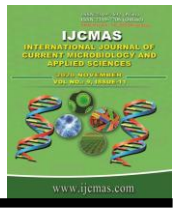
Int.J.Curr.Microbiol.App.Sci (2020) *9*(11): 143-151

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 11 (2020)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2020.911.017

Influence of Nutrients and Plant Growth Regulators on Growth, Flowering and Yield Characteristics of Strawberry cv. Chandler

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Keywords

Nutrients, PGR, Growth, Flowering, Strawberry

Article Info

Accepted:
04 October 2020
Available Online:
10 November 2020

A B S T R A C T

An experiment was undertaken on strawberry cv. Chandler to study the effect of application of nitrogen (N) and potassium (K) prior to planting followed by foliar spray of gibberellic acid (GA_3) or paclobutrazol (PP_{333}) prior to flowering on growth, yield and quality attributes. Results revealed that application of 100 Kg of N, 40 Kg of K and 50 ppm of GA_3 increased plant height (25.62 and 26.97 cm), number of leaves (23.69 and 24.39), leaf area (142.29 and 143.68 cm^2), number of runners (16.77 and 16.97) and number of plantlets per runner (5.56 and 6.14), whereas application of 60 Kg of N, 40 Kg of K and 300 ppm of PP_{333} was found to be most effective in increase in number of flowers per plant (16.56 and 19.41), berry set (83.91 and 84.30%) and berry yield (10.63 and 14.50 t ha^{-1}) during 2010-11 and 2011-12, respectively, besides ameliorating quality parameters.

Introduction

Strawberry (*Fragaria x ananassa* Duch.), an herbaceous perennial plant of Rosaceae family, occupies significant place in fruit growing areas of the world, since it can be cultivated in plains as well as in the hills up to an elevation of 3000 meters above mean sea level in humid or dry regions. It is an attractive fruit with distinct, pleasant aroma and delicate flavour. It is rich source of vitamin C (40-120 mg/ 100g of berries), vitamin B_1, proteins and minerals like phosphorus, potassium, calcium and iron. It is amongst the few crops, which gives quick and very high returns per unit area on the capital investment, as the crop is ready for harvesting within six months of planting. Due to its wider adaptability to climate and soils, it is available fresh from the tropics to subtropics, round the year. In India, Maharastra is the leading state in the production of strawberry.

It is also grown in Dehradun and Nainital (Uttrakhand), Srinagar (J&K) and hills of Darjeeling (W.B.). Recently its area has been considerably increased in Haryana and Punjab. In Uttar Pradesh, growing areas are Saharanpur, Muzaffarnagar, Ghaziabad and Allahabad districts. The most commonly grown cultivar is Chandler which is a short day plant with excellent fruit quality and suitable for fresh marketing and processing.

Though strawberry is a short day plant but it has limited vegetative growth during this short day period that caused less production with low quality (Asrey et al 2004). Among the various factors contributing to growth and yield of strawberry, nutrition is an important aspect of crop production that accounts for about one third of the total cost of production.

Nitrogen (N) is most important for plant growth, runner production, and fruit bud formation in strawberry (Trejo-Téllez and Gómez-Merino 2014). Potassium (K) plays an important role in the plant development, as it promotes the elongation of the cells, takes part in the water management of plant and in the synthesis of carbohydrates. Ebrahimi et al (2012) showed that application of 300 ppm K in nutrient solution increased fruit number, weight and yield, root length and weight in strawberry. Thus, optimum use of fertilizers, particularly nitrogen and potassium is conducive to regulating vegetative growth and obtaining high yield of good quality fruits.

Plant growth regulator like gibberellic acid (GA_3) can control plant growth and fruit development in various ways and at different developmental stages. Application of GA_3 in strawberry can stimulate stimulated the growth of the vegetative shoot apex of indeterminate vegetative growth (Bower and Cutting 1992). Paclobutrazol (PP_{333}), is a triazol that inhibits gibberellin biosynthesis, changes assimilates partitioning; with more assimilate toward buds and fruits. It not only controls growth, but also influences cropping and fruit characteristics (Green and Murray 1983).

Thus, an experiment was undertaken to study the effect of application of major nutrients (N and K) along with foliar spray of GA_3 and PP_{333} on plant growth, flowering, yield and quality in strawberry.

Materials and Methods

The field experiment was conducted at experimental station of Horticulture, Department of Horticulture, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh, India during 2010-12. The uniform runners of strawberry cv. Chandler were collected from Dr. Y.S.Parmar University of Horticulture & Forestry, Solan, H.P for planting. Nine runners were planted at 1 m x 1 m raised bed at a distance of 30 x 30 cm and out of which nine plants per treatment were randomly recorded for the data. Planting was done in the first week of October 2010-11 and 2011-12. The recommended fertilizer doses of NPK (40, 60 and 100 Kg ha^{-1}) in the form of urea, SSP, MOP and FYM (50 t ha^{-1}) were given at the time of field preparation. However, in case of experiment the graded doses of N (40, 60 and 100 Kg ha^{-1}) and K (20, 40 and 60 kg ha^{-1}) in the form of urea and MOP were applied before planting (i.e. at the time of preparation of raised experimental beds). While FYM (50 t ha^{-1}) and recommended quantity of P_2O_5 (40 kg ha^{-1}) were applied in the form of SSP as basal dose in all the treatment combinations. The stock solution of PP_{333} was directly prepared in distilled water. The required amount of GA_3 was first dissolved in alcohol and then the desired volume was made with distilled water. The foliar spray of 50 ppm GA_3 and ppm PP333 was given ten days before the flowering (third

week of January 2010-11 and 2011-12 respectively) on clear and calm day during the morning hours.

The experimental design adopted was randomised design with 19 treatments with three replications and three plants per replication. The treatment included T_1 = Control, $T_2 = N_1 K_1 + 50$ ppm GA_3, $T_3 = N_1 K_2 + 50$ ppm GA_3, $T_4 = N_1 K_3 + 50$ ppm GA_3, $T_5 = N_2 K_1 + 50$ ppm GA_3, $T_6 = N_2 K_2 + 50$ ppm GA_3, $T_7 = N_2 K_3 + 50$ ppm GA_3, $T_8 = N_3 K_1 + 50$ ppm GA_3, $T_9 = N_3 K_2 + 50$ ppm GA_3, $T_{10} = N_3 K_3 + 50$ ppm GA_3, $T_{11} = N_1 K_1 + 300$ ppm PP_{333}, $T_{12} = N_1 K_2 + 300$ ppm PP_{333}, $T_{13} = N_1 K_3 + 300$ ppm PP_{333}, $T_{14} = N_2 K_1 + 300$ ppm PP_{333}, $T_{15} = N_2 K_2 + 300$ ppm PP_{333}, $T_{16} = N_2 K_3 + 300$ ppm PP_{333}, $T_{17} = N_3 K_1 + 300$ ppm PP_{333}, $T_{18} = N_3 K_2 + 300$ ppm PP_{333}, $T_{19} = N_3 K_3 + 300$ ppm PP_{333}. The two years experimental data were subjected to statistical analysis as per the method outline by Gomez and Gomez (1984) and significance of variance was estimated by applying F test at 5% level of significance.

Results and Discussion

Application of nutrients combined with plant growth regulators in present study significantly influenced vegetative growth parameters in strawberry cv. Chandler. Maximum plant height (25.62 and 26.97 cm), number of leaves per plant (23.69 and 24.39), leaf area (142.29 and 143.68 cm^2), number of runners per plant (16.77 and 16.97), length of runner (44.77 and 46.91 cm) and number of plantlets per runner (5.56 and 6.14) were observed in T_9 during both 2010-11 and 2011-12, respectively (Table 1). The increase in vegetative growth might be attributed to the cumulative effect of both fertilizers and GA_3 application. It is known that nitrogen is an essential constituent of protein and chlorophyll whereas potassium helps in translocation of carbohydrates. Thus the combined application of nitrogen and potassium synergistically stimulated plant growth and the effect was further augmented by foliar spray of GA_3 which is well-known to trigger transitions from meristem to shoot growth, and juvenile to adult leaf stage by stimulating cell division and expansion in response to light or dark (photomorphogenesis and skoto-morphogenesis) (Gupta and Chakrabarty 2013). The synergistic effects of fertilisers and plant growth regulator such as GA_3 on growth and vigour of strawberry were also reported by Pipattanawong *et al.,* (1996).

In the present studies it was observed that various nutrient combinations with plant growth regulators significantly influenced reproductive attributes of strawberry. Significantly less number of days was taken by T_{15} for emergence of first flower after planting in both 2010-11 and 2011-12 (97.55 and 104.03 days, respectively), which was statistically at par with T_{18} during 2010-11 (97.59 days). The duration of flowering was significantly more in T_{15} in both 2010-11 and 2011-12 (72.77 and 72.89 days, respectively), which was statistically at par with that of T_9, T_{19} and T_{10} (72.34, 72.26 and 71.55 days, respectively) in 2010-11 and T_9 and T_{18} (72.69 days) in 2011-12 (Table 2). Maximum number of flowers per plant (16.56 and 19.41), per cent berry set (83.91 and 84.30%) and number of berries per plant (13.76 and 16.36) were recorded in T_{15} in both the years, respectively (Table 2). In general, N and K are the most required nutrients and interact for the increment of production and improvement of plant nutrition. Nam et al (2006) showed a positive relation between N and K in the increment of dry matter and this promotive effect of N and K (80:40 kg ha^{-1}) on vegetative development could be restricted with the application of PP_{333} (McArthur and Eaton 1988).

Table.1 Effect of nutrients and PGR on vegetative attributes in strawberry cv. Chandler

Treatments	Plant height (cm)		Leaves plant^{-1}		Leaf area (cm^2)		Runners plant^{-1}		Length of runner (cm)		Plantlets runner^{-1}	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	18.04	20.51	19.38	21.15	109.12	112.16	13.14	13.36	39.86	42.06	4.13	4.27
T_2	18.86	25.27	21.24	21.38	118.20	123.37	13.93	14.88	43.11	43.74	4.72	5.11
T_3	18.91	25.60	21.71	21.82	123.09	125.42	14.39	15.11	43.23	44.34	4.61	5.33
T_4	18.95	25.46	21.59	21.73	125.10	127.14	14.84	15.61	43.46	44.36	4.61	5.44
T_5	19.14	25.67	21.52	23.69	130.14	134.34	15.23	16.34	43.69	45.76	4.82	5.39
T_6	18.64	26.80	21.34	23.63	129.21	137.62	15.63	16.71	43.76	46.12	5.15	5.19
T_7	19.61	26.73	22.42	24.35	132.36	139.33	16.39	16.45	43.88	45.88	5.25	5.37
T_8	21.19	26.54	22.82	24.15	136.99	143.47	16.68	16.83	43.56	46.50	5.34	5.82
T_9	25.62	26.97	23.69	24.39	142.29	143.68	16.77	16.97	44.77	46.91	5.56	6.14
T_{10}	24.43	26.85	23.42	24.25	139.29	143.59	16.64	16.76	44.59	46.65	5.47	5.74
T_{11}	18.08	18.40	19.92	20.35	84.79	86.71	12.56	12.94	37.73	39.30	4.38	4.49
T_{12}	17.92	18.26	19.77	20.18	84.73	86.31	12.64	13.14	37.56	39.67	3.58	4.34
T_{13}	17.23	18.21	19.49	20.38	84.58	86.25	12.53	13.03	37.63	39.60	4.34	4.58
T_{14}	17.56	19.61	18.68	20.15	87.11	89.56	11.75	12.57	35.85	39.19	4.18	4.43
T_{15}	18.17	19.66	19.41	20.24	87.08	89.67	11.54	12.35	35.69	39.23	4.12	4.40
T_{16}	18.22	19.42	19.11	21.59	86.67	89.84	11.35	12.30	35.54	39.43	4.12	4.36
T_{17}	18.09	19.34	18.85	21.76	86.51	90.72	11.77	12.72	33.66	40.17	4.25	4.30
T_{18}	18.08	19.58	18.78	21.66	86.28	92.61	11.59	12.46	33.53	40.42	4.21	4.24
T_{19}	17.69	18.42	18.91	21.36	85.77	92.66	11.72	12.72	33.36	40.28	4.06	4.14
SE±	0.06	0.05	0.03	0.02	0.09	0.59	0.11	0.02	0.07	0.04	0.19	0.03
CD at 5%	0.14	0.12	0.08	0.06	0.23	1.50	0.23	0.06	0.21	0.08	0.44	0.07

Table.2 Effect of nutrients and PGR on flowering and yield attributes in strawberry cv. Chandler

Treatments	Days taken to flower after planting		Duration of flowering (days)		Flowers plant^{-1}		Berry set (%)		berries plant^{-1}		Yield (t ha^{-1})	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	118.23	123.44	53.99	51.76	12.96	13.63	68.92	70.13	9.48	9.92	5.18	5.82
T_2	109.77	115.11	61.44	63.12	14.55	16.23	75.29	77.16	11.39	12.35	7.13	8.85
T_3	108.12	117.23	64.03	65.09	14.67	16.61	75.34	78.25	11.69	12.57	7.43	9.26
T_4	108.12	116.88	64.03	62.55	16.15	16.81	75.69	79.48	11.82	12.83	7.65	9.58
T_5	105.16	114.19	68.29	67.19	15.09	16.59	82.14	80.07	12.19	13.64	8.14	10.47
T_6	103.02	111.15	64.03	68.28	15.18	16.73	81.83	81.32	12.42	13.77	8.63	10.91
T_7	105.21	113.34	67.44	67.19	15.27	17.23	80.34	82.17	12.66	13.93	9.18	11.55
T_8	102.33	110.09	70.12	72.12	15.55	17.32	80.67	82.61	12.82	14.00	9.00	11.31
T_9	100.02	108.88	72.34	72.69	15.75	17.77	80.93	83.25	13.14	14.55	9.12	11.36
T_{10}	103.02	111.23	71.55	72.47	15.85	17.86	81.33	83.57	13.24	14.73	9.27	11.81
T_{11}	103.02	108.88	64.12	67.42	15.85	18.76	81.13	81.80	12.91	15.45	8.91	12.28
T_{12}	104.18	112.66	66.19	65.33	15.95	18.87	81.74	81.95	12.97	15.49	7.45	12.12
T_{13}	99.03	107.67	70.12	68.44	15.85	18.98	81.12	82.56	13.14	15.62	8.83	12.49
T_{14}	103.02	111.23	72.00	71.14	16.33	19.24	82.41	83.15	13.53	15.83	10.21	13.52
T_{15}	97.55	104.03	72.77	72.89	16.56	19.41	83.91	84.30	13.76	16.36	10.63	14.50
T_{16}	99.03	107.07	69.12	68.44	16.16	19.32	80.48	81.74	13.33	15.77	10.18	13.84
T_{17}	99.67	105.55	70.00	69.05	16.10	18.82	82.23	82.53	13.17	15.57	9.88	13.54
T_{18}	97.59	106.08	70.61	72.69	16.06	19.28	77.72	81.41	13.07	14.91	10.00	13.14
T_{19}	101.58	108.88	72.26	71.59	15.92	18.73	77.13	80.71	12.81	14.71	9.56	12.66
SE±	0.05	0.05	0.52	0.10	0.30	0.11	0.15	0.04	0.01	0.08	0.02	0.03
CD at 5%	0.16	0.14	1.52	0.30	0.87	0.33	0.44	0.11	0.08	0.23	0.08	0.08

Table.3 Effect of nutrients and PGR on quality parameters in strawberry cv. Chandler

Treatments	Berry length (mm)		Berry breadth (mm)		Berry weight (g)		Berry volume (cc)		TSS (^{o}B)		Acidity (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	22.74	24.13	15.56	16.61	6.75	6.45	6.84	6.80	7.23	7.45	0.68	0.77
T_2	25.75	27.38	17.79	19.80	7.73	7.87	7.91	7.97	7.70	8.33	0.77	0.76
T_3	25.90	27.73	17.89	19.71	7.85	8.09	7.97	8.11	7.88	8.85	0.77	0.79
T_4	26.14	27.65	18.15	19.61	7.99	8.20	8.06	8.20	8.17	8.62	0.74	0.80
T_5	26.46	27.72	19.70	20.55	8.25	8.43	8.46	8.83	8.41	8.83	0.76	0.73
T_6	26.81	28.46	19.79	20.44	8.57	8.17	8.71	8392	8.74	9.08	0.76	0.82
T_7	26.90	28.25	19.93	20.37	8.95	9.11	8.87	9.29	9.09	9.12	0.73	0.83
T_8	27.56	30.29	20.12	20.71	8.67	8.38	8.98	9.03	9.21	9.26	0.66	0.81
T_9	27.70	30.94	20.32	20.92	8.57	8.78	8.83	8.91	8.96	9.10	0.71	0.83
T_{10}	27.80	30.72	20.42	20.88	8.65	8.81	8.64	8.95	8.78	8.91	0.71	0.80
T_{11}	28.55	29.70	19.76	20.38	8.52	8.73	8.87	8.89	8.15	8.43	0.73	0.75
T_{12}	28.73	29.38	19.89	20.35	7.09	8.59	8.72	8.77	8.29	8.52	0.65	0.81
T_{13}	28.84	29.50	19.80	20.28	8.29	8.79	8.53	9.56	8.41	8.39	0.82	0.79
T_{14}	30.61	32.33	20.10	20.89	9.31	9.38	9.43	9.48	9.20	9.34	0.67	0.80
T_{15}	30.92	32.66	21.24	21.41	9.54	9.74	9.63	9.79	9.39	9.46	0.65	0.74
T_{16}	30.86	32.53	20.86	21.27	9.42	9.64	9.54	9.69	8.77	9.07	0.76	0.85
T_{17}	29.95	30.84	19.90	20.85	9.26	9.53	9.46	9.61	9.13	9.35	0.74	0.81
T_{18}	29.84	30.69	19.84	20.57	9.45	9.68	9.55	9.68	9.24	9.26	0.72	0.73
T_{19}	29.66	30.88	19.73	20.54	9.21	9.46	9.26	9.59	9.05	9.28	0.76	0.73
SE±	0.02	0.04	0.02	0.03	0.30	0.07	0.02	0.04	0.02	0.02	-	-
CD at 5%	0.07	0.12	0.06	0.09	0.88	0.22	0.07	0.12	0.07	0.09	NS	NS

The present results showed that decreased vegetative growth by PP_{333} improved the development of flower buds. Studies have shown that PP_{333} is needed to be applied annually to increase the number of flower and fruit yields in strawberry (Shakeri *et al.*, 2009). Abolfazl *et al.*, (2012) also stated that PP_{333} strongly increased yield and sexual growth of strawberry.

The yield of strawberry was significantly influenced by various nutrient combinations with plant growth regulators (Table 2). The berry yield was significantly highest in T_{15} during both 2010-11 and 2011-12 (10.63 and 14.50 t ha^{-1}). The increase or decrease in yield is entirely depends upon the increase or decrease on total number of fruits $plant^{-1}$ and maximum size of fruits. Current results authenticated that application of nitrogen and potassium resulted in more number of fruits per plant in strawberry. This could be attributed to the fact that a higher nutritional dose helps in vigorous and enhanced growth in strawberries helping the plants to bear a higher number of fruits per plants. This phenomenon is justified by increased carbohydrates synthesis due to increased chlorophyll content of the foliage thus resulting increase number of fruits per plant (Maynard 1962). Nitrogen is a key nutrient in crop growth and yield, because it affects photosynthesis and dry matter partitioning among organs. In strawberry plants, nitrogen deficiency reduces carbon allocation to fruits, fruit number and yield (Deng and Woodward 1998). Thus the effect of nitrogen deficiency on potential fruit yield might be confined to the inhibition of branch crown proliferation and the lack of available sites for flower initiation (Abbott AJ 1968). Similarly, potassium, the most abundant of cations present in phloem sap (almost 80%), helps in the production of sugar and transporting it through the phloem into sink organs. Potassium has crucial role in photosynthesis and metabolism of carbohydrates. As nitrogen and potassium are essential to many of plant metabolic processes such as synthesis of proteins, nucleic acids, coenzymes, secondary metabolism products, enzyme activation, osmotic regulation, energy transfer, respiration and photosynthesis, among many other important processes (Castellanos-Morales et al 2010), therefore, increased berry set and number of berries per plant in the present investigation might be due to the cumulative effect of nutrients (nitrogen and potassium) on plant physiology and restricted vegetative growth by PP_{333}, which might have resulted in the formation of more metabolites resulting into more flowering and fruit set (McArthur and Eaton 1988).

The present investigation exhibited significant influence of nutrients and PGR on quality attributes of strawberry. Among different treatments, T_{15} significantly exhibited superiority to berry length (30.92 and 32.66 mm), breadth (21.21 and 21.41 mm), weight (9.54 and 9.74 g) and volume (9.63 and 9.79 cc) in 2010-11 and 2011-12, respectively, which was statistically at par with T_{18}, T_{16}, T_{14}, T_{19}, T_{17}, T_7 and T_8 for berry weight in 2010-11, T_{18}, T_{16} and T_{17} for berry weight in 2011-12, T_{16} and T_{18} for berry volume in 2011-12 and T_{16} for berry length in 2010-11 (Table 3). The increase in berry size, weight and volume may be due to the better supply of nutrients and metabolites to the berries by nutrients and growth retardant treatments (McArthur and Eaton 1988). Paclobutrazol appears to increase leaf chlorophyll per unit leaf area and enhance the photosynthetic capability of strawberry (Deyton *et al.*, 1991). Thus, increased translocation of assimilates from leaves to the developing fruits might be responsible for the increase of berry size and berry weight in strawberry. The TSS was significantly more in T_{15}, while titrable acidity was non-significant. Thus the application of nutrients in combination with

PP_{333} might have played regulatory role on the absorption and translocation of various metabolites like carbohydrates which affected the quality of fruits. This study implies synergistic effects of fertilisers (nitrogen and potassium) with GA_3 on growth while with PP_{333} on flowering, yield and quality attributes of strawberry cv. Chandler.

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How to cite this article:

Avnish Kumar Pandey, Sanjay Pathak and Prananath Barman and Shailendra K. Dwivedi. 2020. Influence of Nutrients and Plant Growth Regulators on Growth, Flowering and Yield Characteristics of Strawberry cv. Chandler. *Int.J.Curr.Microbiol.App.Sci.* 9(11): 143-151.
doi: https://doi.org/10.20546/ijcmas.2020.911.017