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RESEARCH ARTICLE

Standardization of foliar spray of nutrients, growth regulators and bio-stimulants for vegetative growth & multiplication of pot-*Anthuriums*

Subhasmita Sahu[1], Siddharth Kumar Palai[1], Lopamudra Jena[2], Pranaya Pradhan[3], Narayan Panda[4] & Pradyumna Tripathy[5]

[1]Department of Floriculture and Landscaping, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar 751 003, Odisha, India

[2]Department of Horticulture, Faculty of Agriculture, Sri Sri University, Cuttack 754 006, Odisha, India

[3]NICRA Project, Krishi Vigyan Kendra, Puri, Odisha University of Agriculture and Technology, Bhubaneswar 751 003, Odisha, India

[4]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar 751 003, Odisha, India

[5]Department of Vegetable Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar 751 003, Odisha, India

*Email: subhasmitasahu07@gmail.com

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Abstract

An experiment was conducted on potted-*Anthuriums* (dwarf potted varieties of *Anthurium andraeanum*) at Bio-Technology cum Tissue Culture Centre premises under All India Co-ordinated Research Project on Floriculture, OUAT, Bhubaneswar to study the effect of foliar spray of different nutrient solutions and growth regulators/bio-stimulants applied at varying frequency. The treatments include five number of nutrient solutions, viz. Liquid MS medium, macro and micronutrient mixture, NPK (19:19:19), NPK (10:20:20) and NPK (12:61:40) sprayed weekly (once and twice) along with six numbers of growth regulator solutions. The different growth regulators and bio-stimulants included Gibberellic acid (GA_3), at 100 ppm and 200ppm (applied bimonthly), Benzyl Adenine (BA), at 50 ppm and 100 ppm (applied monthly) and humic acid, at 0.1% and 0.2% (applied monthly). The nutrient solutions of only NPK were sprayed at a concentration of 0.2% and supplemented by a fortnightly spray of micronutrient mixture solution of 0.2%. The result showed that spraying of macro and micronutrient mixture weekly once with GA_3, at 200 ppm (applied bimonthly) resulted in the highest plant height (16.80 cm) and with humic acid 0.1% (applied monthly) produced maximum plant spread E-W direction (19.08 cm). Spraying of N:P: K (12:61:40), at 0.2% weekly once with Gibberellic acid 200 ppm (applied bimonthly) resulted in maximum plant spread (N-S direction) (20.45cm). A combination of N:P: K (12:61:40), at 0.2% weekly once with BA, at 100 ppm (applied monthly) resulted in the maximum number of suckers (5.44) and leaves (40.56). On average, application of 12:61:40, at 0.2% weekly once resulted in maximum plant spread (18.54cm, N-S) and highest number of suckers (4.67).

Keywords

Anthurium andraeanum; gibberellins; humic acid; nutrient solutions

Introduction

The outflow of population to urban areas created a shortage of space and a massive movement of people from a home with outdoor space to small apartments. Environmental and health awareness among the people has raised demand for indoor plants specifically for tropical and sub-tropical species which easily adapt to the Indian indoor climate. The Indian indoor plant market is valued at 250.41 USD million in the current year (2024) with a larger segment contributed by shade-loving plants (1). Flowering pot plants are gaining popularity among the urban population for an instant increase in their indoor aesthetic value. Anthurium is the largest flowering genus of the family Araceae and belongs to the order Spathioflorae. The plant is renowned in both commercial cut-flower and pot-plant ornamental industries ascribed to its enduring colourful and heart-shaped spathe and inflorescences (spadices). Plants belonging to this genus are monocotyledons and commonly cultivated as epiphytes while some ornamental serve as terrestrial (2). The modern-day cultivars collectively known as *Anthurium andraeanum* (Hort.) and have worldwide use as potential cut flowers and perennial flowering pots (3). They are usually multiplied by the division of suckers. This tropical sciophyte plant holds the 11th position in the international cut flower market and the second position in Asia after the orchids (4).

According to Volza's Global Export data, the World exported 178 shipments of Anthurium to India from Mar 2023 to Feb 2024 (5), which indicates the increasing popularity of the flower in our country. The plant's long-lasting spadices with steady growth make it the preferred choice for pot plants. Anthurium as a pot plant not only enhances the beauty of the indoor area but also creates a pure ambiance with clean air by removing formaldehyde, ammonia, toluene and xylene from the surrounding environment (6) according to NASA's Clean Air study. The floriculture industry in the state is still in its infant stage as only 20% to 30% of the flower demand of the state is met by local producers (7). The favourable climate of Odisha, particularly in Malkangiri, parts of Koraput, Rayagada and coastal districts are found suitable for anthurium cultivation in Odisha (8) and provides a great opportunity for the budding entrepreneurs of the state with an excellent opportunity to promote nursery activities for pot plant production in coming years. External application of chemical fertilizer aids plant optimal growth and development. Mainly primary nutrients like Nitrogen, Phosphorus and Potassium play an essential role in plant growth and metabolism.

Nitrogen is a primary constituent of plant chlorophyll, amino acids, proteins and enzymes. Phosphorus plays a crucial role in fat metabolism and is part of energy molecules. Potassium plays an active role water regulation of plants through transpiration and is also important in enhancing plant biotic and abiotic stress resistance. Nitrogen along with potassium and sulphur is also found to be effective in mitigating the harmful effects of water deficit (9). Research also proved that the application micronutrient such as boron, zinc and iron, as both soil and foliar application improved plant growth while deficiency inhibited plant physiological activity (10). Flowering comportments of anthurium plants have been dramatically modified by the foliar application of nutrients (11). In anthurium, nutritional status is greatly efficacious for both quality and yield (12). Hence balanced nutrition is of prime importance for growing plants healthy. Foliar feeding results in an immediate visible effect on plants and it is also considered as the best way to grow plants in water deficit areas. *Anthurium andreanum* cv. Evita with response to N:P: K (19:19:19), at 25g/pot yearly resulted in the highest 4.77 number of suckers and 23.73 leaves (13). Along with the nutrients, growth regulators play a major role in the plant lifecycle. They are naturally produced signal molecules, that occur in very low concentrations inside the plant (14). The exercise of applying growth regulators externally has shown variation in the production, developmental process and flowers' qualities (15,16).

Application of Gibberellic acid, at 200 ppm was found to be resulting in highest plant height and plant spread in *Anthurium andraenum* c.v. Tropical (17). *Anthurium andreanum* (dwarf potted variety) with the application of BA, at 50ppm, was observed resulting in the maximum number of leaves per plant with a wider plant spread in both directions (18). Bio-stimulants have proved to augment plants' nutrient efficiency despite of the nutrient content further improving plants' quality traits and resistance to biotic and abiotic stresses (19). Visibly better vegetative growth was observed in anthurium with the application of humic acids (20). The combination of application Gibberellic acid, at 100 ppm with N:P: K (19:19:19), at 0.2% (weekly twice) and Azosprillum was found to be comparatively better in producing highest numbers of leaves, suckers with maximum plant spread and height in anthurium plants (*Anthurium andraenum*) (21) There are many literatures available only for standardizing nutrient and growth regulators application for cut flower production. However, very few works of literature are available regarding the effect of nutrient growth regulators on pot-*Anthuriums*. Therefore, a necessity for the present experiment was felt to study the effect of external supplementation of nutrition and growth regulators influencing plant characters, important for anthuriums for pot plant purposes.

The entitled experiment "Standardization of foliar spray of nutrient solution combination and frequency along with growth regulators and bio-stimulants for vegetative growth & multiplication of pot-*Anthuriums*" was hence conducted to evaluate the synergistic effect of nutrients and growth regulators on anthurium growth, with a focus on plant height, spread and sucker production to standardize the plant nutrition (quantity and frequency) and growth regulator application.

Materials and Methods

The present experiment was conducted from 2021-2023 under the All India Co-ordinated Research Project, Floriculture on the premises of Biotechnology-cum-Tissue Culture Centre, Odisha University of Agriculture and Technology, Bhubaneswar (Fig. 1). The plants were raised from suckers of previously grown anthurium plants. The separated suckers were treated with Bavistin, at 0.1% and streptocyclin, at 0.02 % solution (quick dipping of the suckers) (4,22). The treated plants were planted in pots (15 cm diameter) containing growing media of cocopeat, perlite and neem cake (10:1:1). The city of Bhubaneswar is located in the coastal region of Odisha, experiencing

Fig. 1. Experimental site at BTTC, Baramunda, Bhubaneswar.

tropical climate. The mean average temperature ranges from 35^{0}C to 40^{0}C in summer and 13^{0}C to 15^{0}C in winter and relative humidity varies from 50% (summer days) to 90% (rainy days). Plants were grown in green shade net house considering its effect in improving foliage growth (23). The shade net was equipped with an overhead sprinkler for an irrigation system regulated based on weather conditions. Necessary plant protection measures, particularly for bacterial blight, were applied during the investigation.

The experiment consisted of 60 treatments combining different nutrient solutions, growth regulators, or bio-stimulants along with their weekly application frequency with the Factorial Complete Randomized Design of the experiment. Five nutrient solutions were tested viz. N_1- Liquid MS medium, N_2- Macro and micro nutrient mixture, N_3- NPK (19:19:19), N_4- NPK (10:20:20) and N_5- NPK (12:61:40) along with six numbers of growth regulator solutions. The growth regulators and biostimulants include GA_3 (Gibberellic acid), at 100 ppm and 200ppm at bimonthly intervals (G_1 and G_2), BA (Benzyl Adenine), at 50 ppm and 100 ppm at monthly intervals (G_3 and G_4) and humic acid, at 0.1% and 0.02% at monthly interval (G_5 and G_6). Nutrient solutions are sprayed weekly once (F_1) or twice (F_2) according to the treatment scheduled. The NPK solutions were sprayed at a concentration of 0.2% and plants treated with those were given an additional spray of micronutrient mixture at fortnightly intervals. The treatments were replicated thrice. Three plants were selected from every treatment for recording observations of different plant vegetative characteristics. Data recorded from different parameters were calculated for averages to get the mean values. These mean values were further used in statistical analysis.

Statistical Analysis

The various characteristic data recorded were analysed by the method of analysis of variance to know the experiment's significance (24). The statistical analysis was executed using the software R.

Results

The data presented in the ANOVA table (Table 1) confirms the significance different of plant characters (plant height, plant spread, number of suckers per plant and number of leaves per plant) due to the application of treatments. The p -value confirms the significant difference among the treatments. The individual effect of frequency of application irrespective of nutrient combination and growth regulator application in the production of suckers was only found to be without any significant difference at 0.05 level.

Effect of nutrient and growth regulators on plant height

The data tabulated (Table 2) show that the interaction $F_1N_2G_2$ (macro and micronutrient mix. along with GA_3, at 200 ppm at bimonthly intervals) resulted in the highest plant height (16.80 cm). Combination GA_3, at 200 ppm and liquid MS medium sprayed weekly once ($F_1N_1G_2$) (16.60 cm) was found at par with the highest. The highest plant height of15.72 cm (Fig. 2) was found in nutrient solution N_2 sprayed weekly once while nutrient solution N_2, irrespective of frequency and growth regulators application, resulted in a plant height of 14.14 cm (Fig. 3). Among the growth regulators, GA_3, at 200 ppm gave highest plant height of 14.31 cm (Fig. 3).

Effect of nutrient and growth regulators on plant spread

The data presented in Table 3 show that the interaction $F_1N_2G_5$ (macro and micronutrient mixture along with humic acid, at 0.1% applied at monthly intervals) resulted in the maximum East-West (E-W) direction (19.08 cm). The widest plant spread in the same direction (17.03 cm) was found in nutrient solution N_2 sprayed weekly once (Fig 4). The nutrient solutions, without any interaction, showed a significant difference in plant spread in the East-West direction (Fig.5). In the North-South (N-S) direction, nutrient solution N_{5-} [N:P: K (12:61:40), at 0.2%+ micro nutrient sprayed at fortnightly interval] weekly once performed best

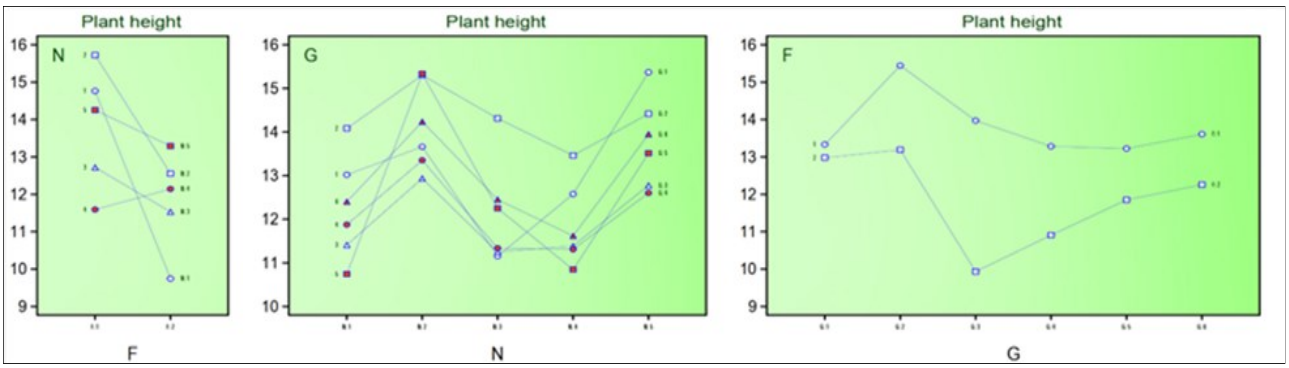

Fig. 2. Effect of two factor interaction of treatments on plant height (cm) [Pooled over 2021-22 & 2022-23].

F×N- $CD_{0.05}$: 0.157, **S.E.m(±):** 0.056; **N×G- $CD_{0.05}$:** 0.272, **S.E.m(±):** 0.097;**G×F- $CD_{0.05}$:** 0.172, **S.E.m(±):** 0.061F: Frequency of application; N: Nutrient solution; G: Growth regulators/ bio-stimulants

Table 1. ANOVA for Effect of nutrient and growth regulators on vegetative characters of pot *Anthuriums* (cm) [Pooled over 2021-22 & 2022-23]

	Source of Variations	F	N	F * N	G	F * G	N * G	F * N * G	Error C	Total	Mean
	DF	1	4	4	5	5	20	20	120	179	12.829
Plant height	Sum of Squares	172.12997	156.64586	168.5819	111.67096	59.12703	65.64386	83.26002	6.78812	823.84773	C.V. %
	Mean Squares	172.12997	39.16147	42.14548	22.33419	11.82541	3.28219	4.163	0.05657	4.6025	1.854
	F Ratio	3042.904	692.294	745.045	394.823	209.049	58.022	73.593			
	Probability	0.00001 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***			
	Sum of Squares	41.35065	412.64458	76.8209	43.03041	16.7126	131.33075	74.04346	8.66717	804.60051	C.V. %
	Mean Squares	41.35065	103.16115	19.20522	8.60608	3.34252	6.56654	3.70217	0.07223	4.49497	1.846
	F Ratio	572.514	1428.302	265.903	119.154	46.278	90.916	51.258			
	Probability	0.00001 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***			
	DF	1	4	4	5	5	20	20	120	179	15.746
	Sum of Squares	73.31068	434.06765	32.43587	91.40562	12.40806	61.0386	74.46967	13.18336	792.3195	C.V. %
	Mean Squares	73.31068	108.51691	8.10897	18.28112	2.48161	3.05193	3.72348	0.10986	4.42637	2.105
	F Ratio	667.302	987.763	73.811	166.402	22.589	27.78	33.893			
	Probability	0.00001 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***			
Plant spread E-W direction	DF	1	4	4	5	5	20	20	120	179	3.84
	Sum of Squares	0.03816	39.1521	12.19623	44.09844	8.44665	16.70706	17.68012	2.12111	140.43988	C.V. %
	Mean Squares	0.03816	9.78803	3.04906	8.81969	1.68933	0.83535	0.88401	0.01768	0.78458	3.462
	F Ratio	2.159	553.749	172.498	498.967	95.572	47.259	50.012			
	Probability	0.14434	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***			
	DF	1	4	4	5	5	20	20	120	179	25.868
	Sum of Squares	257.19273	1707.7764	1630.4411	1774.9018	167.8758	713.49295	695.35834	24.982	6972.0212	C.V. %
	Mean Squares	257.19273	426.94411	407.61027	354.98036	33.57516	35.67465	34.76792	0.20818	38.94984	1.764
	F Ratio	1235.414	2050.808	1957.939	1705.133	161.277	171.362	167.006			
	Probability	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***	0.00000 ***			

Table 2. Effect of nutrient and growth regulators on plant height (cm) [Pooled over 2021-22 & 2022-23]

	F_1 (Application of nutrients once a week)					F_2 (Application of nutrients twice a week)				
	N_1	N_2	N_3	N_4	N_5	N_1	N_2	N_3	N_4	N_5
G_1	15.20	15.49	10.15	10.90	14.92	10.84	11.83	12.15	14.25	15.82
G_2	16.60	16.80	15.08	12.58	16.14	11.57	13.80	13.54	14.34	12.70
G_3	14.15	15.75	12.23	12.85	14.87	8.67	10.12	10.27	9.92	10.69
G_4	14.10	15.73	12.17	11.73	12.67	9.65	10.97	10.50	10.88	12.54
G_5	13.25	16.04	14.28	9.74	12.80	8.23	14.63	10.22	11.95	14.22
G_6	15.28	14.52	12.38	11.72	14.12	9.52	13.95	12.52	11.52	13.78
CD (Critical difference):0.385						S.E.m(±) (standard error of mean): 0.137				

Table 3. Effect of nutrient and growth regulators on plant spread (cm) (East-West direction) [Pooled over 2021-22 & 2022-23]

	F_1 (Application of nutrients once a week)					F_2 (Application of nutrients twice a week)				
	N_1	N_2	N_3	N_4	N_5	N_1	N_2	N_3	N_4	N_5
G_1	16.48	17.30	11.05	13.30	16.30	13.69	16.95	12.16	12.39	16.09
G_2	16.38	16.68	13.57	13.55	18.95	15.74	16.24	13.60	13.60	17.63
G_3	14.17	16.28	12.67	15.10	16.18	10.82	15.09	14.57	11.87	18.30
G_4	12.85	16.68	13.64	13.45	16.20	10.79	14.00	13.63	14.97	15.60
G_5	16.22	19.08	14.67	12.49	15.29	10.22	15.40	13.27	12.90	14.48
G_6	15.34	16.74	12.92	12.58	15.13	10.78	15.60	11.70	12.92	17.50
CD (Critical difference): 0.435						S.E.m(±) (standard error of the mean): 0.155				

(Fig. 6) for plant spread (18.54 cm) in interaction with frequency of application. Combining three-factor interactions the N: P: K (12:61:40), at 0.2% solution sprayed weekly once with GA_3, at 200ppm applied bi-monthly resulted in maximum plant spread (20.45cm) (Table 4). The nutrient solution, N_5 resulted in maximum plant spread in both directions (16.47cm in E-W; 18.06cm in N-S) (Fig. 4, Fig. 6). Among nutrient and growth regulator combination, N_5G_2 [N:P: K (12:61:40), at 0.2% with GA_3, at 200ppm] produced highest plant spread (18.29 cm E-W direction and 19.49cm in N-S direction) (Fig. 4, Fig. 6). Spraying of GA_3, at 200ppm resulted highest plant spread (15.59 cm in E-W; 17.16 cm in N-S direction) (Fig. 5, Fig. 7).

Table 4. Effect of nutrient and growth regulators on plant spread (cm) (North-South direction) [Pooled over 2021-22 & 2022-23]

	F_1 (Application of nutrients once a week)					**F_2 (Application of nutrients twice a week)**				
	N_1	**N_2**	**N_3**	**N_4**	**N_5**	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**
G_1	16.20	16.47	14.52	16.47	18.77	13.69	16.93	14.34	13.90	15.65
G_2	17.40	17.28	15.83	15.35	20.45	16.77	17.72	17.18	14.88	18.53
G_3	14.69	18.65	14.70	14.70	16.75	12.25	16.36	12.37	11.87	18.70
G_4	14.60	18.62	13.70	15.02	18.85	11.52	15.77	14.10	15.04	17.48
G_5	16.52	17.27	16.52	15.80	18.77	11.82	17.32	13.57	14.87	18.07
G_6	15.02	17.24	13.35	14.40	17.67	11.12	16.30	14.64	13.47	17.05
CD (Critical difference):0.536						S.E.$_m$(±) (standard error of mean): 0.191				

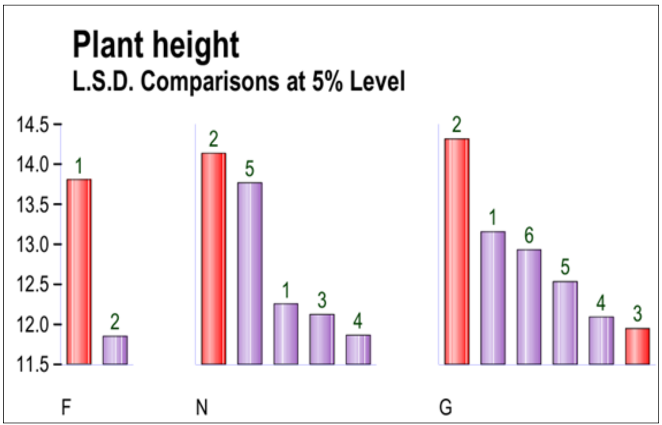

Fig. 3. Effect of individual factors of treatments on plant height (cm) [Pooled over 2021-22 & 2022-23].

F- $CD_{0.05}$:0.070, **S.E.m(±):** 0.025; **N- $CD_{0.05}$:**0.111, **S.E.m(±):** 0.040; **G- $CD_{0.05}$:** 0.122, **S.E.m(±):** 0.043L.S.D: Least Significance Difference

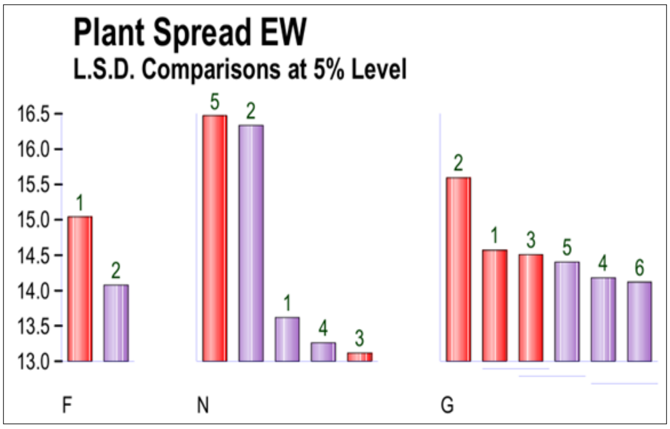

Fig. 5. Effect of individual factor of treatments on plant spread (cm) (East-West direction) [Pooled over 2021-22 & 2022-23].

F- $CD_{0.05}$:0.079, **S.E.m(±):** 0.028; **N- $CD_{0.05}$:**0.125, **S.E.m(±):** 0.045; **G- $CD_{0.05}$:** 0.137, **S.E.m(±):** 0.049

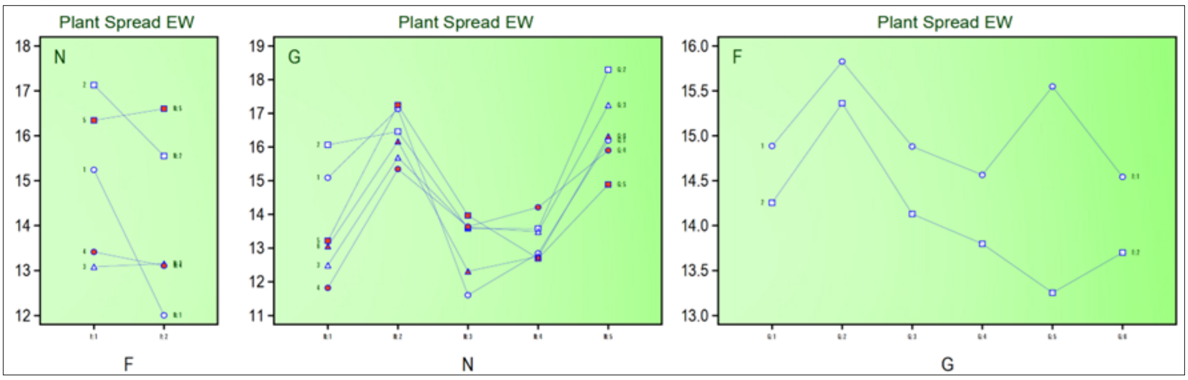

Fig. 4. Effect of two factor interaction of treatments on plant spread(cm) (East-West direction) [Pooled over 2021-22 & 2022-23]

F×N- $CD_{0.05}$:0.177, **S.E.m(±):** 0.063; **N×G- $CD_{0.05}$:**0.307, **S.E.m(±):** 0.110; **G×F- $CD_{0.05}$:**0.194, **S.E.m(±):** 0.069

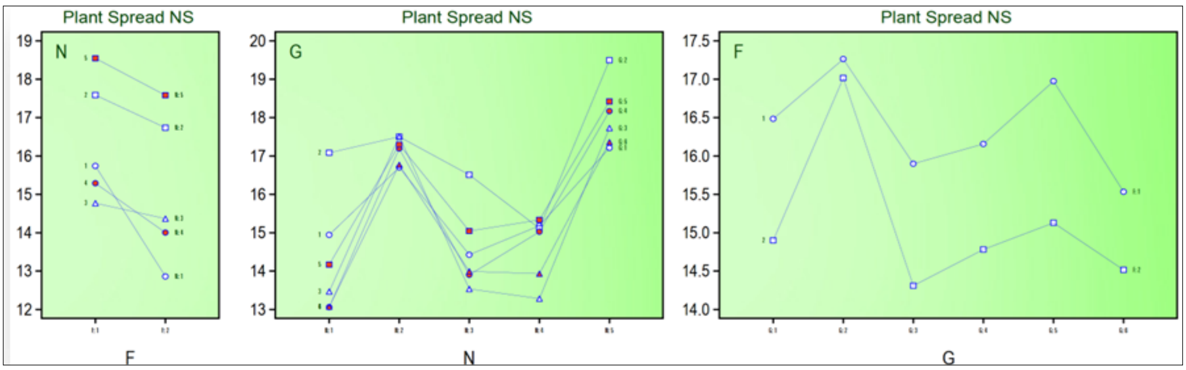

Fig. 6. Effect of two factor interaction of treatments on plant spread(cm) (North-South direction) [Pooled over 2021-22 & 2022-23]

F×N- $CD_{0.05}$:0.177, **S.E.m(±):** 0.063; **N×G- $CD_{0.05}$:**0.307, **S.E.m(±):** 0.110; **G×F- $CD_{0.05}$:**0.194, **S.E.m(±):** 0.069

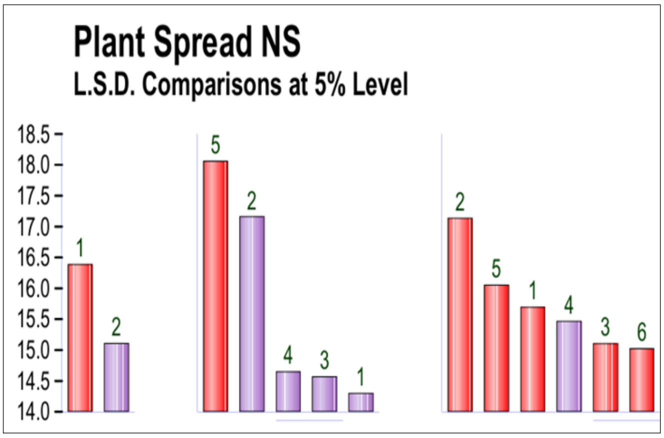

Fig. 7. Effect of individual factors of treatments on plant spread (cm) (North-South direction) [Pooled over 2021-22 & 2022-23].

F- $CD_{0.05}$: 0.098, **S.E.m(±):** 0.035; **N- $CD_{0.05}$:** 0.155, **S.E.m(±):** 0.055; **G- $CD_{0.05}$:** 0.169, **S.E.m(±):** 0.061

fect of nutrient and growth regulators on the number of suckers per plant

The data presented in Table 5 shows that nutrient solution N_5[N:P: K (12:61:40), at 0.2% + spraying of micronutrient at fortnight interval] weekly once with BA, at 100 ppm at monthly intervals ($F_1N_5G_4$) resulted in the maximum number of suckers per plant (5.44). The results revealed that the highest average number of suckers per plant (4.67) (Fig. 8) was recorded in Nutrient solution N_5- sprayed weekly once while nutrient solution N_5 also produced the highest 4.62 suckers per plant irrespective of frequency and growth regulator application (Fig. 9). In nutrient and growth regulator interaction, N_5 with BA, at 50ppm monthly (N_5G_3) produced the highest number of suckers per plant (5.33) (Fig. 8). Among different growth regulators, BA, at 100 ppm at monthly interval performed better result, with an average of 4.11sukers per plant (Fig. 9).

Effect of nutrient and growth regulators on the number of leaves per plant

The pooled data over two years revealed that the highest average number of leaves per anthurium plant (40.56) (Table 6) observed in the interaction treatment $F_1N_5G_4$ [N:P: K (12:61:40), at 0.2% weekly once and micronutrient mixture sprayed at fortnightly interval along with BA, at 100 ppm at monthly interval). Nutrient solution N_2 (macro and micronutrient mixture) twice a week (F_1N_2) produced highest (31.86) number of leaves per plant which was at par with F_1N_5(31.79 number of leaves per plant) (Fig. 10). In nutrient and growth regulator interaction, N_5 with BA, at 100ppm monthly (N_5G_4) produced highest 36.45 number of leaves per plant (Fig. 11). Among nutrient solutions, N_5- [N:P: K (12:61:40), at 0.2%] resulted maximum number of leaves per plant (30.21) (Fig. 10). BA, at 100 ppm applied monthly resulted maximum 30.25 leaves per plant (Fig. 11).

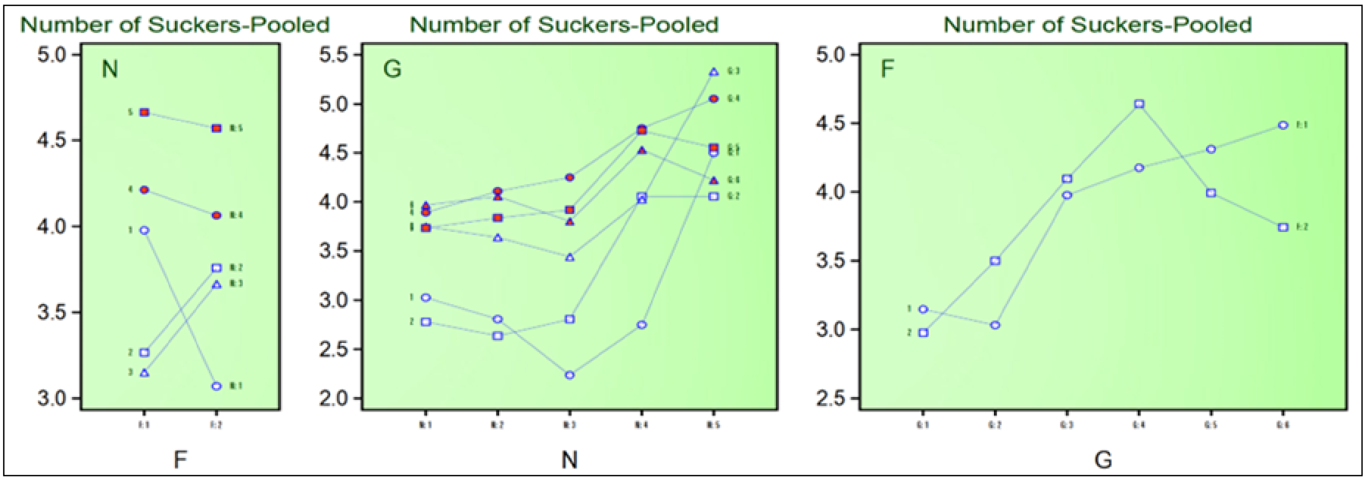

Fig. 8. Effect of two factor interactions of treatments on suckers per plant [Pooled over 2021-22 &2022-23].

F×N- $CD_{0.05}$: 0.088, **S.E.m(±):** 0.031; **N×G- $CD_{0.05}$:** 0.152, **S.E.m(±):** 0.054; **G×F- $CD_{0.05}$:** 0.096, **S.E.m(±):** 0.034

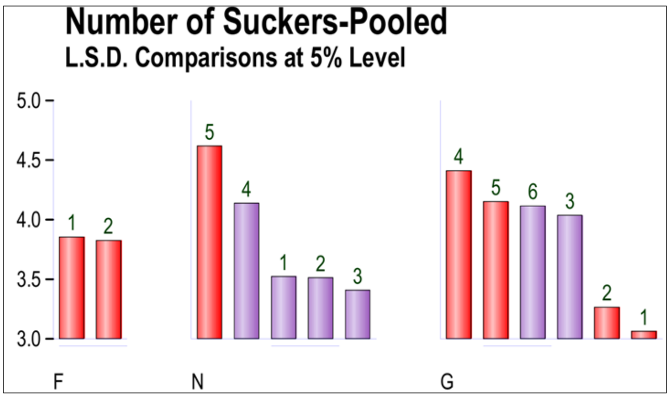

Fig. 9. Effect of individual factor of treatments on suckers per plant [Pooled over 2021-22 &2022-23].

F- $CD_{0.05}$: 0.039, **S.E.m(±):** 0.014; **N- $CD_{0.05}$:** 0.062, **S.E.m(±):** 0.022; **G- $CD_{0.05}$:** 0.068, **S.E.m(±):** 0.024

Table 5. Effect of nutrient and growth regulators on suckers per plant [Pooled over 2021-22 &2022-23]

	F_1 (Application of nutrients once a week)					F_2 (Application of nutrients twice a week)				
	N_1	N_2	N_3	N_4	N_5	N_1	N_2	N_3	N_4	N_5
G_1	3.00	3.22	2.20	3.00	4.33	3.06	2.39	2.28	2.50	4.67
G_2	2.50	2.44	2.39	4.06	3.78	3.05	2.84	3.22	4.06	4.33
G_3	4.39	2.83	3.11	4.28	5.28	3.11	4.44	3.77	3.77	5.39
G_4	4.11	3.44	3.61	4.28	5.44	3.67	4.77	4.89	5.22	4.66
G_5	4.77	3.34	4.17	4.61	4.67	2.70	4.34	3.67	4.83	4.43
G_6	5.10	4.33	3.44	5.06	4.50	2.84	3.78	4.16	4.00	3.94
CD (Critical difference): 0.215						$S.E._m(\pm)$ (standard error of mean): 0.077				

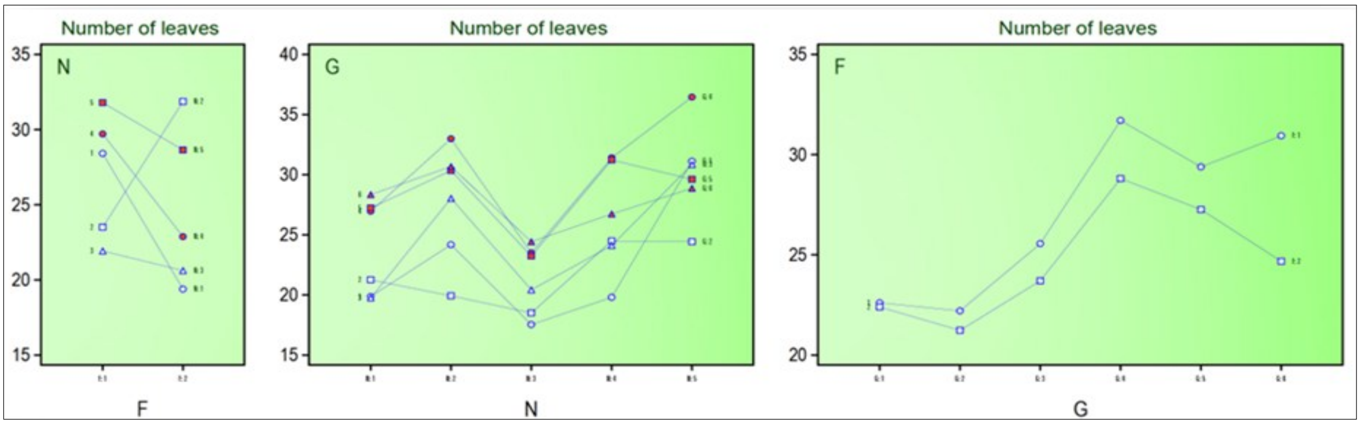

Fig. 10. Effect of two factor interaction of treatments on number of leaves per plant [Pooled over 2021-22 & 2022-23].

F×N- $CD_{0.05}$: 0.301, **S.E.m(±):** 0.108; **N×G- $CD_{0.05}$:** 0.522, **S.E.m(±):** 0.186; **G×F- $CD_{0.05}$:** 0.330, **S.E.m(±):** 0.118

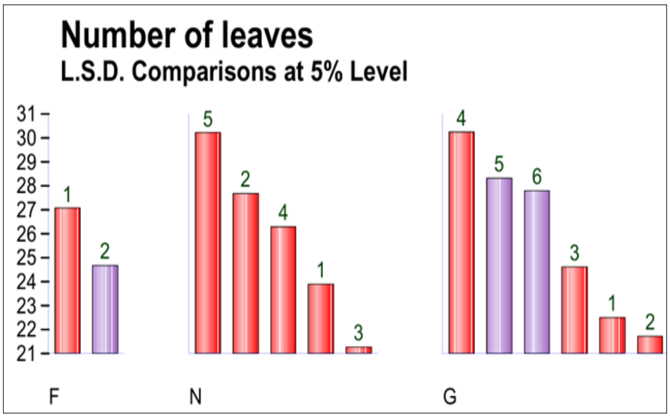

Fig. 11. Effect of individual factor of treatments on number of leaves per plant [Pooled over 2021-22 & 2022-23].

F- $CD_{0.05}$: 0.135, **S.E.m(±):** 0.048; **N- $CD_{0.05}$:** 0.213, **S.E.m(±):** 0.076; **G- $CD_{0.05}$:** 0.0.233, **S.E.m(±):** 0.083

Table 6. Effect of nutrient and growth regulators on number of leaves per plant [Pooled over 2021-22 & 2022-23]

	F_1 (Application of nutrient once in a week)					**F_2 (Application of nutrient twice in a week)**				
	N_1	**N_2**	**N_3**	**N_4**	**N_5**	**N_1**	**N_2**	**N_3**	**N_4**	**N_5**
G_1	22.06	23.00	17.28	20.39	30.27	17.67	25.34	17.78	19.22	31.94
G_2	23.44	16.67	18.50	28.00	24.39	19.06	23.17	18.50	20.95	24.45
G_3	21.72	19.94	22.33	27.72	36.06	17.78	36.11	18.50	20.50	25.61
G_4	31.06	27.83	24.83	34.22	40.56	22.84	38.11	22.17	28.55	32.33
G_5	34.72	24.06	23.56	36.66	27.95	19.72	36.61	22.89	25.78	31.28
G_6	37.45	29.50	25.00	31.22	31.50	19.22	31.83	23.84	22.22	26.22
CD (Critical difference): 0.738						$S.E._m$(±) (standard error of mean): 0.263				

Discussion

Optimum grades of NPK as a nutritional solution amplifies efficient photosynthetic activity and production of carbohydrates, facilitating more efficient nutrient translocation from source (leaf) to sink (growth areas) (25-27) in anthurium. The growth regulators GA_3 promote meristematic transitions, leading to increased shoot length and internodal length (28). Studies have reported the maximum height of plants obtained with foliar application of GA_3 in higher doses in anthuriums (29-31). Similar reports regarding maximum plant height were also observed in cucumber with the application of 200 ppm of Gibberellic acid in coastal West Bengal (32) which possesses nearly similar climatic conditions as of Odisha. It was found that humic acid and the application of micronutrients like zinc resulted in taller plants (33). The increment of height in anthurium could be ascribed to the facilitation of micronutrients movement through the surface of leaves and into the vascular system facilitated by humic acid (20). This also upgrades nutrient absorption, supplementing plant growth. Similarly, humic acid extracted from vermicompost enriched with 1% of each N, P and S was found to result in maximum plant height in canola (34).

The results regarding extended plant spread in both E-W and N-S directions in plants receiving GA3 as treatment are similar to reports suggesting noticeable expansion in the spread of plants with application of higher concentration GA_3 in anthurium plants (29-31). Gibberellic acid is known for its pronounced effect on internodal stem elongation (28) which causes longer leaf petiole length causing a wider spread of plants. The plant spread represents healthy plant growth. Wider plant spread might be the result of greater photosynthetic activity and more assimilation of carbohydrates due to the availability of balanced N, P and K as nutrients (25-27) in Anthurium. The application of humic acid also contributes to better plant growth, for being an efficient bio stimulant due to its role in increasing plant growth and encouraging hormones such as auxin and cytokinin (35-36). Higher phosphorus content in the nutrient composition is attributed to better growth as phosphorus acts as a constituent of nucleoprotein, which plays an indispensable role in photosynthesis, cell division and tissue formation (37). Identical results also have been observed in the geophyte Gladiolus where maximum plants supplied with a higher amount of phosphorus obtained wider spread (38). The stimulating effect of potassium on photosynthesis, phloem loading and carbohydrate translocation also impacts plant growth.

Benzyl adenine being synthetic cytokinin stimulates cell division and it spurs plant growth. There was an increase in production ramets in daylilies as an impact of the application of BA to the plants (39). Available works of literature have shown that a higher number of offsets were observed in aloe vera and a higher number of clusters per vine observed in grapes with the application of BA at higher one among different concentrations of BA (40-41). 100 ppm of BA was also recorded in the highest branches per plant in fennel (42). These abovementioned outcomes support an increase in the number of suckers as an impact of the application of BA to the pot- Anthuriums. A higher number of suckers might be obtained with more amount of potassium availability which is involved in the meristematic growth of plants. The effect of potash has been found advantageous to growth and development in plants of anthurium (43). Phosphorus stimulating more numbers of bulblets and higher bulb yield was also noticed with higher levels of phosphorus application in tuberose (44).

Treatment combinations having the maximum number of leaves may have occurred due to the contribution of BA, as BA being synthetic cytokinin impacting cell division. Foliar application of BA promotes branching (41), the highest number of leaves in croton and rose (45-47). Large-dosed treatments cause a higher number of leaves per plant in dendrobium and cut foliage plants (48) which suggested that elevated doses of phosphorus and potassium might have attributed to the higher number of leaves. Application BA, at 100 ppm also found effective in producing more number leaves per plant in chrysanthemum along with Gibberellic acid, at 200 ppm (49). Hussain and Al-Doori found the superiority of higher concentration BA over lower concentration and also than other chemicals regarding the number of leaves per plant in strawberries (50).

Fig. 12. Plants of treatment F_1N_5.

Conclusion

The outcomes of this experiment highlight the importance of nutrients in improving the vegetative growth of pot-*Anthuriums* and the additive role of growth regulators or bio -stimulants in enhancing them. Application of GA_3 can be recommended for pot plants of anthuriums for decoration and exhibition purposes as elevated plant height and spread. This will be more useful for florist shops. Application of BA led to more bushy plants with an upsurge number of leaves and suckers which can be recommended for nursery practices to produce more plantlets with a simple division process. The outcome ensures the effect of N: P: K (12:61:40) in promoting better plant growth. Spraying of N:P: K (12:61:40), at 0.2% at weekly intervals can be recommended to nurserymen to boost the production pot-*Anthuriums* as it resulted in larger sized plants with higher numbers of suckers (Fig.12) as it will help in producing a greater number of marketable pot-*Anthuriums.*

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Authors' contributions

SKP suggested a blueprint of the research and allocated resources for research and actively associated with research problems as well as data collection, preparation and scrutinization of the manuscript. LJ carried out a graphical representation of collected data and helped in furnishing the data. PP collected the data regarding weather parameters and helped in the analysis of data. NP formulated the treatments. PT suggested the design of the experiment and helped with data analysis.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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