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(RESEARCH ARTICLE)

Improvement of Vegetative Growth of *Solanum xanthocarpum* Subjected to Homobrassinolide and Salicylic Acid Treatment

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Abstract

Brassinosteroids and salicylic acid are considered as the on-going potent plant growth regulators or PGRs in the current research studies in plant physiology. Brassinosteroids commonly called as BRs are low-molecular-weight steroid hormones present in plants, analogous to those identified in animals and salicylic acid (SA) is an endogenous signal molecule capable of regulating plant growth and development and modulating many physiological responses though the induction of stress tolerance in plants. The current study is focusing on the changes in the vegetative growth of *Solanum xanthocarpum* when foliar treatment of homobrassinolide and salicylic acid resulted in improved growth enhancement in terms of plant fresh weight, plant dry weight, shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weight, root dry weight, number of branches, number of leaves, leaf length and width of leaves.

Keywords: Homobrassinolide; Leaf growth; Salicylic acid; Root growth; Shoot growth

1. Introduction

Solanum xanthocarpum L. is commonly called as Indian nightshade or as yellow berried night shade is an important medicinally useful plant (Parmar et al., 2010). *Solanum xanthocarpum* is reported to be considered as one of the ten most important plants used in preparations of ayurvedic medicine. This plant has lots of prickles or thorns and hence called as *Duhsparsa* which means that – it is difficult to touch. The importance of this plant lies in the presence of phytochemicals present in its fresh fruits like glycoalkaloid, solanine and β-sitosterol etc.

Brassinosteroids (BRs) are a novel group of low-molecular-weight plant growth regulators present in plants and the analogous to those identified in animals too (Khripach et al., 2000; Vardhini et al., 2025). These were first discovered in rapeseed (*Brassica napus*) pollen extracts initially conducted by Mitchell et al. (1970) and were named as brassins. They found that approximately 500 pounds of rape's pollen when isolated and processed possessed certain the active factor(s) called 'brassins' and later named as brassinosteroids. There are numerous brassinosteroids and homobrassinolide is one of the potent BR (Vardhini, 2017).

Salicylic acid (SA) is a well-known endogenous signal molecule capable of regulating various physiological responses in plants. SA was found to play a major role in the regulation of plant growth, development, and interaction with other organisms and defense responses to environmental stresses (Devinar et al., 2013; Bastam et al., 2013). The present study is to understand the potentiality of homobrassinolide and salicylic acid in improving the vegetative growth of *Solanum xanthocarpum* like plant fresh weight, plant dry weight, shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weight, root dry weight, number of branches, number of leaves, leaf length and width of leaves grown in semi-arid soils of Nizamabad.

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2. Materials and Methods

The seeds of *Solanum xanthocarpum* L. were collected from the nearby areas of Peddavalgot Village, Sirikonda Mandal, Nizamabad, Telangana State, India. Homobrassinolide was purchased from Godrej Agrovet Private Limited and salicylic acid was procured from Dwarakamai Enterprises, Hyderabad, Telangana State, India.

The seeds of *Solanum xanthocarpum* L. were collected from around Peddavalgot Village of Sirikonda Mandal and carefully dried under the sun for 10 days and these seeds were used for the experimental studies. The seeds were surface first sterilized with 0.5% (v/v) sodium hypochlorite and washed carefully with several changes of sterile distilled water and sowed in the prepared seed bed. Seed germination took place from twelve to eighteen days after sowing.

The saplings of *Solanum xanthocarpum* were carefully removed from the seed bed and transferred to black polythene bags containing black soil and was evenly and uniformly twenty kilograms of conventional compost on the tenth day from sowing. Nine replicates were maintained for each administration of homobrassinolide, salicylic acid and controls. Homobrassinolide at concentrations of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM and 4.0 µM were externally administered to *Solanum xanthocarpum* plants on the 15th, 20th, 30th and 45th days from sowing. Similarly, salicylic acid at concentrations of 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM and 4.0 mM was also externally administered to *Solanum xanthocarpum* plants on 15th, 20th, 30th and 45th days from sowing. The controls of *Solanum xanthocarpum* were administered with distilled water. The present research study was carried out in order to find out the effect of two PGRs viz., homobrassinolide and salicylic acid on the growth and yield of *Solanum xanthocarpum* under the mentioned criteria.

2.1. Plant Fresh Weight of *Solanum xanthocarpum*

Solanum xanthocarpum plants were carefully uprooted and the plant fresh weight was recorded on the 20th, 30th, 45th and 60th days after sowing and the values were noted in grams (g) using a meter balance.

2.2. Plant Dry Weight of *Solanum xanthocarpum*

After a day of drying in an oven set at 110^{o}C, the dry weight of *Solanum xanthocarpum* plants were recorded in grams (g) on 20th, 30th, 45th and 60th days after planting using a meter balance.

2.3. Shoot Length of *Solanum xanthocarpum*

On the 20th, 30th, 45th and 60th days after planting, the shoot length of *Solanum xanthocarpum* plants were recorded using a meter scale and the values were noted in meters (m).

2.4. Shoot Fresh Weight of *Solanum xanthocarpum*

On the 20th, 30th, 45th and 60th days after planting, the shoot fresh weight of *Solanum xanthocarpum* plants were recorded using a meter balance and the values were noted in grams (g).

2.5. Shoot Dry Weight of *Solanum xanthocarpum*

After a day of drying in an oven set at 110^{o}C, the shoot dry weight of *Solanum xanthocarpum* were recorded in grams (g) on 20th, 30th, 45th and 60th days after planting using a meter balance.

2.6. Root Length of *Solanum xanthocarpum*

On the 20th, 30th, 45th and 60th days after planting, the root length of *Solanum xanthocarpum* plants were recorded using a meter scale and the values were noted in meters (m).

2.7. Root Fresh Weight of *Solanum xanthocarpum*

On the 20th, 30th, 45th and 60th days after planting, the root fresh weight of *Solanum xanthocarpum* plants were recorded using a meter balance and the values were noted in grams (g).

2.8. Root Dry Weight of *Solanum xanthocarpum*

After a day of drying in an oven set at 110^{o}C, the root dry weight of *Solanum xanthocarpum* were recorded in grams (g) on 20th, 30th, 45th and 60th days after planting using a meter balance.

2.9. Number of Branches of *Solanum xanthocarpum*

The number of branches of *Solanum xanthocarpum* were recorded on 30th, 45th and 60th days after planting.

2.10. Number of Leaves of *Solanum xanthocarpum*

The number of leaves of *Solanum xanthocarpum* were recorded on 30th, 45th and 60th days after planting.

2.11. Leaf Length of *Solanum xanthocarpum*

The leaf length of *Solanum xanthocarpum* were recorded on 30th, 45th and 60th days after planting using a meter scale. The values were expressed in meters (m).

2.12. Average Width of Leaf of *Solanum xanthocarpum*

The average width of leaf of *Solanum xanthocarpum* was calculated by taking the leaf width at five different places and the average of it were recorded on 30th, 45th and 60th days after planting using a meter scale. The values were expressed in meters (m).

3. Results

3.1. Homobrassinolide and Salicylic Acid on Whole Plant Fresh and Dry Weights of *Solanum xanthocarpum*

The present study documented that administration of homobrassinolide at concentrations of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM and 4.0 µM resulted in the significant enhancement in whole plant fresh and dry weights of *Solanum xanthocarpum* recorded on 20th, 30th, 45th and 60th day as shown in Table 1and 2 compared to the untreated controls. It was also observed on all recorded days that the whole plant fresh and dry weights of *Solanum xanthocarpum* gradually increased with administration of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM of homobrassinolide but decreased on administration 4.0 µM concentration of homobrassinolide though it was more than the untreated controls and 3.0 µM of homobrassinolide was found best among all homobrassinolide applications

Table 1 Homobrassinolide and Salicylic Acid on Whole Plant Fresh Weight of *Solanum xanthocarpum*

S. No.	Treatments	Whole Plant Fresh Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	51.32 ± 2.2	139.33 ± 2.2	189.33 ± 2.3	283.66 ± 3.4
2	0.5 µM HomoBL	62.00 ± 2.2	151.00 ± 2.3	214.66 ± 3.2	330.00 ± 3.3
3	1.0 µM HomoBL	66.00 ± 1.6	155.33 ± 2.4	238.00 ± 3.6	343.00 ± 3.2
4	2.0 µM HomoBL	67.00 ± 1.3	165.00 ± 1.2	243.00 ± 3.4	360.33 ± 3.4
5	3.0 µM HomoBL	86.33 ± 1.2	199.33 ± 1.4	287.33 ± 3.6	387.66 ± 4.2
6	4.0 µM HomoBL	67.33 ± 1.0	162.66 ± 1.4	246.33 ± 3.0	355.00 ± 4.2
7	0.5 mM SA	55.00 ± 2.2	141.66 ± 2.6	226.00 ± 3.0	326.66 ±3.6
8	1.0 mM SA	57.00 ± 1.2	150.33 ±2.6	232.66 ± 3.2	339.66 ± 4.4
9	2.0 mM SA	58.66 ± 1.0	156.33 ± 1.4	244.33 ±3.5	352.33 ± 4.4
10	3.0 mM SA	70.66 ± 2.3	179.66 ± 2.4	265.33 ± 3.5	368.66 ± 4.2
11	4.0 mM SA	63.33 ± 2.3	152.00 ± 2.0	233.33 ± 3.4	354.66 ± 3.6
12	3.0 µM HomoBL + 3.0 mM SA	89.00 ± 1.0	204.66 ± 2.0	298.66 ± 3.4	390.00 ± 4.4

The present study also documented that administration of salicylic acid at concentrations of 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM and 4.0 mM resulted in the significant enhancement in whole plant fresh and dry weights of *Solanum xanthocarpum* in comparison to untreated controls on all recorded days as shown in Table 1 and table 2. It was also documented that the whole plant fresh and dry weights of *Solanum xanthocarpum* gradually increased from 0.5 mM, 1.0

mM, 2.0 mM, 3.0 mM concentrations of salicylic acid but decreased on the administration 4.0 mM concentration of salicylic acid though was more than the untreated controls and 3.0 mM of salicylic acid was found best among all salicylic acid applications.

Table 2 Homobrassinolide and Salicylic Acid on Whole Plant Dry Weight of *Solanum xanthocarpum*

S. No.	Treatments	Whole Plant Dry Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	15.19 ± 1.51	65.48 ± 2.52	98.06 ± 3.71	191.77 ± 4.33
2	0.5 µM HomoBL	16.21 ± 2.72	67.50 ± 1.61	111.28 ± 4.81	211.89 ± 5.32
3	1.0 µM HomoBL	16.23 ± 2.64	69.59 ± 1.54	118.31 ± 7.90	223.94 ± 6.23
4	2.0 µM HomoBL	17.24 ± 2.72	71.61 ± 1.64	123.41 ± 8.99	234.03 ± 6.33
5	3.0 µM HomoBL	17.29 ± 2.62	74.78 ± 3.64	134.75 ±7.89	258.59 ± 6.28
6	4.0 µM HomoBL	16.25 ± 2.51	68.63 ± 1.72	121.37 ± 6.87	249.07 ± 6.36
7	0.5 mM SA	16.19 ± 2.51	66.49 ± 2.82	109.28 ± 5.24	226.78 ± 5.28
8	1.0 mM SA	16.20 ± 1.52	67.55 ± 2.64	111.31 ± 4.23	231.81 ± 6.11
9	2.0 mM SA	17.22 ± 1.64	68.54 ± 2.52	125.55 ± 5.23	239.85 ± 5.88
10	3.0 mM SA	17.25 ± 3.76	70.71 ± 0.66	131.28 ± 5.67	240.05 ± 6.22
11	4.0 mM SA	16.21 ± 2.61	67.55 ± 1.72	120.23 ± 6.27	234.87 ± 5.28
12	3.0 µM HomoBL + 3.0 mM SA	17.33 ± 3.64	78.82 ± 2.56	141.83 ± 5.36	267.66 ± 6.22

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Further, the co-application of homobrassinolide at 3.0 µM and salicylic acid at 3.0 mM showed the highest growth in terms of whole plant fresh and dry weights of *Solanum xanthocarpum* over all the treatments on all recorded days documented in the present study.

3.2. Homobrassinolide and Salicylic Acid on Shoot Growth of *Solanum xanthocarpum*

The present research documented that administration of homobrassinolide at concentrations of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM and 4.0 µM showed marked increments in shoot growth (shoot length, fresh and dry weights) of *Solanum xanthocarpum* recorded on 20th, 30th, 45th and 60th day as shown in Tables 3-5 compared to the untreated controls. It was also observed that the shoot growth (shoot length, fresh and dry weights) of *Solanum xanthocarpum* on all recorded days gradually increased from 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM concentrations but decreased on administration 4.0 µM concentration of homobrassinolide though it was more than the untreated controls and 3.0 µM of homobrassinolide was found best among all homobrassinolide applications.

The present research also documented that administration of salicylic acid on all recorded days at concentrations of 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM and 4.0 mM showed marked increments in whole plant dry weight of *Solanum xanthocarpum* in comparison to untreated controls as shown in Table 3-5. It was also observed that the shoot growth (shoot length, fresh and dry weights) of *Solanum xanthocarpum* gradually increased from administration of 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM concentrations of salicylic acid but decreased with administration 4.0 mM concentration of salicylic acid though was more than the untreated controls and 3.0 mM of salicylic acid was found best among all salicylic acid applications.

Table 3 Homobrassinolide and Salicylic Acid on Shoot Length of *Solanum xanthocarpum*

S. No.	Treatments	Shoot Length (m)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	0.50 ± 0.13	1.50 ± 0.27	2.32 ± 0.48	3.12 ± 0.99
2	0.5 µM HomoBL	0.61 ± 0.23	1.61 ± 0.26	2.41 ± 0.57	3.20 ± 0.87
3	1.0 µM HomoBL	0.65 ± 0.21	1.72 ± 0.34	2.49 ± 0.54	3.30 ± 0.79
4	2.0 µM HomoBL	0.71 ± 0.22	1.79 ± 0.23	2.54 ± 0.66	3.41 ± 0.99
5	3.0 µM HomoBL	0.82 ± 0.34	1.82 ± 0.45	2.69 ± 0.76	3.52 ± 0.94
6	4.0 µM HomoBL	0.70 ± 0.33	1.71 ± 0.43	2.51 ± 0.74	3.40 ± 0.87
7	0.5 mM SA	0.54 ± 0.22	1.59 ± 0.34	2.40 ± 0.84	3.19 ± 0.87
8	1.0 mM SA	0.63 ± 0.23	1.65 ± 0.36	2.46 ± 0.62	3.27 ± 0.86
9	2.0 mM SA	0.69 ± 0.33	1.71 ± 0.32	2.50 ± 0.73	3.39 ± 0.78
10	3.0 mM SA	0.79 ± 0.42	1.80 ± 0.045	2.61 ± 0.84	3.49 ± 0.94
11	4.0 mM SA	0.68 ± 0.42	1.69 ± 0.43	2.53 ± 0.95	3.41 ± 0.95
12	3.0 µM HomoBL + 3.0 mM SA	0.88 ± 0.34	1.87 ± 0.56	2.71 ± 0.95	3.61 ± 0.99

Table 4 Homobrassinolide and Salicylic Acid on Shoot Fresh Weight of *Solanum xanthocarpum*

S. No.	Treatments	Shoot Fresh Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	4.94 ± 1.06	9.32 ± 1.26	19.08 ± 2.19	26.24 ± 3.29
2	0.5 µM HomoBL	5.21 ± 1.23	9.98 ± 2.1 6	21.23 ± 2.57	28.23 ± 3.26
3	1.0 µM HomoBL	5.98 ± 1.15	10.38 ± 2.35	22.56 ± 2.85	29.48 ± 3.45
4	2.0 µM HomoBL	6.72 ± 2.16	11.54 ± 2.58	23.22 ± 2.28	31.24 ± 3.67
5	3.0 µM HomoBL	7.17 ± 2.27	12.23 ± 3.85	25.21 ± 4.39	34.21 ± 0.05
6	4.0 µM HomoBL	6.70 ± 2.37	11.98 ± 3.24	23.11 ± 4.18	33.22 ± 4.17
7	0.5 mM SA	5.16 ± 1.99	9.89 ± 2.33	20.89 ± 3.28	27.89 ± 3.56
8	1.0 mM SA	5.89 ± 1.87	10.17 ± 2.86	21. 99 ± 2.17	30.78 ± 3.48
9	2.0 mM SA	6.58 ± 1.77	11. 44 ± 2.76	22.87 ± 3.55	33.65 ± 4.18
10	3.0 mM SA	7.05 ± 3.16	12.01 ± 2.64	24.99 ± 4.27	34.08 ± 3.29
11	4.0 mM SA	6.46 ± 1.23	11.57 ± 2.15	23.76 ± 3.24	33.12 ± 4.18
12	3.0 µM HomoBL + 3.0 mM SA	7.84 ± 3.26	12.87 ± 3.16	26.08 ± 4.56	35.23 ± 3.98

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Table 5 Homobrassinolide and Salicylic Acid on Shoot Dry Weight of *Solanum xanthocarpum*

S. No.	Treatments	Shoot Dry Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	2.21 ± 1.53	4.21 ± 1.96	8.12 ± 1.12	12.04 ± 1.95
2	0.5 µM HomoBL	2.88 ± 1.72	5.02 ± 1.97	9.85 ± 1.25	12.98 ± 1.47
3	1.0 µM HomoBL	3.22 ± 1.63	5.32 ± 1.97	10.35 ± 1.22	13.56 ± 1.28
4	2.0 µM HomoBL	3.99 ± 1.92	5.99 ± 1.73	11.68 ± 1.16	14.22 ± 1.36
5	3.0 µM HomoBL	4.56 ± 2.06	6.24 ± 1.95	12.24 ± 1.19	15.98 ± 2.14
6	4.0 µM HomoBL	3.84 ± 1.82	5.67 ± 1.84	11.23 ± 1.18	14.11 ± 1.46
7	0.5 mM SA	2.74 ± 1.71	4.94 ± 1.73	9.45 ± 1.10	12.67 ± 1.14
8	1.0 mM SA	3.08 ± 1.93	5.24 ± 1.75	10.10 ± 1.12	13.28 ± 1.56
9	2.0 mM SA	3.79 ± 1.92	5.86 ± 1.94	11.34 ± 1.06	14.04 ± 1.32
10	3.0 mM SA	4.28 ± 2.95	6.03 ± 1.95	12.06 ± 1.34	15.23 ± 2.15
11	4.0 mM SA	3.58 ± 1.81	5.42 ± 1.98	11.08 ± 1.39	13.98 ± 1.14
12	3.0 µM HomoBL + 3.0 mM SA	5.10 ± 2.12	6.72 ± 1.94	12.83 ± 2.10	16.18 ± 1.26

Further, the co-application of homobrassinolide at 3.0 µM and salicylic acid at 3.0 mM showed the highest shoot growth (shoot length, fresh and dry weights) of *Solanum xanthocarpum* over all the treatments documented on all recorded days in the present research study.

3.3. Homobrassinolide and Salicylic Acid on Root Growth of *Solanum xanthocarpum*

Table 6 Homobrassinolide and Salicylic Acid on Root Length of *Solanum xanthocarpum*

S. No.	Treatments	Root Length (m)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	0.10 ± 0.01	1.12 ± 0.12	2.30 ± 0.21	4.40 ± 1.12
2	0.5 µM HomoBL	0.15 ± 0.01	1.25 ± 0.17	2.90 ± 0.39	4.49 ± 1.21
3	1.0 µM HomoBL	0.26 ± 0.02	1.36 ± 0.12	3.57 ± 0.78	4.54 ± 1.32
4	2.0 µM HomoBL	0.34 ± 0.01	1.43 ± 0.17	3.93 ± 0.89	4.59 ± 1.22
5	3.0 µM HomoBL	0.46 ± 0.02	1.57 ± 0.19	4.20 ± 0.94	4.67 ± 1.82
6	4.0 µM HomoBL	0.32 ± 0.01	1.41 ± 0.15	3.75 ± 0.87	4.56 ± 1.61
7	0.5 mM SA	0.12 ± 0.02	1.19 ± 0.16	2.75 ± 0.79	4.48 ± 1.71
8	1.0 mM SA	0.21 ± 0.02	1.29 ± 0.18	3.38 ± 0.89	4.51 ± 1.81
9	2.0 mM SA	0.33 ± 0.02	1.32 ± 0.19	3.78 ± 0.98	4.57 ± 1.92
10	3.0 mM SA	0.40 ± 0.01	1.40 ± 0.19	4.06 ± 0.76	4.60 ± 2.12
-11	4.0 mM SA	0.31 ± 0.01	1.50 ± 0.17	3.65 ± 0.87	4.52 ± 1.31
12	3.0 µM HomoBL + 3.0 mM SA	0.51 ± 0.02	1.62 ± 0.19	4.36 ± 0.98	4.71 ± 2.01

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Table 7 Homobrassinolide and Salicylic Acid on Root Fresh Weight of *Solanum xanthocarpum*

S. No.	Treatments	'Root Fresh Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	1.87 ± 0.93	4.21 ± 1.10	8.67 ± 1.32	13.21 ± 1.95
2	0.5 µM HomoBL	2.18 ± 1.32	5.01 ± 1.22	9.54 ± 1.54	14.09 ± 2.12
3	1.0 µM HomoBL	2.96 ± 1.03	5.98 ± 1.20	10.44 ± 1.37	15.35 ± 2.28
4	2.0 µM HomoBL	3.73 ± 0.91	6.21 ± 1.28	11.24 ± 1.92	16.76 ± 2.19
5	3.0 µM HomoBL	4.67 ± 1.02	7.32 ± 1.93	12.24 ± 1.87	17.21 ± 2.23
6	4.0 µM HomoBL	3.40 ± 0.83	6.34 ± 1.56	11.11 ± 1.65	16.79 ± 2.67
7	0.5 mM SA	2.09 ± 0.98	4.99 ± 1.36	9.32 ± 1.49	13.99 ± 2.44
8	1.0 mM SA	2.84 ± 1.02	5.76 ± 1.65	10.02 ± 1.57	15.03 ± 2.54
9	2.0 mM SA	3.92 ± 1.03	6.04 ± 1.42	11.16 ± 1.63	16.22 ± 2.69
10	3.0 mM SA	4.39 ± 0.02	7.17 ± 1.89	12.02 ± 1.98	17.00 ± 2.98
11	4.0 mM SA	3.79 ± 0.93	6.02 ± 1.75	11.00 ± 1.76	16.45 ± 2.67
12	3.0 µM HomoBL + 3.0 mM SA	4.99 ± 1.01	8.02 ± 1.97	12.98 ± 1.93	17.42 ± 2.72

Table 8 Homobrassinolide and Salicylic Acid on Root Dry Weight of *Solanum xanthocarpum*

S. No.	Treatments	Root Dry Weight (g)			
		(20th Day)*	(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	0.90 ± 0.01	2.34 ± 0.93	4.98 ± 1.14	7.99 ± 2.04
2	0.5 µM HomoBL	1.23 ± 0.12	3.01 ± 1.12	5.87 ± 1.32	8.54 ± 1.21
3	1.0 µM HomoBL	1.72 ± 0.16	3.89 ± 0.98	6.34 ± 1.43	10.23 ± 1.32
4	2.0 µM HomoBL	1.99 ± 0.32	4.21 ± 1.03	7.21 ± 1.67	11.56 ± 1.26
5	3.0 µM HomoBL	2.24 ± 0.38	5.54 ± 1.14	8.65 ± 1.72	12.67 ± 1.56
6	4.0 µM HomoBL	1.87 ± 0.24	4.31 ± 1.09	7.25 ± 1.54	11.23 ± 2.11
7	0.5 mM SA	1.19 ± 0.29	2.99 ± 1.02	5.59 ± 1.68	8.24 ± 2.14
8	1.0 mM SA	1.56 ± 0.31	3.75 ± 1.16	6.22 ± 1.34	9.98 ± 1.98
9	2.0 mM SA	1.79 ± 0.36	4.11 ± 1.19	7.05 ± 1.46	11.13 ± 1.87
10	3.0 mM SA	2.05 ± 0.64	5.32 ± 1.31	8.25 ± 1.81	12.35 ± 2.14
11	4.0 mM SA	1.67 ± 0.23	4.13 ± 1.29	7.12 ± 1.61	11.09 ± 2.10
12	3.0 µM HomoBL + 3.0 mM SA	1.99 ± 0.43	6.15 ± 1.38	9.00 ± 1.67	13.22 ± 2.21

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Administration of homobrassinolide at concentrations of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM and 4.0 µM resulted in the significant enhancement in root growth (root length, fresh and dry weights) of *Solanum xanthocarpum* recorded on 20th, 30th, 45th and 60th day as shown in Tables 6-8 compared to the untreated controls. It was also observed that the root growth (root length, fresh and dry weights) of *Solanum xanthocarpum* on all recorded days gradually increased with

administration of 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM of homobrassinolide but decreased on administration 4.0 µM concentration of homobrassinolide though it was more than the untreated controls and 3.0 µM of homobrassinolide was found best among all homobrassinolide applications.

It was also documented that administration of salicylic acid on all recorded days at concentrations of 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM and 4.0 mM resulted in the significant enhancement in root growth (root length, fresh and dry weights) of *Solanum xanthocarpum* in comparison to untreated controls as shown in Tables 6-8. It was also documented that the root growth (root length, fresh and dry weights) of *Solanum xanthocarpum* gradually increased from 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM concentrations of salicylic acid but decreased on the administration 4.0 mM concentration of salicylic acid though was more than the untreated controls and 3.0 mM of salicylic acid was found best among all salicylic acid applications.

Further, the co-application of homobrassinolide at 3.0 µM and salicylic acid at 3.0 mM showed the highest growth in terms of root growth (root length, fresh and dry weights) of *Solanum xanthocarpum* over all the treatments documented on all recorded days in the present study.

3.4. Homobrassinolide and Salicylic Acid on Foliage of *Solanum xanthocarpum*

The effect of homobrassinolide on the foliage (number of branches, number of leaves, leaf length and average width of leaf) supplied at 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM and 4.0 µM to *Solanum xanthocarpum* is presented in Tables 9-12. The effect of homobrassinolide on the foliage (number of branches, number of leaves, leaf length and average width of leaf) in *Solanum xanthocarpum* recorded on the 30th, 45th and 60th day showed the capability of homobrassinolide in enhancing the foliage (number of branches, number of leaves, leaf length and average width of leaf) gradually from 0.5 µM, 1.0 µM, 2.0 µM, 3.0 µM concentrations but decreased on administration 4.0 µM concentration of homobrassinolide though it was more than the untreated controls and 3.0 µM of homobrassinolide was found best among all homobrassinolide applications.

The effect of salicylic acid supplied at 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM and 4.0 mM to *Solanum xanthocarpum* is also presented in Tables 9 -12. The effect of salicylic acid on the foliage (number of branches, number of leaves, leaf length and average width of leaf) in *Solanum xanthocarpum* recorded on the 30th, 45th and 60th day showed the capability of salicylic acid in enhancing the foliage (number of branches, number of leaves, leaf length and average width of leaf) gradually from 0.5 mM, 1.0 mM, 2.0 mM, 3.0 mM concentrations but decreased on administration 4.0 mM concentration of salicylic acid though it was more than the untreated controls and 3.0 mM of salicylic acid was found best among all salicylic acid applications.

Table 9 Homobrassinolide and Salicylic Acid on Number of Branches of *Solanum xanthocarpum*

S. No.	Treatments	Number of Branches		
		(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	4.66 ± 0.92	10.33 ± 1.98	13.33 ± 2.12
2	0.5 µM HomoBL	5.33 ± 1.03	12.33 ± 2.12	14.33 ± 2.65
3	1.0 µM HomoBL	6.00 ± 1.13	12.66 ± 2.19	15.33 ± 2.87
4	2.0 µM HomoBL	6.66 ± 1.24	13.00 ± 2.43	16.33 ± 2.91
5	3.0 µM HomoBL	7.50 ± 1.33	15.33 ± 2.65	19.33 ± 2.97
6	4.0 µM HomoBL	6.00 ± 1.24	13.33 ± 2.54	16.00 ± 2.56
7	0.5 mM SA	5.33 ± 1.53	10.66 ± 2.46	13.33 ± 2.76
8	1.0 mM SA	5.66 ± 1.41	11.33 ± 2.61	15.00 ± 2.87
9	2.0 mM SA	6.50 ± 1.52	11.66 ± 2.54	16.33 ± 2.98
10	3.0 mM SA	7.66 ± 1.68	12.00 ± 2.69	17.00 ± 2.99
11	4.0 mM SA	6.00 ± 1.43	11.00 ± 2.45	15.33 ± 2.76
12	3.0 µM HomoBL + 3.0 mM SA	8.30 ± 1.54	15.00 ± 2.65	21.66 ± 2.90

Table 10 Homobrassinolide and Salicylic Acid on Number of Leaves of *Solanum xanthocarpum*

S. No.	Treatments	Number of Leaves		
		(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	13.33 ± 1.18	21.66 ± 1.54	24.33 ± 2.12
2	0.5 µM HomoBL	15.66 ± 1.16	22.66 ± 1.34	29.00 ± 2.16
3	1.0 µM HomoBL	16.00 ± 1.25	23.66 ± 1.87	30.33 ± 2.27
4	2.0 µM HomoBL	16.33 ± 1.15	25.00 ± 1.76	32.00 ± 2.19
5	3.0 µM HomoBL	21.00 ± 1.53	29.00 ± 1.98	35.33 ± 2.56
6	4.0 µM HomoBL	16.66 ± 1.35	22.00 ± 1.78	27.00 ± 2.47
7	0.5 mM SA	13.66 ± 1.23	19.33 ± 1.82	25.66 ± 2.63
8	1.0 mM SA	14.00 ± 1.34	17.66 ± 1.34	26.33 ± 2.71
9	2.0 mM SA	14.66 ± 1.43	19.00 ± 1.68	26.66 ± 2.54
10	3.0 mM SA	16.00 ± 1.55	22.33 ± 1.79	28.00 ± 2.90
11	4.0 mM SA	14.33 ± 1.42	19.33 ± 1.45	25.33 ± 2.67
12	3.0 µM HomoBL + 3.0 mM SA	24.33 ± 1.76	33.00 ± 1.92	38.66 ± 2.94

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Table 11 Homobrassinolide and Salicylic Acid on Leaf Length of *Solanum xanthocarpum*

S. No.	Treatments	Leaf Length (cm)		
		(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	3.36 ± 0.82	5.63 ± 0.94	7.13 ± 1.78
2	0.5 µM HomoBL	3.60 ± 0.86	6.06 ± 1.12	7.60 ± 1.69
3	1.0 µM HomoBL	3.76 ± 0.92	6.26 ± 1.18	7.80 ± 1.86
4	2.0 µM HomoBL	4.03 ± 0.94	6.50 ± 1.23	8.70 ± 1.74
5	3.0 µM HomoBL	5.43 ± 0.94	7.20 ± 1.39	9.26 ± 1.93
6	4.0 µM HomoBL	4.06 ± 0.82	7.56 ± 01.27	7.53 ± 1.69
7	0.5 mM SA	3.40 ± 0.72	5.80 ± 1.26	7.63 ± 1.72
8	1.0 mM SA	3.80 ± 0.91	6.20 ± 1.28	7.66 ± 1.90
9	2.0 mM SA	4.16 ±0.72	6.33 ± 1.29	8.20 ± 1.88
10	3.0 mM SA	4.76 ± 0.82	6.73 ± 1.37	9.10 ± 2.01
11	4.0 mM SA	4.26 ± 0.73	6.43 ± 1.39	7.36 ± 1.89
12	3.0 µM HomoBL + 3.0 mM SA	5.60 ± 0.93	7.50 ± 1.43	9.70 ± 2.93

Table 12 Homobrassinolide and Salicylic Acid on Average Width of Leaf of *Solanum xanthocarpum*

S. No.	Treatments	Average Width of Leaf (cm)		
		(30th Day)*	(45th Day)*	(60th Day)*
1	Control (Distilled water)	2.93 ± 0.72	3.86 ± 0.92	4.13 ± 1.03
2	0.5 µM HomoBL	3.30 ± 0.92	4.16 ± 0.95	4.60 ± 1.12
3	1.0 µM HomoBL	3.66 ± 0.82	4.36 ± 0.83	5.13 ± 1.27
4	2.0 µM HomoBL	4.03 ± 0.91	4.53 ± 0.92	5.26 ± 1.23
5	3.0 µM HomoBL	4.76 ± 0.93	5.36 ± 0.81	5.76 ± 1.65
6	4.0 µM HomoBL	4.13 ± 0.83	4.33 ± 0.73	5.33 ± 1.56
7	0.5 mM SA	3.03 ± 0.71	3.93 ± 0.93	4.36 ± 1.65
8	1.0 mM SA	3.06 ± 0.71	4.26 ± 0.72	4.40 ± 1.56
9	2.0 mM SA	3.73 ± 0.93	4.40 ± 0.92	4.56 ± 1.76
10	3.0 mM SA	4.03 ± 0.83	4.93 ± 0.93	5.26 ± 1.79
11	4.0 mM SA	3.56 ± 0.72	4.30 ± 0.81	4.66 ± 1.56
12	3.0 µM HomoBL + 3.0 mM SA	5.06 ± 0.92	6.00 ± 0.83	5.98 ± 1.78

* Mean ± SE (n = 9); The Mean if followed by same alphabet in a column was discovered not to be notably different at p=0.05 according to Post Hoc test; HomoBL = Homobrassinolide; SA = Salicylic acid

Further, the co-application of homobrassinolide at 3.0 µM and salicylic acid at 3.0 mM showed the highest growth in terms of foliage (number of branches, number of leaves, leaf length and average width of leaf) of *Solanum xanthocarpum* over all the treatments documented on all recorded days in the present research study.

4. Discussion

Solanum xanthocarpum is an important medicinal plant used widely in many parts of India. It is an established fact that medicine derived from herbs is being widely used across the globe as the ever - increasing population, drastic environmental changes, birth of new diseases is creating a havoc in the world. The usage of herbs in combatting diseases has become more prevalent as it is being documented that usage of synthetic medicines is causing lots of disorders and allergies as well as the synthetic medicines is known their potential side effects. The physiological responses linked to PGRs (plant growth regulators) especially brassinosteroids and salicylic acid are documented to exhibit variations that are capable of influencing the growth behaviour patterns of plants. This led the scientist to further dive into understanding the role of brassinosteroids and salicylic acid into the intricate secrets of nature especially the medicinal plants whose potentially is widely being used to combat diseases (Vardhini and Anjum, 2015; Sampath Kumar et al., 2015).

The supplementation of brassinosteroid treatment demonstrated a rapid positive growth response in *Arabidopsis* leading to enhanced root and shoot growth as documented by Yamagami et al., (2017). Application of homobrassinolide was very effective in stimulating the shoot growth (length, fresh weight, diameter, and dry weight), root growth (length, fresh weight, diameter, and dry weight) as well as the foliar growth (plant fresh weight, leaves per plant and leaf area) of mustard plants (Latha and Vardhini, 2018). Earlier research also indicated that BR-activated transcription factor, BES1, engaged in a physical interaction with BRAVO (Brassinosteroids at vascular and organizing centre), a cell-specific repressor of cell divisions at the quiescent centre (QC) in the primary root and this interaction represses the activity of BRAVO which leads in modulations of the divisions in QC of the root stem cell (Vilarrasa-Blasi et al., 2014).

Numerous studies have indicated that brassinosteroids are able to regulate a broad range of physiological and developmental processes. This includes effects observed in leaves, such as increases in leaf number, leaf area, and leaf mass, as well as enhancements in the functional metabolism of plants in dynamic environments wherein Yin et al. (2019) investigated the effects of exogenous application of brassinosteroids resulted in significant enhancement of leaf growth, specifically in leaf area and leaf mass, in cucumber leaves subjected to autotoxicity stress.

The super compact-2 mutant of cucumber was identified to exhibit the characteristic phenotype associated with BR biosynthetic deficiency. The mutants were also found to exhibit wrinkled leaves characterized by a dark green hue and a reduced leaf area, alongside deficiencies in vascular development and cellular structure emphasizing the importance of brassinosteroids in plants (Caño-Delgado et al., 2004, Hou et al., 2017). The reduced leaf blade size in the *Arabidopsis* BR-deficient mutant, 'cpd' (caused by a loss-of-function mutation in the *CYP90A1* gene, which encodes a cytochrome P450 enzyme essential for catalyzing the C-23 hydroxylation step in brassinosteroid biosynthesis), was attributed to a decrease in both cell size and cell number and the exogenous application of brassinosteroids was found to enhance the leaf size of the 'cpd' mutant through an increase in both cell size and cell number, as well as in venation length and complexity suggesting that brassinosteroids facilitate leaf growth by regulating cell division and cell expansion (Zhiponova et al., 2013). The mechanism by which brassinosteroids induce the cell elongation resembles that of auxins and this process involves the extrusion of protons through ATPases, resulting in the hyperpolarisation of the cell membrane and the acidification of the apoplast, which subsequently activates the enzymes that modify the cell wall (Haubrick and Assmann, 2006) clearly portraying the role of brassinosteroids in regulating the external morphology of the plants by certain changes in the internal signal transduction. The role of brassinosteroids in improving the plant growth and development is an important aspect of it to be considered as a potent plant growth regulator.

Iqbal et al. (2023) documented that application of salicylic acid at 75ppm positively increased the plant growth like plant height in green gram crops. Patil and Gaikwad (2019) documented that administration of different plant growth substances like gibberellic acid, naphthalene acetic acid, chlormequat chloride and salicylic acid at 100ppm and 200 ppm, along with urea at 1% and 2% given as foliar sprays displayed remarked enhancements in plant characteristics such as plant height, number of branches, and total dry matter in soybean plants. Khandaker et al. (2011) concluded that the application of 10^{-5}M salicylic acid improved the plant growth of red amaranth when compared to the controls. The administration of salicylic acid sprayed in three concentrations viz., 0.5 mM, 1.0 mM and 3.0 mM was found to stimulate the shoot and root growth of two varieties of cotton (*Gossypium herbaceum* L.) viz., *Bt*-cotton and non-*Bt* plants grown in the semi-arid tropics of Nizamabad (Vardhini and Venkateshwarlu, 2015). Vasu and Vardhini (2022) documented on the role of salicylic acid in successfully mitigating cadmium stress (100 µM) and increasing the vegetative parameters like vegetative parameters like root and shoot length, root and shoot fresh weights, root and shoot dry weights as well as foliage in groundnut (*Arachis hypogaea*., L.) field experiments wherein the foliar spraying of 1mM and 2mM salicylic acid on 20th, 30th, 45th, and 60th days after sowing. Ebrahimzadeh et al. (2012) documented that the foliar application of salicylic acid at concentrations of 0, 0.1, 0.5, and 1 mM, along with paclobutrazol at doses of 0, 50, 100, and 150 mg per liter, resulted in an increase in total biomass, the number of leaves, and lateral branches in safflower. The foliar supplication of homobrassinolide and salicylic acid positively enhanced the vegetative growth of *Solanum xanthocarpum* viz., plant fresh weight, plant dry weight, shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weight, root dry weight, number of branches number of leaves, leaf length and width of leaf. Homobrassinolide at 3.0 µM and salicylic at 3.0 mM was very effective and combination of homobrassinolide at 3.0 µM and salicylic at 3.0 mM was found to be most effective in enhancing the vegetative growth of *Solanum xanthocarpum* indicating the synergistic effect of the plant growth regulators.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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