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Effect of Growth Regulators on Physiological Parameters of Strawberry (*Fragaria x ananassa* Duch.) cv. Chandler

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A B S T R A C T

The experiment was conducted at an elevation of 1250 m above mean sea level at 30° 51'N latitude and 76° 11'E longitude at the experimental area of the Department of Fruit Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh). The aim of present investigation is to study the effect of different growth regulators on physiological parameters in Chandler cultivar of strawberry in terms of stomatal resistance, transpiration rate, leaf photosynthetic rate and chlorophyll content. The experiment was conducted in randomized block design with three replications and 19 treatments viz., Pro.Ca @ 30,60,90 ppm; CPPU @ 2, 4, 6 ppm, GA_3 @ 25, 50, 75 ppm, Ethephon @ 50, 100, 150 ppm, NAA @ 20, 30, 60 ppm, CPPU + GA_3 @ 2+50, 4+50, 6+50 ppm and control. The growth regulators applied to the plants twenty days before flowering. The growth regulators exhibited significant effect on the physiological characters in strawberry plants. The CPPU treatment followed by GA_3 alone and combined treatment resulted in maximum chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration rate and minimum stomatal resistance.

Introduction

Strawberry (*Fragaria x ananassa* Duch.) is one of the most popular soft fruit, being delicate in flavour and rich in vitamins and minerals, is a valuable food in the diets of millions of people around the globe. Among the fruits, strawberry gives the quickest return in the shortest possible time. During the recent years, there has been a phenomenal increase in its area and production in northern Indians plains under subtropical climate (Sharma and Sharma, 2004). Strawberry in these localities is planted in autumn and it comes to flowering in spring after about four months. In this short growing period, plants make only limited in vegetative growth, as a result, low yields are achieved (Arsey *et al.*, 2004). Shan *et al.*, (2007) reported that foliar application of IAA at 50 ppm on strawberry cv. French improved the fruit quality in autumn and significantly increased the net photosynthesis and the content of chlorophyll a and b. Shan *et al.*, (2007) studied the effect of different plant

growth regulators on the photosynthesis and quality of strawberry cv. French. The result showed that 6-BA applied at 50 ppm in late autumn significantly increased the net photosynthesis rate, the content of chlorophyll a and b and improved the quality. Application of GA_3 significantly increased photosynthesis because of increased vegetative growth Ashraf *et al.,* (2002) in wheat and Yuan and Xu (2001) in broad bean and soybean and Coulombe and Paquin (1959) in Tomato.

Materials and Methods

The present investigation was carried out in the experiment area of Department of Fruit Science, University of Horticulture and Forestry, Nauni, Solan, H. P. India. Thirty two healthy runners were planted in 2x2 m raised bed at a distance of 50x25 cm.

The whole experiment was conducted in randomized block design with three replications. A single spray of growth regulators were applied to the plants twenty days before flowering. The treatments of growth regulators were applied as follows :

T_1 - Pro.Ca @ 30 ppm, T_2 - Pro.Ca @ 60 ppm, T_3 - Pro.Ca @ 90 ppm, T_4- CPPU @ 2 ppm, T_5 - CPPU @ 4 ppm, T_6 - CPPU @ 6 ppm, T_7 - GA_3 @ 25 ppm, T_8 - GA_3 @ 50 ppm, T_9 - GA_3 @ 75 ppm, T_{10} - Ethephon @ 50 ppm, T_{11}- Ethephon @ 100 ppm, T_{12} - Ethephon @ 150 ppm, T_{13}- NAA @ 20 ppm, T_{14}- NAA @ 30 ppm, T_{15} - NAA @ 60 ppm, T_{16} - CPPU + GA_3 @ 2+50 ppm, T_{17} - CPPU + GA_3 @ 4+50 ppm, T_{18} - CPPU + GA_3 @ 6+50 ppm and T_{19} - control. Observations on various growth and fruiting characters were recorded by using standard method.

Chlorophyll content

Five fully expanded and mature leaves from each treatment were collected in the month of July during morning hours (Halfacre *et al.*, 1968) and immediately placed in ice box and brought to the laboratory. The samples were then kept in refrigerator at sub-zero degree temperature to avoid degradation of chlorophyll pigment.

The leaves under each sample were then chopped into fine pieces under subdued light and 100 mg of chopped leaf samples were placed in vials containing 7 ml of Dimethyl Sulphoxide. The contents of the vials were incubated at 65° C for half an hour and then, the extract was transferred to graduated test tube and the final volume was made to 10 ml with Dimethyl sulphoxide (Hiscox and Israelstam, 1979).

Estimation

The optical density (O.D.) values of the extracts were recorded in spectrophotometer (Spectronic-20) at 645 and 663 nm wavelengths against a dimethyl sulphoxide blank. The total chlorophyll content was calculated by using the following formula:

$$\text{Total chlorophyll content} = \frac{20.2\ A_{645} + 8.02\ A_{663}}{a \times 1000 \times W} \times V$$

Where,

V = Volume of the extract made

a = Length of the light path in cell (usually 1cm)

W = weight of the sample

A_{645} = Absorbance at 645 nm

A_{663} = Absorbance at 663 nm

The results obtained were expressed as mg of total chlorophyll per gram of fresh weight.

Photosynthesis, stomatal conductance, resistance and transpiration

Photosynthesis, stomatal resistance, conductance and transpiration were recorded during fruit development stage. The observations were recorded between 9:00 to 12:00 am with the help of LICOR-6200 portable photosynthesis meter. The results were expressed in μ mol/m^2/s, S cm^{-1}, m mol/s and m mol/m^2/s for photosynthesis, stomatal conductance, resistance and transpiration respectively (Fig. 1).

Data were subjected to statistical analysis in accordance with the method described by Gomez and Gomez (1984).

Results and Discussion

Physiological parameters

The growth regulators registered significant increase in the leaf chlorophyll content, photosynthesis, stomatal conductance, resistance and transpiration of strawberry cv. Chandler (Table 1 and 2) the maximum chlorophyll content (3.729), photosynthesis (8.31) stomatal conductance (0.311) and transpiration (27.930) were recorded in T_{15} as compared to control (T_{19}).

It is clear from the present investigation that the leaf photosynthesis was significantly influenced with the application of various growth regulator treatments. The maximum photosynthesis was recorded with CPPU 6 ppm + GA_3 50 ppm (Table 1). These finding are in conformation with the work of Shan *et al.*, (2007) in strawberry cv. French.

The increase in photosynthesis may be due to increased chlorophyll content (Winger *et al.*, 1998). Application of GA_3 significantly increased photosynthesis because of increased vegetative growth (Table 1). The present results are in conformity with those of Ashraf *et al.*, (2002) in wheat and Yuan and Xu (2001) in broad bean and soybean and Coulombe and Paquin (1959) in Tomato.

Fig.1 LI-COR 6200 portable photosynthesis system

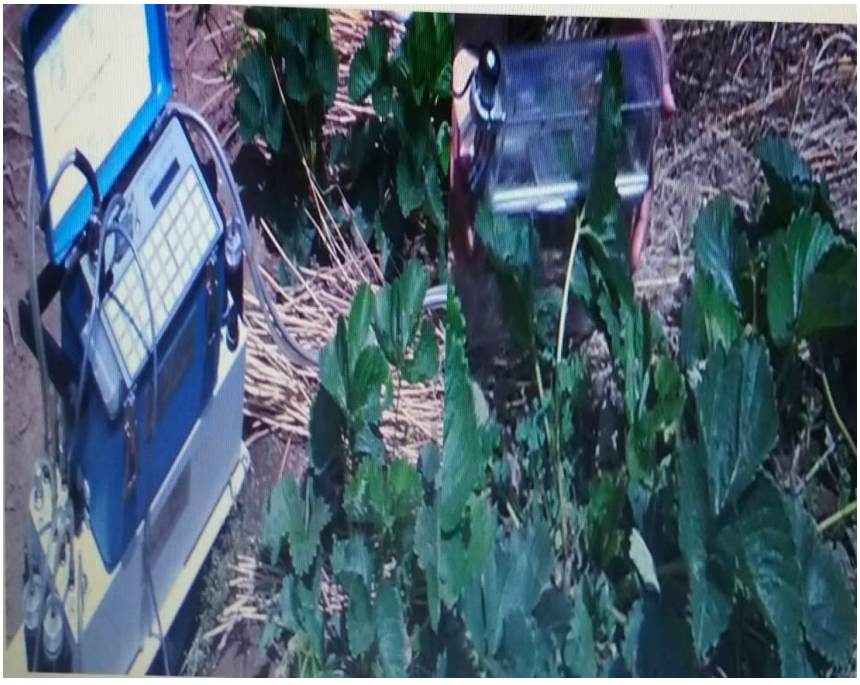

Table.1 Effect of different growth regulators on chlorophyll content and photosynthesis

Treatment	Chlorophyll content (mg/g)			Photosynthesis (micro mole/m^2/sec.)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
T_1 Pro. Ca 30 ppm	2.632	2.641	2.637	5.26	4.44	4.85
T_2 Pro. Ca 60 ppm	2.648	2.654	2.651	4.78	5.25	5.02
T_3 Pro. Ca 90 ppm	2.872	2.851	2.862	7.65	7.04	7.35
T_4 CPPU 2 ppm	3.298	3.372	3.336	5.1	6.26	5.68
T_5 CPPU 4 ppm	3.631	3.582	3.607	6.74	6.82	6.78
T_6 CPPU 6 ppm	3.695	3.596	3.646	7.39	7.37	7.38
T_7 GA_3 25 ppm	3.160	3.148	3.154	7.59	6.18	6.89
T_8 GA_3 50 ppm	3.168	3.184	3.176	7.62	6.69	7.16
T_9 GA_3 75 ppm	3.201	3.217	3.209	8.32	7.49	7.91
T_{10} Ethephon 50 ppm	2.591	2.584	2.588	4.33	4.76	4.55
T_{11} Ethephon 100 ppm	2.674	2.684	2.679	6.45	5.46	5.96
T_{12} Ethephon 150 ppm	2.685	2.692	2.688	6.57	5.59	6.08
T_{13} NAA 20 ppm	2.324	2.352	2.338	5.66	5.19	5.43
T_{14} NAA 30 ppm	2.436	2.395	2.416	5.46	5.62	5.54
T_{15} NAA 60 ppm	2.458	2.424	2.442	6.67	6.20	6.44
T_{16} CPPU 2 ppm + GA_3 50 ppm	3.524	3.518	3.521	7.81	7.69	7.75
T_{17} CPPU 4 ppm + GA_3 50 ppm	3.524	3.572	3.548	7.90	8.19	8.05
T_{18} CPPU 6 ppm + GA_3 50 ppm	3.682	3.775	3.729	8.24	8.37	8.31
T_{19} Control	2.287	2.296	2.291	3.37	3.41	3.39
$CD_{0.05}$	0.048	0.063	0.045	1.19	0.85	0.70

Table.2 Effect of different growth regulators on stomatal conductance, resistance and transpiration

Treatment	Stomatal conductance (m mol/s)			Stomatal resistance (S cm^{-1})			Transpiration rate (m mol/m^2/s)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
T_1 Pro. Ca 30 ppm	0.407	0.399	0.403	0.720	0.762	0.741	20.02	19.34	19.680
T_2 Pro. Ca 60 ppm	0.448	0.369	0.408	0.572	0.994	0.783	20.67	20.64	20.637
T_3 Pro. Ca 90 ppm	0.422	0.412	0.417	0.843	0.788	0.815	21.35	20.31	20.830
T_4 CPPU 2 ppm	0.569	0.547	0.558	0.660	0.717	0.688	25.51	23.09	24.300
T_5 CPPU 4 ppm	0.547	0.572	0.560	0.664	0.776	0.720	23.64	24.76	24.200
T_6 CPPU 6 ppm	0.679	0.645	0.662	0.712	0.764	0.738	23.65	23.62	24.633
T_7 GA_3 25 ppm	0.547	0.525	0.536	0.569	0.596	0.582	22.47	20.76	21.613
T_8 GA_3 50 ppm	0.552	0.526	0.539	0.643	0.652	0.647	21.01	20.68	21.930
T_9 GA_3 75 ppm	0.527	0.587	0.557	0.683	0.671	0.677	24.12	24.26	24.190
T_{10} Ethephon 50 ppm	0.376	0.418	0.397	0.916	0.914	0.915	15.77	15.16	15.463
T_{11} Ethephon 100 ppm	0.443	0.351	0.397	0.904	0.973	0.938	16.66	16.29	16.473
T_{12} Ethephon 150 ppm	0.418	0.390	0.404	0.843	0.887	0.865	18.07	16.36	17.563
T_{13} NAA 20 ppm	0.415	0.431	0.423	0.864	0.785	0.824	17.92	19.18	18.450
T_{14} NAA 30 ppm	0.447	0.429	0.438	0.855	0.885	0.870	19.29	20.06	19.673
T_{15} NAA 60 ppm	0.445	0.433	0.439	0.867	0.901	0.884	20.93	18.94	19.937
T_{16} CPPU 2 ppm + GA_3 50 ppm	0.531	0.585	0.558	0.514	0.547	0.530	25.14	25.04	26.090
T_{17} CPPU 4 ppm + GA_3 50 ppm	0.565	0.603	0.584	0.488	0.632	0.560	25.06	25.65	26.853
T_{18} CPPU 6 ppm + GA_3 50 ppm	0.702	0.760	0.731	0.586	0.600	0.593	27.07	28.79	27.930
T_{19} Control	0.326	0.296	0.311	0.926	0.842	0.884	15.15	14.62	14.383
$CD_{0.05}$	0.132	0.130	0.126	0.146	0.140	0.158	1.310	1.285	1.263

In the present investigation, the increased photosynthesis was observed with Pro.Ca treatments. This finding is in accordance with the results of Sabatini *et al.,* (2003) whose results exhibited higher net photosynthesis and 50 per cent increase in CO_2 uptake when treated with Pro.Ca in apple. In low specific leaf area (SLA) of leaves, with the higher density of chlorophyll and photosynthetic enzymes increased the leaf net photosynthesis (Evans and Poorter, 2001). This investigation also shows that all concentrations of NAA increased net photosynthesis compared to control. This finding are in line with those of Shan *et al.,* (2007) and Bidwell and Wendy (1966) who reported similar increase in photosynthesis rate with NAA application in strawberry cv. French and in beans, respectively. Similarly, Shun (2000) observed the effect of CO_2 enrichment on application of NAA, GA and CPPU on photosynthesis in strawberry and found that their application were significantly effective in increasing net photosynthetic rate, with close correlations between net photosynthetic rate and intracellular CO_2, stomatal conductance and transpiration rate, respectively. The application of GA_3 at 150 ppm also resulted in significantly higher rate of photosynthesis, stomatal conductance, transpiration rate in rice cultivars 'MR 219' and 'Pokkali' compared to those cultivars with no GA_3 application (Misratia *et al.,* 2013).

Chlorophyll content

The results of present investigation revealed that the growth regulators significantly increased the chlorophyll content (Table 1) and were the highest chlorophyll content was observed with CPPU @ 6 ppm + GA_3 @ 50 ppm followed by CPPU @ 6 ppm and CPPU @ 4 ppm, respectively. The higher chlorophyll content may be due to greater synthesis and translocation of assimilates and water by cytokinins (CPPU) and gibberellins, which checks the degradation of chlorophyll in leaves (Reis *et al.,* 1977). It may be due to some kind of anti-senescence property of these growth regulators. In the present study the application of Pro.Ca increased the leaf chlorophyll content. Similar increase in the chlorophyll per unit leaf area in apple leaves was also reported by Sabatini *et al.,* (2003).

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