 60.00 and 58.89 % for GA_3 at 20 ppm and 43.52 and 38.52 % for 4-CPA at 40 ppm over the control (spraying with tap water) in the 1st and 2nd seasons, respectively.

3.2.3. Interaction effect

Data in Tables 4-6 show that, the interaction effect between pepper cultivars and PGRs. Fruit yield/plant and total fruit yield/fad were increased in Chillina cultivar treated with GA_3 (30 ppm) followed by Chillina sprayed with GA_3 (20 ppm) in both seasons, whereas, minimum values were observed in Shampion cultivar treated with tap water (control) in both seasons.

From the obtained results, it could be concluded that Parbirian cultivar recorded maximum number of flowers/ plant , followed by Chillina cultivar. Chillina cultivar recorded maximum number of fruits/ plant and fret set (%), followed by Hyffa cultivar. Chillina cultivar recorded maximum fruit weight / plant and total fruit yield /fad. followed by Parbirian cultivar, Shampion cultivar recorded minimum number of fruits/ pant , fruit set , yield / plant, early and total yield /fad.

Also, spraying with GA_3 at 30 ppm increased number of flowers/ plant, number of fruits/ plant and fret set (%), fruit weight / plant and total fruit yield /fad., followed by spraying with GA_3 at 20 ppm , whereas spraying with NAA at 20 ppm, followed by spraying with 4-CPA at 20 ppm gave the lowest values of these characters.

3.3. Fruit quality

3.3.1. TSS and vitamin C

3.3.1.1. Effect of cultivars. There were a significant differences among four cultivars in fruit quality, i.e., total soluble solids (TSS) and vitamin C (Vit.C) in fruits in both seasons (Tables 7 and 8). Chillina cultivar recorded maximum values of TSS and Vit. C in fruits compared to other cultivars.

3.3.1.2. Effect of the PGRs. Spraying chilli plants with the PGRs increased TSS and Vit C in fruits in both seasons compared to control (sprayed with tap water) as shown in (Tables 7 and 8). Spraying with GA_3 at 30 ppm increased TSS and Vit C in fruits, followed by spraying with GA_3 at 20 ppm in both seasons.

3.3.1.3. Effect of the interaction. Data in Tables 7 and 8 indicate that, the interaction between cultivars and spraying with the PGRs at different concentrations had significant effect on TSS and Vit.C in fruits in both season, where the interaction between Chillina cultivar and spraying with GA_3 at 30 ppm increased TSS and Vit. C in fruits, followed by Chillina cultivar sprayed with GA_3 at 20 ppm and Hyffa cultivar with GA_3 at 30 ppm in both seasons.

3.3.2. Capsaicin content

3.3.2.1. Effect of cultivars. There were significant differences among four cultivars in Capsaicin content in chilli fruits (Table 9). Chillina cultivar recorded maximum Capsaicin content in fruits compared to other cultivars.

3.3.2.2. Effect of the PGRs. Foliar spray with the PGRs at different concentrations increased capsaicin content in chili fruits compared to control (spraying with tap water) as shown in table (Table 9).

Table 5
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on total fruit yield /fad. ton) of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA		GA_3		NAA		Mean (C)
	0.0	20	40	20	30	10	20	
2015/2016 season								
Chillina	1.997	2.352	2.408	2.613	2.828	2.109	2.315	**2.375**
Parbirian	1.521	1.559	2.081	2.464	2.436	1.344	1.857	**1.895**
Shampion	0.467	0.597	0.569	0.663	0.784	0.541	0.523	**0.592**
Hyffa	1.045	1.475	1.773	1.876	2.147	1.241	1.484	**1.577**
Mean (PGRs)	**1.258**	**1.496**	**1.708**	**1.904**	**2.049**	**1.309**	**1.545**	
LSD at 5%	**(C) = 0.037**		**(P) = 0.064**			**(C × P) = 0.124**		
2016/ 2017 season								
Chillina	2.352	2.539	2.912	3.024	3.341	2.464	2.632	**2.752**
Parbirian	1.307	1.484	1.997	2.520	2.651	1.531	2.016	**1.929**
Shampion	0.411	0.625	0.541	0.616	0.859	0.495	0.532	**0.583**
Hyffa	1.092	1.708	1.699	1.885	2.119	1.400	1.577	**1.640**
Mean (PGRs)	**1.291**	**1.589**	**1.787**	**2.011**	**2.243**	**1.473**	**1.689**	
LSD at 5%	**(C) = 0.021**		**(P) = 0.070**			**(C × P) = 0.132**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Table 6
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on relative ± (%) in total fruit yield of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA		GA_3		NAA		RYcv
	0.0	20	40	20	30	10	20	
	2015/2016 season							
Chillina	100.00	117.78	120.58	130.85	141.61	105.61	115.92	**100.0**
Parbirian	76.16	78.07	104.21	123.39	121.98	67.30	92.99	**78.14**
Shampion	23.39	29.89	28.49	33.20	39.26	27.09	26.19	**24.92**
Hyffa	52.33	73.86	88.78	93.94	107.51	62.14	74.31	**66.40**
RY PGRs	**100.00**	**125.71**	**143.52**	**160.00**	**172.18**	**110.00**	**129.83**	
	2016/ 2017 season							
Chillina	100.00	107.95	123.81	128.57	142.05	104.76	111.90	**100.0**
Parbirian	55.57	63.10	84.91	107.14	112.71	65.09	85.71	**72.08**
Shampion	17.47	26.57	23.00	26.19	36.52	21.05	22.62	**84.79**
Hyffa	46.43	72.62	72.24	80.14	90.09	59.52	67.05	**59.59**
RY PGRs	**100.0**	**123.25**	**138.52**	**155.89**	**173.79**	**114.10**	**130.93**	

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid.
Relative total yield %= Yield of treatment / yield of control x100.
Control of cultivars : Chillina, Control of PGRs = spraying with tap water.
Control of the interaction = Chillina × spraying with tap water.
RYcv = Relative yield of cultivar.
RY PGRs. = Relative yield of PRGs.

Table 7
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on total soluble solids (TSS) of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control		4-CPA		GA_3		NAA	Mean (C)
	0.0	20	40	20	30	10	20	
2015/2016 season								
Chillina	6.17	6.43	6.80	7.20	7.57	6.50	6.90	**6.80**
Parbirian	6.10	6.27	6.67	7.00	7.17	6.37	6.80	**6.63**
Shampion	5.93	6.03	6.37	6.43	6.87	6.07	6.37	**6.30**
Hyffa	6.03	6.37	6.67	6.83	7.07	6.30	6.77	**6.58**
Mean (PGS)	**6.06**	**6.28**	**6.63**	**6.87**	**7.17**	**6.31**	**6.71**	
LSD at 5%	**(C) = 0.06**		**(P) = 0.08**			**(C × P) = 0.16**		
2016/ 2017 season								
Chillina	6.33	6.27	6.97	7.07	7.67	6.73	6.83	**6.84**
Parbirian	6.20	6.33	6.83	6.93	7.30	6.37	6.70	**6.67**
Shampion	6.07	6.23	6.77	6.60	6.97	6.43	6.73	**6.54**
Hyffa	6.10	6.33	6.73	6.83	7.27	6.43	6.73	**6.63**
Mean (PGS)	**6.18**	**6.29**	**6.83**	**6.86**	**7.30**	**6.49**	**6.75**	
LSD at 5%	**(C) = 0.07**		**(P) = 0.08**			**(C × P) = 0.16**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Table 8
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on Vitamin C content (mg/100 g, f. w.) of chilli plant during 2015/2016 and 2016/2017 seasons under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							Mean (C)
	Control	4-CPA		GA_3		NAA		
	0.0	20	40	20	30	10	20	
	2015/2016 season							
Chillina	179.63	195.77	211.10	208.27	224.73	186.93	205.43	**201.69**
Parbirian	178.27	177.03	193.00	183.67	195.60	177.80	191.93	**185.33**
Shampion	172.57	172.27	183.03	174.10	179.47	173.53	182.07	**176.72**
Hyffa	180.17	185.00	198.43	197.90	209.23	185.33	195.10	**193.02**
Mean (PGRs)	**177.66**	**182.52**	**196.39**	**190.99**	**202.26**	**180.90**	**193.63**	
LSD at 5%	**(C) = 1.75**		**(P) = 3.25**			**(C × P) = 6.27**		
	2016/2017 season							
Chillina	182.33	183.27	205.43	219.17	232.00	190.60	199.10	**201.70**
Parbirian	174.77	177.63	195.43	198.50	208.43	177.57	194.07	**189.49**
Shampion	169.34	173.20	184.33	177.17	191.83	168.07	190.73	**179.24**
Hyffa	177.43	184.27	201.73	203.10	220.23	191.87	198.73	**196.77**
Mean (PGRs)	**175.97**	**179.59**	**196.73**	**199.49**	**213.12**	**182.03**	**195.66**	
LSD at 5%	**(C) = 1.45**		**(P) = 1.85**			**(C × P) = 3.71**		

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid.

Spraying with 4-CPA at 40 ppm or with GA_3 at 30 ppm increased capsaicin content in chili fruits.

3.3.2.3. Effect of the interaction. The foliar spray of 4-CPA at 40 or GA_3 at 30 ppm on Chillina cultivar or Champion cultivars recorded maximum Capsaicin content in chili fruits (Table 9).

4. Discussion

Plant growth regulators (PGRs) are organic compounds, which alter plant physiology. They play an important role in increasing plant growth and quality, stem elongation, and flower production, additionally, affect vegetative and fruit production (Ouzounidou et al., 2008; Leclerc et al., 2006). Growth regulators increased the number, size, and weight of sweet pepper fruits (Das et al. 2015). Spraying hot peppers with GA3, 4-CPA, and NAA showed better results for improving fruit set, quantity, and quality (Mahindre et al., 2018; Tapdiya et al., 2018; Deshmukh et al., 2010) compared to non-sprayed plants.

The variability in fruit yield may be due to the effect of temperature of the growing environment, associated features such as canopy diameter, which could restrict the number of branches. Moreover, as a number of major, secondary and tertiary divisions increased, there may be a possibility of growing the number of buds producing fruit that are the locations for fruit production (Delelegn, 2011).

Chili yield variability between different varieties may be due to difference in genetic make-up and prevailing soil environmental condition. Shashidhara (2003) stated that improvements in yield might be due to varieties' adaptability to local climatic and soil conditions. These results are agreeable with those reported by Hasanuzzaman et al. (2007), Dahanayake et al. (2012), Wahb-Allah (2013), Das et al. (2015), Bilal et al. (2019) and Ngullie and Biswas (2019) on chilli. They showed that the differences among cultivars, genotypes and varieties regarding total yield of chilli. In addition, Results are harmony with those obtained with Sarker et al. (2009) showed that spraying BARI Chilli-1 with NNA at 40 ppm significantly increased total yield per hectar than other interaction treatments.

Chowdhury et al. (2015), Chouhan et al. (2017), Soreng and Kerketta (2017) and Kesumawati et al. (2019) reported that number of lowers/ plant, number of fruits/ in chili plant and fruit set percentage significantly affected by different cultivars, genotypes and varieties.

The regulatory impact of exogenous application of PGRs affects early floral initiation, application of auxin at flowering time, and reduced flowers that improve fruit setting and lead to higher fruit setting percentage (Das et al. 2015).

Our Results are harmony with Chaudhary, et al. (2006), Sreenivas et al.(2017), Akhter et al. (2018), Arivazhagan et al. (2018) on Brinjal cv. Annamalai, Mahindre, et al. (2018) on chilli. They showed that spraying plants PGRs recorded the highest values of number of flowers/ plant, number of fruits/ plant and fruit set percentage, especially when sprayed with n GA_3 as compared to other PGRs or unsprayed plant.

Chaudhary, et al. (2006) showed that the interaction between Suryamukhi chilli cultivar and sprayed with NAA at 40 ppm recorded the highest values of number of fruits/ plant than other interaction treatments. In addition, Sarker et al. (2009) showed that spraying BARI Chilli-1 with NNA at 40 ppm significantly increased fruit set (%), number of fruits / plant, than other interaction treatments. In addition, Das et al. (2015) showed that the highest number of flowers and fruits /plant of chilli were recorded with spraying Lamuyo variety with 4-CPA than spraying BARI Misti morich-1 with tap water.

An improvement in fruit yield and its component characteristics due to the application of 4-CPA and GA_3 could be attributed to a more effective use of food for reproductive growth (flowering and fruit set), increased photosynthetic output and increased source for plant sinking, increased nutrient and water intake, reduced transpiration and breathing, increased translocation and accumulation of sugar and other metabolites (Chaudhary, et al. 2006).

Balraj et al. (2002), Natesh et al. (2005), Vandana and Verma, 2014, Sanjay, and Singh (2019) found that the highest early and total yield of chilli were obtained with the plants, which sprayed with PGRs, especially GA_3. On the other hand, the fruit quality affected with PGRs spraying where the different cultivars, genotypes and varieties showed significant differences concerning TSS and Vit. C in fruits according to Chaudhary, et al. (2006) Gungor and Yildirim, (2013) Chowdhury et al. (2015) and Ibrahim et al. (2019). The increase of ascorbic acid with GA_3 treatment may be due either to the promotion of ascorbic acid biosynthesis or to the defense of synthesized ascorbic acid from oxidation by the ascorbic acid oxidase enzyme.

Table 9
Effect of different cultivars (C), plant growth regulators (P) types and their interaction (C × P) treatments on total capsaicin content (mg/100 g as dry weight) in fruits of chilli plant during 2016/2017 season under plastic tunnels conditions.

Chilli cultivars	Plant growth regulators types (ppm)							
	Control	4-CPA			GA_3		NAA	Mean (C)
	0.0	20	40	20	30	10	20	
Chillina	129.24	137.44	140.97	137.59	140.03	130.51	134.91	**135.81**
Parbirian	124.67	134.58	136.65	134.83	138.60	128.52	134.01	**133.12**
Shampion	127.92	134.46	141.86	138.48	138.99	129.92	133.14	**134.97**
Hyffa	126.84	132.45	137.43	133.96	137.50	131.51	135.60	**133.61**
Mean (PGRs)	**127.16**	**134.73**	**139.23**	**136.22**	**138.78**	**130.12**	**134.41**	
LSD at 5%	**(C) = 0.66**			**(P) = 1.09**			**(C × P) = 2.12**	

4- CPA = 4-chlorophenoxy acetic acid, GA_3 = gibberllic acid **and** NAA = naphthalene acetic acid

Chaudhary et al. (2006) and Deshmukh et al. (2010) showed that fruit quality such as TSS and Vit. C in fruits were the highest with the plants, which sprayed with different PGRs as compared the other treatments. In this regard, Sarker et al. (2009) showed that spraying BARI Chilli-1 with NNA at 40 ppm significantly increased ascorbic acid content in fruits, while the interaction between spraying the same cultivar with tap water gave the highest values of TSS than other interaction treatments. capsaicin content (%) was varied based on cultivars, genotypes and varieties (Phimchan and Techawongstien, 2012).

Growth hormones, whether auxins or cytokinins improve plant growth, productivity, and quality, some natural substances acting the same role, i.e., herbal extracts (Saad et al, 2020a; El-Tarabily et al, 2021; Abdel-Moneim et al, 2022; El-Saadony et al, 2021b), peptides (Saad et al, 2020b; Saad et al, 2021b; El-Saadony et al, 2022; El-Saadony et al, 2021d), microorganisms (Desoky et al, 2020), and phenolic compounds extracted from agricultural wastes (Saad et al, 2021c; Saad et al, 2021d). Conventional growth regulators can also be mixed with natural materials to maximize yield. The mechanism of growth promoters is briefed in production of phenolics in chili peppers, i.e., ABA can act as a biochemical signaler and trigger the expression of genes that encode proteins involved in the biosynthesis and metabolism of phenylpropanoids, and the phenylpropanoid pathway is important in the secondary metabolism of vegetables, the main products produced include phytoalexins, phenolic acids, and important precursors, such as chalcones (Tan et al., 2016; Moreira et al., 2020), which are fundamental in the synthesis of flavonoids.

5. Conclusion

The foliar spray of PGRs on chili pepper significantly affected fruit quantity and quality where Plant growth regulators (PGRs) play a vital role in increasing plant growth, quality, stem elongation, and flower production, additionally, affect vegetative, and fruit production increased the number, size, and weight of sweet pepper fruits. Spraying hot peppers with GA3, 4-CPA, and NAA showed better results for improving fruit set, quantity, and quality. We recommended using GA_3 as PGRs in improving chili yield quality.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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