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Mallikarjun Dhotre
Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka, India

SM Mantur
Special Officer (Seeds), University of Agricultural Sciences, Dharwad, Karnataka, India

MS Biradar
Assistant Professor, Hi-Tech Horticulture Unit, University of Agricultural Sciences, Dharwad, Karnataka, India

SM Hiremath
Professor, Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka, India

Correspondence
Mallikarjun Dhotre
Department of Horticulture, University of Agricultural Sciences, Dharwad, Karnataka, India

Enhancing the yield and quality parameters of polyhouse grown hybrid sweet pepper by using plant growth regulators

Mallikarjun Dhotre, SM Mantur, MS Biradar and SM Hiremath

Abstract
The yield and quality parameters of sweet pepper as influenced by plant growth regulators and their spraying intervals were studied. The experiment was laid out in factorial design with six growth regulators and three spraying intervals as well as one absolute control making 19 treatment combinations. The results revealed that, CCC @ 600 ppm (G_6), CCC @ 400 ppm (G_5) and NAA @ 100 ppm (G_2) resulted in significantly higher fruit yield (2.17, 2.14 and 2.13 kg/plant). The chemical and nutraceutical parameters of sweet pepper fruits were significantly improved by the application of plant growth regulators. The higher dose of plant growth retardant CCC @ 400 and 600 ppm resulted in higher TSS (5.50 and 5.44 ^{0}Brix, respectively). However, NAA @ 100 and 150 ppm considerably increased the amount of Asocrbic acid (137.53 and 130.84 mg/100 g, respectively) and total dietary fibres (2.99 and 2.94 %, respectively) in sweet pepper fruits. The effect of growth regulators increased significantly with the spraying intervals. Compared to control (1.74 kg/plant), the fruit yield was significantly higher under the combinations of NAA @ 100 ppm sprayed at 4 intervals (2.42 kg/plant) CCC @ 600 ppm sprayed at 4 intervals (2.39 kg/plant) and the same interactions outperformed control with respect to TSS, ascorbic acid and dietary fibre components in sweet pepper.

Keywords: Sweet pepper, growth regulators, polyhouse, quality and yield

Introduction
Sweet pepper (*Capsicum annuum* L.) has attained a status of high value crop in India in recent years and occupies a pride place among vegetables in Indian cuisine because of its delicacy and pleasant flavor. Nutritionally, sweet peppers are rich in vitamins particularly, vitamin C. Hundred gram of edible portion of sweet pepper provides 29 Kcal of energy, 1.3 g of protein, 6.9 g of carbohydrates which include 2.5 g dietary fibres and 3.6 g sugars and 0.3 g of fat (Anon., 2012) [2]. Ascorbic acid is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in the human body. Vitamin C, as an antioxidant, reportedly reduces the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Lee and Kader, 2000) [16]. Dietary fibers perform important biological functions, though they supply no calories or nutrients and are resistant to digestive enzymes. Insoluble fiber passes through the stomach and intestines undigested, but it absorbs water and organic toxins and waste (Knudsen, 2001) [13]. Soluble fibres, such as pectin and lignin, helps to prevent cholesterol from building up in blood vessel walls, and thus helps to prevent heart disease (Camire *et al*., 2001) [7].
Protected cultivation is characterized by a high input of production means viz., fertilizers, chemicals, plastic, etc. (Leonardi *et al*., 2009) [17]. However, excess application of fertilizers has been reported to cause several ill effects on growing environment and adds to the cost of production (Sabli, 2012) [20]. This calls for an alternative ways to improve the productivity of the greenhouse cultivation, use of plant growth regulators (PGRs). PGRs are new generation of agro chemicals when added in small amounts, modify the growth of plant usually by stimulating or inhibiting the natural growth regulatory system (Latimer, 1992) [14]. Foliar sprays with NAA enhance vegetative growth, reduce flower and fruit drop in chilli; it also increased the TSS and ascorbic acid contents in tomato. Use of growth retardants such as CCC has been shown to increase the yield due to inhibition of the vegetative growth in sweet pepper (Abd-Alla *et al*. 1984) [1]. The reduced vegetative growth promotes reproductive phase in the crop plants (Leclerc *et al*., 2006[15] and Rajput *et al*., 2011[18]). It has been shown that multiple low rate applications of plant growth regulator are more effective than a single, high-rate treatment (Brown *et al*., 1997) [6].
Owing to the suitability of the location and horticulture development in the area, many kinds of vegetables are grown and consumed. Sweet pepper being one of popular vegetable among

the Indian households as well the growing fast food industry, it was necessary to gather the information regarding the chemical composition, vitamin C and dietary fibre content and studying the possibilities for improvements by using plant growth regulators, since not much information is available on the effects of plant growth regulators on productivity as well as quality of sweet pepper grown in protected structures, there is an imminent need to assess the optimum levels and spraying intervals of growth regulators for sweet pepper cultivation in greenhouses.

Material and Methods

The study was carried out in a naturally ventilated polyhouse with cropping area of 500 sq.m. The soil media was brought to a fine tilth and raised beds of 30 cm height and 1 m width were prepared with 50 cm walking space between them. Seedlings of hybrid Indra were transplanted at 45 x 30 cm spacing on the beds in zigzag manner. The crop was irrigated at 60 % of ETc and was given with 75 % of RDF (150:150:150 kg/ha NPK). Twenty per cent of the dosage was applied as basal dose and the remaining was supplied through fertigation using water soluble fertilizer (19:19:19). Daily E_0 was obtained using Class A pan evaporimeter and the amount of required irrigation water was calculated based on the equation, [IR=(ETc x Kr x I/IE) + LR] (where, IR= irrigation required (mm); ETc = Crop evapotranspiration, Kr = reduction factor; I= Irrigation interval; IE= irrigation efficiency and LR=leaching requirement (Vermeiren and Jobling, 1984) [24].

The crop was subjected to foliar sprays with a growth promoter - NAA (4.5 % SL) - Planofix® by Bayer Crop Science Ltd. and a growth retardant - CCC, (Chlormequat chloride 50 % SL) - Lihocin® by BASF with different concentrations. The experiment was laid out in two replications following factorial randomized block design wherein, the first factor was plant growth regulators (G) *viz*., NAA @ 50 ppm (G_1); NAA @ 100 ppm (G_2); NAA @ 150 ppm (G_3); CCC @ 200 ppm (G_4); CCC @ 400 ppm (G_5) and CCC @ 600 ppm (G_6) and the second factor was spray intervals (I) *viz*., I_1: spray at 30, 45 DAP; I_2: spray at 30, 45 and 60 DAP and I_3: spray at 30, 45, 60 and 75 DAP as well as one absolute control wherein no spraying carried out.

The laboratory analyses were carried for quantifying the quality parameters. Total soluble solids were determined by using hand refractometer (Erma), crude fibre content by following the method given by Jacobs (1958) [10], ascorbic acid content by following the procedure as suggested by AOAC (1990)[3] and expressed in mg per 100 g fresh weight. Soluble, insoluble and total components of dietary fibre of moisture and fat free samples were estimated by using standard enzymatic gravimetric method (Asp *et al*., 1983) [4].

Results and Discussion

Fruit yield

The fruit yield per plant was significantly influenced by the application of plant growth regulators (Table 1). Significantly higher yield was noticed due to spray of CCC @ 600 ppm (G_6: 2.17 kg) which was on par with G_5 (2.14 kg) and G_2 (2.13 kg). Minimum fruit yield of sweet pepper was recorded in G_1 (1.86 kg/plant). Spraying interval I_3 (spraying at 30, 45, 60 and 75 DAP) was recorded with significantly highest yield (2.25 kg/ plant) than other spray intervals. The comparison between control and G × I interactions exhibited marked variations. Significantly higher yield was recorded under $G_6 \times I_3$, $G_5 \times I_3$, $G_2 \times I_3$, $G_3 \times I_3$, $G_4 \times I_3$, $G_6 \times I_2$ and $G_5 \times I_2$ interactions when compared to control (1.76 kg/plant).

Earlier reports of different workers revealed that application of growth regulators ultimately affect the endogenous level of auxin which finally work on the growth and development of the plants. The time of application with respect to growth stage of plant with the concentration of chemical play an important role on growth modification and yield. NAA as the principal auxin in higher plants, stimulate fundamental processes such as cell elongation and division (Kende and Zeevaart, 1997) [12]. The improvement in yield attributes and increase in fruit yield by CCC application might be attributed to reduced vegetative growth which result in diversion of flow of food materials for improvement of flowering and fruiting. Similar beneficial effects of using plant growth hormones to achieve higher yield levels were also reported by Belakbir *et al.* (1998) [5] and Shetty and Manohar (2008) [22] in polyhouse grown capsicum; Sharma *et al.* (1999) [21] in bell pepper; Kannan *et al.* (2008) [11] in paprika; Sridhar *et al.* (2009) [23] in capsicum with NAA and Gelmesa *et al.* (2010) [9] in tomato with GA_3. Furthermore, treatment combinations of all the growth regulators at I_1 and I_2 levels of spraying intervals did not produce any significant effects over control. This is in conformity with the reports by Brown *et al.* (1997) [6] who highlighted the importance of multiple applications of growth regulators in achieving desired results rather than high dose at once.

Quality parameters

Chemical compositions

The sweet pepper fruits were also studied for the chemical compositions such as moisture content, total soluble solid content and crude fibre content (Table 1). The results revealed significant results with respect to total soluble solid (TSS) content of fruits by the application of plant growth regulators at different spraying intervals over control. Total soluble content improved considerably (5.95 and 5.88 ^{0}Brix) by the application of CCC @ 600 ppm and CCC @ 400 ppm both sprayed at four intervals ($G_6 \times I_3$ and $G_5 \times I_3$, respectively) over control (5.10 ^{0}Brix). Among the growth regulators, significantly highest TSS was recorded with CCC @ 600 ppm (5.50 ^{0}Brix) followed by CCC @ 400 ppm (5.44 ^{0}Brix). Spraying NAA @ 50 ppm recorded with least TSS (4.89 ^{0}Brix). Spraying of growth regulators at four intervals (I_3) recorded with the highest TSS (5.54 ^{0}Brix).

The higher content of total soluble solids might be attributed to accumulation of high level of soluble carbohydrates produced due to high level of respiration caused by the intensive fruit growth and high degree metabolic activity. This increment could also be ascribed to the increase of chlorophyll content, as a result of CCC treatment which in turn increases the photosynthetic rate and hence the photosynthate accumulation (El-Sayed *et al*., 2012) [8]. Similar results of increased TSS content due to spray of CCC were reported earlier by Abd-Alla *et al.* (1984) [1] and Belakbir *et al.* (1998) [5] in greenhouse capsicum. Regarding crude fibre content none of the treatments resulted in significant influences. The content of crude fibres remained unchanged even comparing with that of control. Regarding crude fibre content none of the treatments resulted in significant influences. The content of crude fibres remained unchanged even comparing with that of control. However, comparatively higher crude fibre content was recorded by spraying NAA @ 150 ppm (2.57 %) and spraying at I_3 interval (2.52 %).

Table 1: Influence of plant growth regulators and their spraying intervals on fruit yield and chemical compositions of sweet pepper grown under polyhouse

Treatment	Fruit yield (kg/plant)	Moisture content (%)	Crude fibres (%)	TSS (^{0}Brix)
A. Growth regulators				
G_1: NAA @ 50 ppm	1.86	92.98	2.41	4.89
G_2: NAA @ 100 ppm	2.13	92.87	2.51	5.28
G_3: NAA @ 150 ppm	2.08	92.79	2.57	5.10
G_4: CCC @ 200 ppm	1.97	92.52	2.34	5.15
G_5: CCC @ 400 ppm	2.14	92.16	2.35	5.44
G_6: CCC @ 600 ppm	2.17	92.02	2.41	5.50
S.Em. ±	**0.05**	**0.05**	**0.08**	**0.06**
C.D. (P = 0.05)	**0.14**	**0.15**	**NS**	**0.18**
B. Spray intervals				
I_1: Spray at 30, 45 DAP	1.87	92.94	2.32	4.98
I_2: Spray at 30, 45, 60 DAP	2.05	92.63	2.45	5.16
I_3: Spray at 30, 45, 60, 75 DAP	2.25	92.11	2.52	5.54
S.Em. ±	**0.03**	**0.04**	**0.05**	**0.04**
C.D. (P = 0.05)	**0.10**	**0.11**	**NS**	**0.13**
C. Interactions				
$G_1 \times I_1$	1.77	93.20	2.33	4.78
$G_1 \times I_2$	1.85	93.18	2.44	4.90
$G_1 \times I_3$	1.95	92.58	2.45	4.98
$G_2 \times I_1$	1.91	93.08	2.25	4.95
$G_2 \times I_2$	2.07	93.02	2.60	5.15
$G_2 \times I_3$	2.42	92.50	2.67	5.75
$G_3 \times I_1$	1.90	93.05	2.41	4.95
$G_3 \times I_2$	2.02	92.99	2.64	5.10
$G_3 \times I_3$	2.32	92.33	2.65	5.25
$G_4 \times I_1$	1.80	92.90	2.26	4.95
$G_4 \times I_2$	1.99	92.70	2.28	5.05
$G_4 \times I_3$	2.13	91.95	2.50	5.45
$G_5 \times I_1$	1.90	92.77	2.36	5.10
$G_5 \times I_2$	2.21	92.02	2.38	5.35
$G_5 \times I_3$	2.31	91.70	2.31	5.88
$G_6 \times I_1$	1.94	92.62	2.31	5.15
$G_6 \times I_2$	2.17	91.87	2.38	5.40
$G_6 \times I_3$	2.39	91.59	2.53	5.95
Absolute Control*	1.74	92.71	2.31	5.10
S.Em. ±	**0.08**	**0.08**	**0.13**	**0.10**
C.D. (P = 0.05)	**NS**	**0.26**	**NS**	**NS**
Control × interactions S.Em. ±	**0.08**	**0.08**	**0.14**	**0.11**
C.D. (P=0.05)	**0.36**	**0.38**	**NS**	**0.49**

*Absolute Control: Without any spray, NS: Non significant

Nutraceutical contents

Sweet pepper fruits were analyzed for their nutraceutical contents like, ascorbic acid, soluble dietary fibres, insoluble dietary fibres and total dietary fibres (Table 2). Vitamin C is also known to have many biological functions in collagen formation, absorption of inorganic iron, reduction of plasma cholesterol level, enhancement of the immune system, and reaction with singlet oxygen and other free radicals. The results revealed significant improvement in ascorbic acid content as the highest content (143.53 mg/100 g) reported due to the application of NAA @ 150 ppm at four intervals ($G_3 \times I_3$) against the control treatment (115.45 mg/100 g). Similarly, the ascorbic acid content was also improved by the four time application of CCC @ 600 ppm ($G_6 \times I_3$), NAA @ 100 ppm ($G_2 \times I_3$) and CCC @ 400 ppm ($G_5 \times I_3$). Among the growth regulators, the higher ascorbic acid content (137.53, 133.69, 130.84 and 130.10 mg/100 g) was recorded under G_3, G_6, G_2 and G_5, respectively and were on par with each other. Irrespective of growth regulators, spraying at four intervals was found significantly superior with respect to ascorbic acid content (135.52 mg/100 g). Similar reports of increasing ascorbic acid content were reported earlier by Belakbir *et al.* (1998) [5] with CCC and NAA; Rana and Singh (2012) [19] with NAA in greenhouse capsicum; Sridhar (2009) [23] in capsicum with NAA.

With regard to dietary fibre content in sweet pepper *viz.*, soluble, insoluble and total dietary fibre, the results obtained in the present experiment due to the influence of plant growth regulators and their spraying intervals are of considerable importance. The soluble and insoluble dietary fibres together constitute total dietary fibres (TDF) in the sweet pepper fruit. Insoluble fibres account to a greater extent. Irrespective of the growth regulators and their spraying interval, there was general increase in the total dietary fibre when compared to control (2.47 %). However, the significant increase was noticed with the treatment combinations, including NAA all concentrations sprayed at I_2 and I_3 intervals (ranged from 2.93 to 3.19 %) and CCC with 400 ppm and 600 ppm concentration both sprayed at I_3 intervals (3.03 and 3.05 %, respectively). However, the highest (3.19 %) was obtained by $G_3 \times I_3$ combination. Among the growth regulators, the maximum TDF in sweet pepper fruit was recorded due to the application of NAA @ 100 ppm (G_3: 2.99 %). Whereas, CCC @ 200 ppm spray recorded with the least TDF (2.68 %). Like

earlier, spraying at four intervals (30, 45, 60 and 75 DAP) irrespective of growth regulators resulted in significantly highest total dietary fibres (3.03 %) over the other spraying intervals.
From the study, it could be concluded that, the combination of NAA @ 100 ppm sprayed at 4 intervals ($G_2 \times I_3$) and CCC @ 600 ppm sprayed at 4 intervals ($G_6 \times I_3$) was found superior in view of increasing the yield and fruit quality parameters of polyhouse grown sweet peppers with higher amount of TSS, ascorbic acid as well as dietary fibre contents.

Table 2: Influence of plant growth regulators and their spraying intervals on nutraceutical content of sweet pepper grown under polyhouse

Treatment	Ascorbic acid (mg/100g)	Soluble dietary fibres (%)	Insoluble dietary fibres (%)	Total dietary fibres (%)
A. Growth regulators				
G_1: NAA @ 50 ppm	123.72	0.69	2.12	2.81
G_2: NAA @ 100 ppm	130.84	0.71	2.23	2.94
G_3: NAA @ 150 ppm	137.53	0.70	2.29	2.99
G_4: CCC @ 200 ppm	121.04	0.63	2.04	2.67
G_5: CCC @ 400 ppm	130.10	0.64	2.15	2.79
G_6: CCC @ 600 ppm	133.69	0.66	2.18	2.84
S.Em. ±	**2.79**	**0.01**	**0.05**	**0.06**
C.D. (P = 0.05)	**8.32**	**0.03**	**NS**	**0.16**
B. Spray intervals				
I_1: Spray at 30, 45 DAP	123.86	0.63	2.02	2.65
I_2: Spray at 30, 45, 60 DAP	129.08	0.67	2.17	2.84
I_3: Spray at 30, 45, 60, 75 DAP	135.52	0.72	2.31	3.03
S.Em. ±	**1.97**	**0.01**	**0.04**	**0.04**
C.D. (P = 0.05)	**5.88**	**0.02**	**0.11**	**0.12**
C. Interactions				
$G_1 \times I_1$	118.75	0.66	1.94	2.59
$G_1 \times I_2$	123.70	0.70	2.18	2.88
$G_1 \times I_3$	128.72	0.73	2.23	2.95
$G_2 \times I_1$	124.88	0.66	2.09	2.75
$G_2 \times I_2$	130.10	0.73	2.20	2.93
$G_2 \times I_3$	137.54	0.75	2.39	3.14
$G_3 \times I_1$	131.24	0.67	2.16	2.83
$G_3 \times I_2$	137.83	0.69	2.25	2.94
$G_3 \times I_3$	143.53	0.74	2.46	3.19
$G_4 \times I_1$	117.98	0.59	1.97	2.56
$G_4 \times I_2$	120.17	0.63	2.05	2.68
$G_4 \times I_3$	124.97	0.69	2.10	2.79
$G_5 \times I_1$	122.79	0.60	1.95	2.55
$G_5 \times I_2$	128.81	0.65	2.15	2.79
$G_5 \times I_3$	138.69	0.68	2.36	3.04
$G_6 \times I_1$	127.52	0.61	2.01	2.62
$G_6 \times I_2$	133.88	0.65	2.19	2.84
$G_6 \times I_3$	139.66	0.71	2.33	3.05
Absolute Control*	115.45	0.56	1.91	2.47
S.Em. ±	**4.83**	**0.02**	**0.09**	**0.11**
C.D. (P = 0.05)	**14.41**	**NS**	**NS**	**0.35**
Control × interactions S.Em. ±	**4.72**	**0.02**	**0.09**	**0.11**
C.D. (P=0.05)	**21.37**	**0.09**	**0.41**	**0.54**

*Absolute Control: Without any spray, NS: Non significant

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