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Impact of plant growth regulators and different portions of vine on yield and yield attributes of sweet potato [*Ipomoea batatas* (L.) Lam.]

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Abstract
In the northern arid zone of Karnataka, at the vegetable block, department of vegetable sciences, College of Horticulture, Munirabad (Koppal), a field experiment was carried out in 2019 and 2020. Thirteen treatments were used in the factorial RCBD trial design. Two factors were *viz.*, different portions of vine for planting and plant growth regulators. Basal portion (P_1), middle portion (P_2) and top portion (P_3) were three different portions of vine. CCC @ 500 ppm (G_1), CCC @ 1000 ppm (G_2), Ethrel @ 150 ppm (G_3) and Ethrel @ 300 ppm (G_4) were four plant growth regulators. The control treatments were basal portion of vine (C_1), middle portion of vine (C_2) and top portion of vine (C_3) all without application of growth regulator. Pooled results indicated, among the different portions of vine used for planting, the top portion of vine recorded significantly higher total tuber yield of 21.49 (t/ha) over other two treatments. The overall tuber yield of 23.31 (t/ha) was considerably higher after the application of CCC at 500 ppm. A considerably greater overall tuber yield of 25.70 (t/ha) and a marketable tuber yield of 23.37 (t/ha) was obtained as a result of the interaction effect of planting vine tops followed by the application of CCC at 500 ppm.

Keywords: Plant growth regulators, portions of vine, total tuber yield, marketable tuber yield

Introduction
In tropical, subtropical, and warm temperate regions of the world, the sweet potato [*Ipomoea batatas* (L.) Lam.], a tuber crop belonging to the Convolvulaceae family, is a significant starchy food crop (Low *et al.*, 2015) [4]. In India, it is popularly known as Sakarkand. The plant is farmed for its edible tuberous roots, which have a carbohydrate content of about 27% and high levels of calcium, iron, vitamin A, and vitamin C. It can be eaten as a fresh vegetable, boiling food, or baked good. It is a staple food for tribal populations and a significant global food crop. One of the most recent developments in the study of horticulture is the application of growth regulators, which has resulted in a sort of revolution in the growth of crop yields.

When used at the right timing and concentration, plant growth-regulating chemicals have reportedly been shown to have a positive impact on the physiological and other biochemical functions of crop plants. This results in increased crop yield. The use of chemicals that control plant development has recently become a crucial part of agri-technical practise. Gibberellic acid (GA3), cycocel (CCC), and ethrel are significant growth regulators that can alter plant development, yield, and yield-contributing traits for the majority of cultivated crops (Alexopoulos *et al.*, 2006) [1].

The demand for sweet potato production is increasing due to commercialization, but biotic constraints such as insect pests, diseases, and a shortage of superior planting materials pose challenges. Sweet potatoes are vegetatively propagated via vine cutting. There is relatively little information available on the potential of various vine segments and foliar application of plant growth regulators in sweet potatoes grown in India. Many horticultural crops, especially those where the underground component is economically significant, have evidence that growth regulators increase yield.

Materials and Methods
At the vegetable block, department of vegetable sciences, college of horticulture, Munirabad (Koppal), University of Horticultural Sciences, Bagalkot, Karnataka, India, located at 15° 17' 33" North latitude, 76° 19' 17" East longitude, and 529 m above Mean Sea Level, a field

experiment was carried out in 2019 and 2020. The experimental site is physically located in an area that has 31 average wet days per year, spread out across four to six months (June to December), with an average yearly rainfall of 569 mm. The area's typical maximum temperature is 36 °C, and the typical minimum is 20 °C. 60 to 90% of the relative humidity is present. Design of experiment was factorial RCBD along with three control treatments. Two factors were *viz.*, different portions of vine for planting and plant growth regulators. Basal portion (P_1), middle portion (P_2) and top portion (P_3) were three different portions of vine. CCC @ 500 ppm (G_1), CCC @ 1000 ppm (G_2), Ethrel @ 150 ppm (G_3) and Ethrel @ 300 ppm (G_4) were four plant growth regulators. The control treatments were basal portion of vine without application of growth regulator (C_1), middle portion of vine without application of growth regulator (C_2) and top portion of vine without application of growth regulator (C_3). With a sandy loam texture and a medium level of organic carbon (0.45%), the experimental field had this composition. In terms of response, the soil had a normal pH of 7.9, was medium in terms of available nitrogen (304.0 kg ha^{-1}), high in terms of available phosphorus (62.0 kg ha^{-1}), and low in terms of available potassium (129.0 kg ha^{-1}).

Five randomly chosen labelled plants from the net plot area of each treatment and replication were used in the experiment to collect data on the following yield metrics. Five plants were recorded for each treatment, and the data were averaged and statistically analysed.

Tuber diameter (cm)

Five randomly chosen tubers from five tagged plants were measured for their diameter in the centre using a Vernier calliper, and the average of those measurements was calculated and represented in centimetres.

Tuber length (cm)

The same tubers that were used to estimate diameters were also used to estimate tuber length. The length of the tuber was measured in centimetres from top to bottom using a thread, and mean values were calculated.

Number of tubers per plant

At harvest, the total number of tubers from five tagged plants was counted, and the average was used to determine the number of tubers per plant.

Average tuber weight (g)

Ten tubers were chosen from each plot to represent each grade, and their weights were recorded using an electronic scale. The average weight was reported in grams.

Tuber yield per plant (g)

Tubers obtained from each tagged plant were weighed and average was worked out for five tagged plants and expressed in grams.

Total tuber yield (t/ha)

Each plot's tubers were harvested separately, and the yield per plot was recorded in kilogram's and converted to tonnes per hectare. Both commercially viable and undesirable tubers are included.

Marketable tuber yield (t/ha)

For all treatments in each replication, the marketable tuber yield (excluding weevil-infested and very small tubers) was recorded on a net plot basis, computed as the marketable tuber yield, and reported in tonnes per hectare.

Results and Discussion

Tuber diameter and length

Different portions of vine differed significantly for tuber diameter. Among the different portions of vine, top portion of vine (P_3) recorded significantly superior tuber diameter (5.42 cm) and tuber length (13.63 cm) as compared to middle and basal portion of vine. In comparison to semi-hard wood and hard wood cuttings, which have all of the aforementioned characteristics to a lesser extent, and hard wood cuttings due to overage, have high wilting ability which causes rapid loss of water that reduces rooting ability of the cutting, soft wood cuttings have resulted in better growth performance than other types of cutting (Lencha *et al.*, 2016) [3].

Among growth regulators, CCC application at 500 ppm (G_1) recorded significantly higher tuber diameter (5.80 cm) and tuber length (14.82 cm) as compared to other growth regulators. Significantly lower tuber diameter (4.04 cm) and tuber length (11.21 cm) was recorded with ethrel @ 300 ppm (G_4).

In comparison to all other interactions, the interaction of P3G1, or the top portion of the vine, with the administration of CCC @ 500 ppm, resulted in significantly bigger tuber diameter (6.40 cm). While, significantly lowest tuber diameter (3.81 cm) was recorded with interaction of basal portion of vine with the application of ethrel @ 300 ppm (P_1G_4).The middle portion of vine with application CCC @ 500 ppm (P_2G_1) recorded significantly highest tuber length (15.15 cm) which was on par with interaction of P_3G_1 (15.10 cm) and P_1G_1 (14.21 cm). While, lowest tuber length was recorded with interaction of P_1G_4 (9.03 cm).

The largest tuber diameter ever recorded in CCC at 500 ppm may be the result of inhibited vine growth brought on by the increase in photo assimilates allocated to the tuber part alone. These outcomes can be compared to those from Vahab and Kumaran (1980) [9].

Number of tubers, average tuber weight and total tuber yield per plant

In comparison to all other treatments, the top portion of the vine produced substantially more sweet potato tubers (3.17), had an average tuber weight of 219.0 g, and produced 357.50 g of tubers per plant. While there were considerably fewer tubers (2.63), average tuber weight (193.05 g), and tuber production per plant (322.13 g) in the treatment containing the basal section of the vine.

The increased tuber width and tuber length can be directly linked to an increase in the average tuber weight per plant. Essilfie *et al.* (2016) [2] and Netsai *et al.* (2019) [5] also reported on related findings that are similar to these. According to the dry matter partitioning theory, sweet potatoes often exhibit three growth periods. Shoot growth predominates in the initial phase, with an increasing amount of dry matter being directed towards it. A second phase of continuous dry matter partitioning between shoot and tuber growth follows this. A significant fraction of the dry matter is divided into tubers during the third phase. Cuttings from the shoot apex are preferable than basal or middle vine cuttings as planting material.

In the treatment of CCC application at 500 ppm, there were noticeably more sweet potato tubers (3.61), an average tuber weight of 235.15 g, and a tuber yield per plant of 406.17 g. The cause may be because of restricted vegetative development, which caused photo assimilates to be diverted for the creation of more tubers per vine. These outcomes are consistent with Vahab and Kumaran's (1980) [9] conclusions. Due to the biggest tuber diameter, longest tuber length, and most tubers per plant compared to the other treatments, treatment CCC @ 500 ppm produced the maximum tuber production per plant. These results are consistent with Sahu *et al.* (2021) [6] and Sarkar and Sarma's (2008) [7] studies.

Regarding the quantity of tubers, the average tuber weight, and the tuber yield per plant, the interaction effect of various vine parts in combination with growth regulators varied greatly. Significantly more sweet potato tubers (4.17), average tuber weight (248.12 g), and tuber yield per plant (449.0 g) were seen when CCC was applied to the P3G1 region of the vine at a 500 ppm concentration. An appreciably greater average tuber production per plant can be attributed to a rise in average tuber weight, an increase in the number of tubers per plant, and improvements in tuber diameter and length. Similar findings were made on sweet potatoes by Shedge *et al.* (2008) [8], who discovered that CCC 500 ppm produced the highest tuber output per vine.

Total tuber yield and marketable tuber yield

Total tuber yield and marketable tuber yield varied greatly with different vine parts, according to pooled statistics. The treatment containing the top portion of the vine (P3) had the highest overall tuber production (21.49 t/ha) and marketable tuber yield (19.25 t/ha), respectively. The treatment with the basal section of the vine (P1), however, considerably reduced both the marketable tuber yield (16.90 t/ha) and the overall tuber yield (19.14 t/ha). Overall tuber production parameters due to physiological benefits by employing the top half of the vine for planting can be directly attributed to increased yield attributes, including tuber length, tuber diameter, number of tubers per plant, and average tuber weight.

When CCC was applied at 500 ppm (G1), the highest overall tuber yield (23.31 t/ha) and marketable tuber yield (21.40 t/ha) were both observed. The interaction effects of different portions of vine in combination with growth regulators found significant during pooled basis with respect to the total tuber yield and marketable tuber yield. P3G1 interaction resulted in significantly greater overall tuber yield (25.70 t/ha) and marketable tuber yield (23.37 t/ha).While the interaction of P1G4 resulted in considerably decreased total tuber yield (16.53 t/ha) and marketable tuber yield (14.05 t/ha), respectively.

The storage roots of sweet potato plants that were propagated from apical and middle cuttings contain the most-dry materials. An important consideration is the age of the source plants from which cuttings are taken. When cuttings from older plants are employed, storage root yields are drastically decreased. According to Villamayor and Perez (1988) [10], the yield of plants from basal cuttings was 56% lower than that of plants from apical branch cuttings. The highest possible tuber production can be ascribed to higher average tuber weight, more tubers per plant, and improvements in tuber diameter and length, which have all had a noticeable impact on higher average tuber weight. Both Sarkar and Sarma (2008) [7] and Shedge *et al.* (2008) [8] found comparable results in sweet potato.

Table 1: Effect of different portions of vine and plant growth regulators on tuber diameter (cm) and tuber length (cm) of sweet potato

Treatment		Tuber diameter (cm)			Tuber length (cm)		
		2019	2020	Pooled	2019	2020	Pooled
Portions of vine (P)							
P_1	Basal portion	4.74	4.44	4.55	12.29	12.28	12.28
P_2	Middle portion	5.13	5.00	5.06	13.43	13.40	13.41
P_3	Top portion	5.38	5.47	5.42	13.73	13.52	13.63
S. Em.±		0.09	0.08	0.06	0.27	0.24	0.18
C.D at 5%		0.26	0.23	0.17	0.78	0.72	0.52
Plant growth regulators (PGR) (G)							
G_1	CCC @ 500 ppm	5.95	5.73	5.80	15.07	14.56	14.82
G_2	CCC @ 1000 ppm	4.87	4.95	4.91	13.31	13.03	13.17
G_3	Ethrel @ 150 ppm	5.30	5.32	5.31	13.32	13.14	13.23
G_4	Ethrel @ 300 ppm	4.21	3.86	4.04	10.90	11.52	11.21
S. Em.±		0.10	0.09	0.07	0.31	0.28	0.20
C.D at 5%		0.31	0.27	0.19	0.90	0.83	0.60
Interaction (P x G)							
P_1G_1		5.49	4.92	5.07	14.53	13.88	14.21
P_1G_2		4.88	4.52	4.70	13.04	12.79	12.92
P_1G_3		4.58	4.70	4.64	12.98	13.00	12.99
P_1G_4		4.00	3.61	3.81	8.62	9.43	9.03
P_2G_1		5.98	5.85	5.92	15.31	14.98	15.15
P_2G_2		4.73	4.81	4.77	13.54	13.18	13.36
P_2G_3		5.68	5.63	5.66	13.62	13.25	13.44
P_2G_4		4.12	3.70	3.91	11.24	12.18	11.71
P_3G_1		6.37	6.43	6.40	15.36	14.83	15.10
P_3G_2		5.00	5.51	5.26	13.35	13.12	13.24
P_3G_3		5.65	5.64	5.65	13.36	13.18	13.27
P_3G_4		4.51	4.28	4.40	12.85	12.95	12.90
S. Em.±		0.18	0.16	0.11	0.53	0.49	0.35
C.D at 5%		0.53	0.47	0.33	1.56	1.43	1.04

Control (C)							
C_1	Basal portion without PGR	3.20	3.26	3.23	9.40	9.45	9.43
C_2	Middle portion without PGR	3.65	3.72	3.69	10.12	10.03	10.08
C_3	Top portion without PGR	3.74	4.17	3.96	11.00	10.29	10.65
S. Em.±		0.16	0.16	0.10	0.51	0.46	0.34
C.D at 5%		0.47	0.45	0.29	1.49	1.32	0.98

Table 2: Effect of different portions of vine and plant growth regulators on number of tubers per plant, average tuber weight and tuber yield per plant of sweet potato

Treatment		Number of tubers per plant			Average tuber weight (g)			Tuber yield per plant (g per plant)		
		2019	2020	2019	2019	2019	Pooled	2019	2019	Pooled
Portions of vine (P)										
P_1	Basal portion	2.50	2.75	2.63	194.33	191.78	193.05	325.00	319.25	322.13
P_2	Middle portion	2.92	3.25	3.08	212.63	206.84	209.73	344.50	337.25	340.88
P_3	Top portion	3.00	3.33	3.17	217.97	220.03	219.00	358.50	356.50	357.50
S. Em.±		0.06	0.07	0.05	3.76	3.42	2.31	6.42	6.15	4.97
C.D at 5%		0.18	0.20	0.15	11.04	10.04	6.78	18.82	18.04	14.56
Plant growth regulators (G)										
G_1	CCC @ 500 ppm	3.44	3.78	3.61	235.13	235.18	235.15	403.67	408.67	406.17
G_2	CCC @ 1000 ppm	2.56	2.89	2.72	207.95	205.97	206.96	310.00	310.00	310.00
G_3	Ethrel @ 150 ppm	2.89	3.22	3.06	217.86	217.91	217.89	380.00	373.67	376.83
G_4	Ethrel @ 300 ppm	2.33	2.56	2.44	172.31	165.79	169.05	277.00	258.33	267.67
S. Em.±		0.07	0.08	0.06	4.35	3.95	2.67	7.41	7.10	5.73
C.D at 5%		0.21	0.23	0.17	12.74	11.59	7.83	21.73	20.84	16.81
Interaction (P x G)										
P_1G_1		2.67	3.00	2.83	219.87	218.14	219.01	374.00	377.00	375.50
P_1G_2		2.33	2.67	2.50	197.41	190.48	193.95	289.00	300.00	294.50
P_1G_3		2.67	3.00	2.83	211.20	210.45	210.83	372.00	368.00	370.00
P_1G_4		2.33	2.33	2.33	148.85	148.03	148.44	265.00	232.00	248.50
P_2G_1		3.67	4.00	3.83	237.23	239.45	238.34	395.00	393.00	394.00
P_2G_2		2.67	3.00	2.83	212.21	212.19	212.20	323.00	312.00	317.50
P_2G_3		3.00	3.33	3.17	220.68	222.74	221.71	386.00	384.00	385.00
P_2G_4		2.33	2.67	2.50	180.39	152.96	166.68	274.00	260.00	267.00
P_3G_1		4.00	4.33	4.17	248.28	247.95	248.12	442.00	456.00	449.00
P_3G_2		2.67	3.00	2.83	214.23	215.25	214.74	318.00	318.00	318.00
P_3G_3		3.00	3.33	3.17	221.70	220.55	221.13	382.00	369.00	375.50
P_3G_4		2.33	2.67	2.50	187.68	196.37	192.03	292.00	283.00	287.50
S. Em.±		0.13	0.14	0.10	7.53	6.84	4.62	12.83	12.30	9.93
C.D at 5%		0.37	0.40	0.29	22.07	20.07	13.56	37.64	36.09	29.12
Control										
C_1	Basal portion	1.67	1.67	1.67	136.53	130.69	133.61	239.00	232.00	235.50
C_2	Middle portion	2.00	2.00	2.00	147.75	148.68	148.22	260.00	257.00	258.50
C_3	Top portion	2.33	2.33	2.33	151.86	170.16	161.01	259.00	280.00	269.50
S. Em.±		0.12	0.14	0.08	6.81	6.43	4.51	12.10	11.79	9.07
C.D at 5%		0.36	0.39	0.24	19.73	18.64	13.08	35.06	34.15	26.26

Table 3: Effect of different portions of vine and plant growth regulators on total tuber yield and marketable tuber yield per hectare of sweet potato

Treatment		Total tuber yield (t/ha)			Marketable tuber yield (t/ha)		
		2019	2020	Pooled	2019	2020	Pooled
Portions of vine (P)							
P_1	Basal portion	19.51	18.77	19.14	17.20	16.60	16.90
P_2	Middle portion	20.74	20.50	20.62	18.74	18.54	18.64
P_3	Top portion	21.62	21.36	21.49	19.37	19.14	19.25
S. Em.±		0.45	0.32	0.25	0.34	0.28	0.24
C.D at 5%		1.31	0.93	0.73	1.01	0.83	0.69
Plant growth regulators (PGR) (G)							
G_1	CCC @ 500 ppm	23.49	23.13	23.31	21.51	21.29	21.40
G_2	CCC @ 1000 ppm	19.43	19.26	19.35	17.22	17.07	17.15
G_3	Ethrel @ 150 ppm	21.62	20.90	21.26	19.38	18.73	19.06
G_4	Ethrel @ 300 ppm	17.96	17.54	17.75	15.63	15.27	15.45
S. Em.±		0.51	0.37	0.29	0.40	0.33	0.27
C.D at 5%		1.51	1.07	0.84	1.16	0.96	0.80
Interaction (P x G)							
P_1G_1		21.10	20.46	20.78	18.99	18.62	18.81
P_1G_2		19.00	18.69	18.85	16.72	16.44	16.58
P_1G_3		20.56	20.25	20.41	18.29	18.01	18.15
P_1G_4		17.39	15.66	16.53	14.78	13.31	14.05
P_2G_1		23.79	23.12	23.46	22.30	21.75	22.03
P_2G_2		19.54	19.56	19.55	17.38	17.40	17.39
P_2G_3		21.87	21.12	21.50	19.67	19.00	19.34
P_2G_4		17.75	18.20	17.98	15.62	16.01	15.82
P_3G_1		25.59	25.81	25.70	23.24	23.49	23.37
P_3G_2		19.74	19.54	19.64	17.56	17.38	17.47
P_3G_3		22.43	21.33	21.88	20.18	19.19	19.69
P_3G_4		18.73	18.76	18.75	16.48	16.50	16.49
S. Em.±		0.89	0.63	0.50	0.69	0.57	0.47
C.D at 5%		2.62	2.46	1.54	2.01	1.66	1.38
Control (C)							
C_1	Basal portion without PGR	15.25	15.65	15.45	12.95	13.31	13.13
C_2	Middle portion without PGR	17.20	16.56	16.88	14.53	14.07	14.30
C_3	Top portion without PGR	17.11	17.07	17.09	14.62	14.50	14.56
S. Em.±		0.85	0.58	0.46	0.63	0.51	0.43
C.D at 5%		2.46	1.67	1.34	1.83	1.49	1.24

Conclusion

Better yield characteristics were obtained by sowing the top portion of the vine and then applying CCC at 500 ppm 40 and 60 days later. This method produced the highest overall tuber yield per hectare (25.70 tonnes) and marketable tuber yield (23.37 tonnes) in comparison to other treatments. The next best interaction was found with middle portion of vine in combination with the application of growth regulator CCC @ 500 ppm (P_2G_1). In general, irrespective of growth regulators, planting with basal portion of vine (Control: C_1) recorded lowest yield attributes.

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