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Influence of Biostimulant on Growth, Flowering and Yield of Summer Squash (*Cucurbita pepo* L.) Hybrids in Gangetic Plains of West Bengal

Satadal Chakraborty[1], Chandan Karak[1], Biswajit Chakraborty[2], Sanjita Marandi[1], Sourav Mollick[2], Partha Choudhuri[1], Umesh Thapa[1] and Pran Krishna Thakur[3]

[1]Dept. of Vegetable Science, [3]Dept. of Post Harvest Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252), India

[2]Dept. of Vegetable and Spice Crops, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal (736 165), India

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Corresponding todrck@gmail.com

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ABSTRACT

The experiment was undertaken during December, 2023–February, 2024 to evaluate the effect of different concentrations of the ECOHUME biostimulant on the vegetative growth, flowering, and yield of two different summer squash hybrids. The experiment was framed employing two-factorial Randomized Block Design (RBD) consisting five levels of treatments including untreated control and ECOHUME doses of 0.5, 1, 2, and 4 ml l^{-1} and two hybrids. Observations were recorded on key parameters of growth, flowering, yield and phytotoxicity effects on plants. Results revealed significant interactions between biostimulant doses and hybrids across most of the growth and yield parameters. ECOHUME at 2 ml l^{-1} (T_4) was found to be the most effective dose, significantly enhancing plant height, number of leaves, number of male and female flowers, fruit length, diameter, average fruit weight, and total yield plant^{-1} and plot^{-1}. Sunny house consistently outperformed Golden house in most of the parameters, indicating a stronger varietal response to the ECOHUME biostimulant. However, excessive application at 4 ml l^{-1} (T_5) resulted in phytotoxic symptoms such as stunted growth, leaf burn, browning of flower buds, fruit necrosis and eventual crop failure. ECOHUME application at optimal concentrations improved vegetative growth and enhances reproductive efficiency as well as overall yield in compare to untreated control, demonstrating its potential as a sustainable input in integrated nutrient management in the Alluvial plains of West Bengal. The study underscored the importance of precised dose management to avoid toxicity and supported the role of biostimulant in enhancing crop performance, especially for high-value vegetable crops like summer squash in particular in the region.

KEYWORDS: Summer squash, biostimulant, ECOHUME, growth, flowering, yield

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1. INTRODUCTION

Summer squash (*Cucurbita pepo* L.) is an economically significant vegetable crop cultivated extensively across temperate and subtropical regions of the world. The species *C. pepo* exhibits substantial morphological and genetic diversity, encompassing various horticultural groups such as zucchini, cocozelle, crookneck, scallop, and straightneck squashes (Paris, 1996). Among these, zucchini stands out as the most commercially important type worldwide, favoured for its high productivity, tender flesh, and adaptability to different agro-ecological conditions. Summer squash has gained prominence as a cash crop for smallholder farmers due to its ability to provide quick returns in West Bengal, which aligns with the region's demand for high-value vegetables. From a nutritional standpoint, summer squash is rich in vitamins (A and C), dietary fiber, and bioactive compounds with antioxidant properties, contributing to human health and dietary diversity (Frelier et al., 2021). The tender fruits, consumed in an immature stage, offer culinary versatility and are increasingly valued in both urban and rural diets. Consequently, efforts to enhance the productivity and quality of summer squash are central to meeting consumer demand and improving farmers' incomes in resource-constrained agricultural systems. Over time, this crop has become an essential component of diversified vegetable systems due to its short growth cycle, nutritional richness, and high market demand. The application of biostimulants rich in phytohormones and bioactive compounds promote meristematic activity, resulting in taller and vigor plants Paradikovic et al. (2019), Olguín-Hernández et al. (2023) and Garcia-Gonzalez and Sommerfeld (2016) and has shown significant improvements in germination rate, vegetative growth, photosynthetic efficiency, flowering, and yield attributes in vegetables due to the presence of plant growth regulators and micronutrients which stimulate cell division and elongation, while humic substances enhance soil structure and nutrient retention. Microbial biostimulants, such as plant growth-promoting rhizobacteria (PGPR), facilitate nutrient solubilization and produce phytohormones that directly influence plant vigor (Calvo et al., 2014). Conventional practices that rely heavily on synthetic fertilizers to meet nutrient demands often lead to reduced nutrient-use efficiency, soil degradation, and environmental pollution. Thus, integrating biostimulants into the production system of summer squash offers an eco-friendly strategy to enhance resource-use efficiency and crop resilience. Biostimulants can play a pivotal role in mitigating abiotic stresses, particularly under the variable climatic conditions of the new alluvial plains (Mollick et al., 2024, Karak et al., 2026). The region experiences a subtropical climate with moderate to high temperatures, adequate sunlight, and seasonal rainfall, which align well with the growth requirements of *Cucurbita pepo*. However, despite the inherent soil fertility, production and yield gaps persist in summer squash cultivation in this region and the proven efficacy of biostimulants in numerous crops globally, empirical evidence on their performance in summer squash under the agro-climatic conditions of the new alluvial plains of West Bengal remains scarce. Even in India there is a critical knowledge gap in terms of the optimal type, dose, and application method of biostimulants for summer squash hybrids. Moreover, the physiological and agronomic responses of summer squash to biostimulant treatments under local soil and climatic conditions have not been systematically evaluated. Keeping in the information under consideration the present investigation was basically framed to study the effect of biostimulant treatments on vegetative growth, flowering and yield related parameters of summer squash hybrids and the interaction effects between biostimulant and summer squash hybrids in Gangetic plains of West Bengal to identify the most effective biostimulant dose for the agro-climatic conditions of the study area.

2. MATERIALS AND METHODS

The field experiments were carried out during the *rabi* (December, 2023–February, 2024) at Horticulture Research Station, Mondouri of Bidhan Chndra Krishi Viswavidyalaya, West Bengal, employing one commercial biostimulant namely ECOHUME and two zucchini-type summer squash hybrids namely green fruited Sunny house and yellow fruited Golden house collected from the local market following Factorial Randomized Complete Block Design with three replications. The farm soil was sandy loam with good drainage and moderate fertility with a near-neutral pH of 6.6–6.7. The details of treatments along with symbols are T_1 of Control (Untreated), T_2 of ECOHUME at 0.5 ml l^{-1} , T_3 of ECOHUME at 1 ml l^{-1} , T_4 of ECOHUME at 2 ml l^{-1} and T_5 of ECOHUME at 4 ml l^{-1} and spray volume of water was 500 l ha^{-1} . Seeds of summer squash were sown on 1st week of December during the year 2023 in well prepared beds of 1.0×4.5 m^2 size. Proper moisture was maintained to facilitate germination. The experiment comprised of five treatments having two different levels with three replications, following a spacing of 90 cm between plants, accommodating five plants $plot^{-1}$. A basal dose of FYM and NPK fertilizers was applied prior to sowing to provide essential nutrients for early crop establishment. Fertilization was supplemented with NPK (19:19:19) and Urea to meet nutrient requirements. NPK (19:19:19) was applied at the rate of 5 g l^{-1} of water as foliar spray at 10 DAS and 30 DAS, while Urea was used to provide additional nitrogen during critical growth stages at a rate of 3 g $plant^{-1}$ $application^{-1}$. The first spray of biostimulant was administered at 20 days after sowing (DAS) followed by the second spray at 40 DAS. The solution was prepared with different treatment combinations and applied uniformly across all designated plots to ensure proper coverage. Five plants were selected and tagged for recording the growth parameters. Growth attributes were recorded at 20, 40, and 60 days after sowing (DAS). Flower characters were recorded after initiation of flowers and up to full blooming stages and yield parameters were assessed harvested fruits from the observational plants respectively. Ten representative fruits were considered replication^{-1} for quantitative analysis of the fruits. Phytotoxicity effects like stunting of growth, burning effects on different plant parts, puckering of leaves, yellowing of leaves, necrosis, mottling of leaves, reduced fruit size, abnormal shapes of fruits, etc., have been observed and rated in the scale of 1 to 10 as per Dutta et al. (2021). The experimental data were analysed statistically to test the significance of differences of treatments and their interaction effects between treatments and the hybrids.

3. RESULTS AND DISCUSSION

The results demonstrated a statistically significant interaction of Factor A for treatment combinations of biostimulant and Factor B for two different hybrids of summer squash across most of the parameters, indicating that the effect of ECOHUME influenced depending on the hybrid varieties used. The performance of both the hybrids of summer squash differed considerably, in which green fruited Sunny house generally outperforming the yellow fruited Golden house under the same treatment levels illustrated in Figure 1. The results were summarised here under with following subheads.

Figure 1: Influence of Biostimulant on growth, flowering and yield of Summer Squash hybrids in West Bengal condition

3.1. *Vegetative growth characters of plants*

3.1.1. *Plant height (cm)*

Plant height of summer squash was significantly influenced by the interaction between variety and biostimulant doses presented in the Table 1. At 20 DAS, no major differences were observed across treatments. However, by 40 and 60 DAS, T4 (ECOHUME at 2 ml l^{-1}) consistently produced the tallest plants in both hybrids, with Sunny house (28.33, 39.43 cm) outperforming Golden house (24.73, 37.30 cm). The lowest heights were recorded in T_5 (ECOHUME at 4 ml l^{-1}) in both the hybrids of Sunny house (20.07, 26.73 cm) and Golden house (18.70, 23.63 cm) respectively even

Table 1: Combined effect of biostimulant and summer squash hybrids on plant height (cm)

Treatment	Plant height (cm)								
	20 DAS			40 DAS			60 DAS		
	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	12.47	12.67	12.57	24.17	22.63	23.40	34.33	32.30	33.32
T_2: ECOHUME at 0.5 ml l^{-1}	12.90	12.47	12.68	25.33	23.67	24.50	35.33	34.27	34.80
T_3: ECOHUME at 1 ml l^{-1}	11.83	12.57	12.20	27.00	24.40	25.70	35.73	35.17	35.45
T_4: ECOHUME at 2 ml l^{-1}	11.40	12.73	12.07	28.33	24.73	26.53	39.43	37.30	38.37
T_5: ECOHUME at 4 ml l^{-1}	12.13	12.43	12.28	20.07	18.70	19.38	26.73	23.63	25.18
Mean	12.15	12.57		24.98	22.83		34.31	32.53	
	A	B	AB	A	B	AB	A	B	AB
SEm±	0.578	0.366	0.817	0.742	0.470	1.050	1.048	0.663	1.482
CD (p=0.05)	1.717	1.086	2.429	2.206	1.395	3.120	3.113	1.969	4.402

lower than the control plot, indicating a negative effect of the highest dose. Overall, Sunny house responded better to ECOHUME, particularly at moderate doses, suggesting a strong positive interaction between the biostimulant and variety.

The results of the present study clearly indicated that the application of ECOHUME as biostimulant significantly enhanced plant height in both Summer Squash hybrids namely Sunny house and Golden house, particularly at later growth stages of 40 DAS and 60 DAS. These findings corroborated previous research results highlighting the positive role of biostimulants in vegetative growth. Kaur et al. (2025) reported that seaweed extract-based biostimulants improved plant height and biomass accumulation in cucurbit crops by stimulating hormonal activity and nutrient uptake. Similarly, Hassan et al. (2021) observed the positive effects of biostimulant under stress conditions led to greater stem elongation and shoot vigour due to enhanced osmotic adjustment and chlorophyll synthesis.

Earlier researchers like Paradikovic et al. (2019), Olguin-Hernandez et al. (2023) and Garcia-Gonzalez and Sommerfeld (2016) collectively reported that biostimulants rich in phytohormones and bioactive compounds promote meristematic activity, resulting in taller and more robust plants. While, Olguin-Hernandez et al. (2023) reported an 11–12.5% increase in plant height of *Solanum quitoense* with AMF and biostimulant application and Garcia-Gonzalez and Sommerfeld (2016) reported a 27% increase in tomato height with algal based treatments.

3.1.2. Number of leaves plant^{-1}

The interaction between summer squash hybrids and ECOHUME concentrations significantly influenced leaf production at 20, 40, and 60 DAS presented in Table 2. Though variation was minimal at 20 DAS and noticeable differences emerged at later stages. At 40 and 60 DAS, T_4 (ECOHUME at 2 ml l^{-1}) consistently produced the highest leaf numbers in both Sunny house (9.07, 12.27) and Golden house (7.67, 11.53) respectively. The lowest leaf counts were observed under T_5 of ECOHUME at 4 ml l^{-1} both in Sunny house (6.07, 7.93) and Golden house (4.80, 5.93) respectively in comparison to untreated control. Sunny house outperformed Golden house across all stages of vegetative growth, indicating a more favourable varietal response.

The present study suggested that ECOHUME effectively enhanced the photosynthetic surface area, ensuring a greater source of assimilates for reproductive development and yield formation. These findings were in line with Kaur et al. (2025), who reported that Basfoliar (*Ecklonia maxima* extract) combined with the recommended fertilizer dose significantly increased leaf number in summer squash cv. Punjab Chappan Kaddu-1. The authors attributed this improvement to the presence of natural growth regulators such as auxins and cytokinins, along with polysaccharides and minerals which promoted cell division and leaf primordia development in summer squash.

3.2 Flowering characters of summer squash

3.2.1 Total number of male flowers plant^{-1}

The total number of male flowers plant^{-1} was significantly influenced by the interaction between summer squash hybrids and ECOHUME doses presented in Table 3. The treatment T_4 (ECOHUME at 2 ml l^{-1}) resulted in the highest flower count, particularly in Sunny house (34.67), while T_5 (ECOHUME at 4 ml l^{-1}) produced the fewest in compare to control indicating the adverse effects of higher dose of ECOHUME due to the phytotoxicity. Sunny house

Table 2: Combined effects of biostimulant and summer squash hybrids on number of leaves plant^{-1}

Treatment	Number of leaves plant^{-1}								
	20 DAS			40 DAS			60 DAS		
	Sunny house	Golden house	Mean	Sunny house	Golden House	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	4.47	3.80	4.13	7.40	5.80	6.60	10.40	9.00	9.70
T_2: ECOHUME at 0.5 ml l^{-1}	4.40	4.00	4.20	7.87	6.53	7.20	11.13	9.13	10.13
T_3: ECOHUME at 1 ml l^{-1}	4.47	3.80	4.13	8.53	7.13	7.83	11.73	10.27	11.00
T_4: ECOHUME at 2 ml l^{-1}	4.60	3.60	4.10	9.07	7.67	8.37	12.27	11.53	11.90
T_5: ECOHUME at 4 ml l^{-1}	4.20	3.80	4.00	6.07	4.80	5.43	7.93	5.93	6.93
Mean	4.43	3.80		7.79	6.39		10.69	9.17	
	A	B	AB	A	B	AB	A	B	AB
SEm±	0.163	0.103	0.231	0.351	0.221	0.496	0.431	0.272	0.609
CD (p=0.05)	0.485	0.307	0.686	1.042	0.659	1.474	1.280	0.809	1.810

Table 3: Combined effects of biostimulant and summer squash hybrids on total number of male flowers plant^{-1}

Treatment	Total number of male flowers plant^{-1}			Total number of female flowers plant^{-1}			Sex ratio		
	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	27.87	25.93	26.90	17.07	16.20	16.63	1.64	1.61	1.62
T_2: ECOHUME at 0.5 ml l^{-1}	31.00	25.00	28.00	19.93	19.47	19.70	1.56	1.29	1.42
T_3: ECOHUME at 1 ml l^{-1}	31.93	26.93	29.43	24.60	20.13	22.37	1.30	1.35	1.33
T_4: ECOHUME at 2 ml l^{-1}	34.67	29.00	31.83	27.20	23.67	25.43	1.29	1.23	1.26
T_5: ECOHUME at 4 ml l^{-1}	23.13	20.00	21.57	15.33	14.60	14.97	1.51	1.37	1.44
Mean	29.72	25.37		20.83	18.81		1.46	1.37	
	A	B	AB	A	B	AB	A	B	AB
SEm±	0.875	0.554	1.238	0.664	0.420	0.939	0.064	0.041	0.091
CD (p=0.05)	2.601	1.645	3.678	1.972	1.247	2.789	0.191	0.121	0.269

consistently outperformed Golden house across treatments.

This result reflected both the positive result of application of ECOHUME at 2 ml l^{-1} the negative effect of excessive ECOHUME application in at 4 ml l^{-1}. Salama et al. (2019) highlighted that yeast extract and potassium silicate improved flowering parameters in squash by promoting hormonal balance and nutrient assimilation.

3.2.2. Total number of female flowers plant^{-1}

The total number of female flowers plant^{-1} was significantly influenced by variety, ECOHUME dose, and their interaction presented in Table 3. The average highest flower count (27.20) was recorded under T_4 (ECOHUME at 2 ml l^{-1}) in Sunny house, while the lowest (14.60) was found in Golden house under T_5 (ECOHUME at 4 ml l^{-1}) even which was lower than the control. Sunny house consistently produced more female flowers than Golden house. Treatments with ECOHUME at 1 ml l^{-1} and 2 ml l^{-1} enhanced flower development, whereas excessive dosage at 4 ml l^{-1} negatively affected flowering. Hybrid means revealed that Sunny house (20.83) produced more female flowers than Golden house (18.81), highlighting varietal differences in reproductive response to biostimulants. Interaction (A×B) showed that Sunny house responded more positively to increasing ECOHUME doses up to 2 ml l^{-1} compared to Golden house.

The enhancement of female flower production under ECOHUME doses (1–2 ml l^{-1}) could be attributed to improved hormonal regulation (auxins, cytokinins, gibberellins) and nutrient uptake provided by humic and fulvic acids in ECOHUME. These findings corroborated with Kaur et al. (2025), who observed that seaweed-based biostimulants enhanced early and abundant flowering in summer squash, and Salama et al. (2019), who reported similar results with yeast extract and potassium silicate in squash cultivars.

3.2.3. Sex ratio

Sex ratio (male:female flower ratio) was significantly influenced by combined effects of ECOHUME and hybrids presented in Table 3. The lowest and most balanced ratios were observed under T_4 (ECOHUME at 2 ml l^{-1}) treatment, with the values of 1.29 in Sunny house and 1.23 in Golden house. In contrast, the untreated control (T_1) showed the highest ratio, indicating male flower dominance irrespective varieties. Sunny house exhibited a slightly higher overall sex ratio (1.46) than Golden house (1.37). Hybrid means indicated that Sunny house (1.46) exhibited a slightly higher sex ratio compared to Golden house (1.37), suggesting a higher proportion of male flowers in Sunny house.

The findings of this study aligned with the results reported by Dobhal et al. (2022), who demonstrated that the application of plant growth regulators significantly influenced sex expression in summer squash (*Cucurbita pepo* L. var. Pattypan).

3.2.4. Days to first flowering

The number of days to first flowering was significantly influenced by the interaction effects of hybrid varieties of summer squash and ECOHUME doses presented in Table 4. The earliest flowering was observed under T_4 of ECOHUME at 2 ml l^{-1}, with both hybrids initiating flowering around 30.3 days. In contrast, T5 (ECOHUME at 4 ml l^{-1}) resulted in the latest flowering, averaging 34.4 days. While varietal means were statistically similar with Sunny house (32.15 days) and Golden house (32.23 days), the treatment effects were more prominent. The interaction between T_4 (ECOHUME at 2 ml l^{-1}) and Golden house led to the earliest flowering (30.27 days), suggesting the

Table 4: Combined Effects of Biostimulant and Summer Squash Hybrids on Days to 1st Flowering and 50% Flowering

Treatment	Days to First Flowering			Days to 50% Flowering		
	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	32.20	32.47	32.33	43.80	45.27	44.53
T_2: ECOHUME at 0.5 ml l^{-1}	31.40	32.20	31.80	43.73	45.33	44.53
T_3: ECOHUME at 1 ml l^{-1}	32.33	31.67	32.00	42.93	43.53	43.23
T_4: ECOHUME at 2 ml l^{-1}	30.47	30.27	30.37	42.53	42.33	42.43
T_5: ECOHUME at 4 ml l^{-1}	34.33	34.53	34.43	47.80	49.33	48.57
Mean	32.15	32.23		44.16	45.16	
	A	B	AB	A	B	AB
SEm±	0.263	0.166	0.372	0.781	0.494	1.104
CD (p=0.05)	0.781	0.494	1.104	2.319	1.467	3.280

earliness of variety. Regarding varietal means, Sunny house (32.15 days) and Golden house (32.23 days) were statistically at par, indicating that varietal differences had minimal influence compared to treatment effects.

The findings clearly demonstrated that moderate doses of ECOHUME accelerated the onset of flowering in both hybrids. The earliest flowering recorded under T_4 (ECOHUME at 2 ml l^{-1}) might be attributed to the balanced supply of bioactive compounds such as amino acids, humic substances, and growth regulators in ECOHUME, which promoted hormonal signaling (especially gibberellins and cytokinins) and expedited the transition from vegetative to reproductive phase. These results aligned with the reports of Weisser et al. (2023), who observed earlier flowering in tomato with fortified biostimulant extracts, and Paradikovic et al. (2019), who confirmed the positive influence of biostimulants on reproductive traits across horticultural crops.

3.2.5. Days to 50% flowering

The combined effects of ECOHUME doses and hybrids significantly affected the days to 50% flowering presented in Table 4. The earliest flowering was recorded under T_4 (ECOHUME at 2 ml l^{-1}), averaging 42.43 days across both hybrids than the control plants. In contrast, the highest delay was observed with T_5 (ECOHUME at 4 ml l^{-1}), with a mean of 48.57 days even surpassed the control plants indicating the suppressing effects of biostimulant in higher dose. Varietal means showed that Sunny house (44.16 days) reached 50% flowering earlier than Golden house (45.16 days), highlighting better responsiveness to optimal doses of ECOHUME treatment. The varietal means indicated that Sunny house (44.16 days) showed 50% flowering earlier compared to Golden house (45.16 days). The interaction effect revealed that interaction between Golden house and T_5 (ECOHUME at 4 ml l^{-1}) recorded the highest delay in 50% flowering (49.33 days), while Golden house and T_4 (ECOHUME at 2 ml l^{-1}) interaction recorded the earliest 50% flowering (42.33 days).

These results suggested that, the application of biostimulants substantially influenced flowering dynamics by accelerating the transition from vegetative to reproductive stages. In the present study, treatments containing ECOHUME reduced the number of days to 50% flowering compared to untreated plots, suggesting enhanced metabolic activity and hormonal regulation. This aligned with the findings of Weisser et al. (2023), where a fortified biostimulant extract comprising seaweed, fish, and humic substances significantly advanced flower initiation in tomatoes by approximately 6.8 days, along with improved nutrient uptake and chlorophyll content.

3.3. Fruit and yield characters of summer squash

3.3.1. Fruit length (cm)

Fruit length was significantly influenced by both ECOHUME doses and hybrid types, as well as their interaction presented in Table 5. The highest average fruit length (23.73 cm) was observed under T_4 of ECOHUME at 2 ml l^{-1}, while the shortest (15.07 cm) was recorded in T_5 (ECOHUME at 4 ml l^{-1}) than untreated control, indicating negative effects of excessive biostimulant. Although hybrid means were nearly identical (Golden house: 20.73 cm; Sunny house: 20.71 cm), interaction effects confirmed that T_4 (ECOHUME at 2 ml l^{-1}) significantly improved fruit length across both hybrids.

The similar findings has been shown by Salama et al. (2019) where he found an increased fruit length and fruit size in three squash cultivars including Eskandarany, Revera, and Azyad using yeast extract (3 and 6 g l^{-1}) and potassium silicate (2 and 4 g l^{-1}).

3.3.2. Fruit diameter (cm)

Table 5: Combined effect of biostimulant and summer squash hybrids on fruit length (cm), diameter (cm) and number of fruits plant^{-1}

Treatment	Fruit length (cm)			Fruit diameter (cm)			Number of fruits plant^{-1}		
	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	21.00	20.40	20.70	4.60	3.33	3.97	3.67	3.33	3.50
T_2: ECOHUME at 0.5 ml l^{-1}	22.00	21.20	21.60	4.53	3.53	4.03	4.00	3.43	3.72
T_3: ECOHUME at 1 ml l^{-1}	22.97	22.03	22.50	5.00	3.73	4.37	4.53	4.73	4.63
T_4: ECOHUME at 2 ml l^{-1}	24.10	23.37	23.73	4.70	3.67	4.18	7.20	6.67	6.93
T_5: ECOHUME at 4 ml l^{-1}	13.47	16.67	15.07	3.70	3.60	3.65	1.33	1.33	1.33
Mean	20.71	20.73		4.51	3.57		4.15	3.90	
	A	B	AB	A	B	AB	A	B	AB
SEm±	0.468	0.296	0.666	0.143	0.090	0.202	0.269	0.170	0.380
CD (p=0.05)	1.390	0.879	1.965	0.425	0.269	0.601	0.798	0.505	1.128

Fruit diameter was significantly influenced by combined effects of ECOHUME doses, and hybrids of summer squash presented in Table 5. The highest fruit diameter of 5.00 cm was observed in Sunny house under the treatment T_3 of ECOHUME at 1 ml l^{-1}, while the lowest diameter of 3.60 cm recorded in Golden house under T_5 of ECOHUME at 4 ml l^{-1} even lower than the control plants. Overall, Sunny house exhibited a greater mean in fruit diameter (4.51 cm) than Golden house (3.57 cm), confirming a stronger positive response to ECOHUME at optimal concentrations and adverse effects of higher concentrations compared to untreated control.

This result was in parallel with the findings of Taha (2021) who has shown increased fruit diameter in crops, chlorophyll content of leaves, fruit number, NPK accumulation in response to different biostimulants.

3.3.3. Number of fruits plant^{-1}

The application of ECOHUME significantly influenced the number of fruits plant^{-1} through its interaction effects of with summer squash hybrids presented in Table 5. The average highest fruit set of 7.20 was observed in Sunny house under T_4 (ECOHUME at 2 ml l^{-1}), highlighting its optimal efficacy at this concentration. In contrast, the lowest fruit number (1.33) was recorded under T_5 (ECOHUME at 4 ml l^{-1}) for both hybrids than the untreated control, indicating a possible phytotoxic or inhibitory effect at higher doses. Overall, Sunny house (4.15) exhibited marginally superior performance over Golden house (3.90), suggesting a better varietal response to biostimulant application in case of fruit numbers plant^{-1}.

The positive response in the current study suggested that ECOHUME stimulated reproductive organ differentiation and assimilate partitioning toward fruit production. Similarly, Salama et al. (2019) reported that yeast extract and potassium silicate improved flowering and fruit development in squash, resulting in a higher fruit count.

3.3.4. Average fruit weight (g)

The average individual fruit weight of summer squash was significantly influenced by the interaction between hybrids and ECOHUME doses presented in Table 6. The highest fruit weight of 304.00 g was recorded in Sunny house under T_4 (ECOHUME at 2 ml l^{-1}), followed by Golden house under the same treatment (278.30 g). Conversely, the lowest fruit weights were observed in T_5 (ECOHUME at 4 ml l^{-1}), with 161.97 g in Sunny house and 111.97 g in Golden house, indicating a negative effect of excessive biostimulant concentration compared to the control plants. Across treatments, Sunny house (262.84 g) consistently produced heavier fruits compared to Golden house (202.10 g), affirming its superior response to ECOHUME application.

Likewise, Hassan et al. (2021) demonstrated that seaweed extract application in cucumber enhanced fruit weight due to the presence of natural phytohormones such as cytokinins and auxins, which improved cell division, elongation, and assimilate accumulation in developing fruits. These results collectively indicated that ECOHUME enhanced fruit weight by improving nutrient utilization and promoting hormonal balance during fruit growth.

3.3.5. Yield plant^{-1} (kg)

The average yield plant^{-1} was significantly affected by the combined effects of summer squash hybrids and ECOHUME doses presented in Table 6. The maximum yield of 2.17 kg was recorded in Sunny house under T_4 (ECOHUME at 2 ml l^{-1}), followed by Golden house (1.85 kg) under the same treatment. The lowest yield of 0.22 kg in Sunny house and 0.15 kg in Golden house recorded under

Table 6: Combined effects of biostimulant and summer squash hybrids on average fruit weight (g), yield plant-1 and yield plot^{-1} (kg)

Treatment	Average fruit weight (g)			Yield plant^{-1} (kg)			Yield plot^{-1} (kg)		
	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean	Sunny house	Golden house	Mean
T_1: Untreated control	270.18	214.30	242.24	0.98	0.71	0.84	4.90	3.55	4.22
T_2: ECOHUME at 0.5 ml l^{-1}	279.63	200.27	239.95	1.12	0.69	0.90	5.59	3.43	4.51
T_3: ECOHUME at 1 ml l^{-1}	298.42	205.67	252.04	1.35	0.96	1.16	6.75	4.82	5.79
T_4: ECOHUME at 2 ml l^{-1}	304.00	278.30	291.15	2.17	1.85	2.01	10.85	9.25	10.05
T_5: ECOHUME at 4 ml l^{-1}	161.97	111.97	136.97	0.22	0.15	0.19	1.12	0.75	0.94
Mean	262.84	202.10		1.17	0.87		5.85	4.36	
	A	B	AB	A	B	AB	A	B	AB
SEm±	10.935	6.916	15.465	0.0559	0.0353	0.0790	0.279	0.177	0.395
CD (p=0.05)	32.490	20.549	45.948	0.166	0.105	0.235	0.830	0.525	1.174

T_5 (ECOHUME at 4 ml l^{-1}) even lower than the untreated plot, indicating a detrimental effect of higher ECOHUME dose. Overall, Sunny house (1.17 kg) yielded more than Golden house (0.87 kg), confirming better responsiveness to ECOHUME application.

The present study revealed that ECOHUME significantly increased yield plant^{-1}, with T_4 (ECOHUME at 2 ml l^{-1}) performing best in both summer squash hybrids. These results align with Fernando et al. (2018), who reported a 16.04% increase in melon yield with Trichoderma-based biostimulants. Similarly, Cristofano et al. (2021) emphasized that biostimulants enhance metabolic efficiency, nutrient uptake, and reproductive development, leading to greater yields in cucurbits. Furthermore, Li et al. (2022) confirmed through meta-analysis that yield response to biostimulants averages 17.9%, particularly under stress conditions. These findings collectively supported the current study's observation that ECOHUME boosted productivity by improving physiological and biochemical functions, thereby optimizing assimilate partitioning toward fruit development.

3.3.6. Yield plot^{-1} (kg)

The average yield plot^{-1} was significantly influenced by hybrids, ECOHUME doses, and their interaction presented in Table 6 and illustrated in Figure 5. The average highest plot yield of 10.85 kg was recorded in Sunny house under T_4 (ECOHUME at 2 ml l^{-1}), followed by Golden house (9.25 kg), under the same treatment with a mean of 10.05 kg. The lowest yield (0.94 kg) was noted under T_5 (ECOHUME at 4 ml l^{-1}) in both hybrids even lesser than the untreated plot. Sunny house (5.85 kg) outperformed Golden house (4.36 kg), highlighting better responsiveness to ECOHUME application. These results revealed that ECOHUME application at optimal doses enhanced yield while higher dose affected adversely at the plot level, contributing to higher production efficiency in total yield.

The results indicated that ECOHUME treatments, particularly T_4-ECOHUME at 2 ml l^{-1}, recorded the highest yield plot^{-1} in both hybrids, significantly outperforming the control. It could be said that ECOHUME application not only improved individual plant performance but also translated into significant yield advantages at the plot level, contributing to more efficient and sustainable production systems if applied in proper doses. These findings were consistent with Fernando et al. (2018), where *Trichoderma*-based biostimulants increased melon productivity by over 16%. Furthermore, Cristofano et al. (2021) highlighted the role of biostimulants in optimizing nutrient uptake and hormonal regulation, ultimately enhancing reproductive growth and yield at the field scale. The meta-analysis by Li et al. (2022) further supported this trend, reporting an average yield increase of 17.9% across diverse crops and conditions.

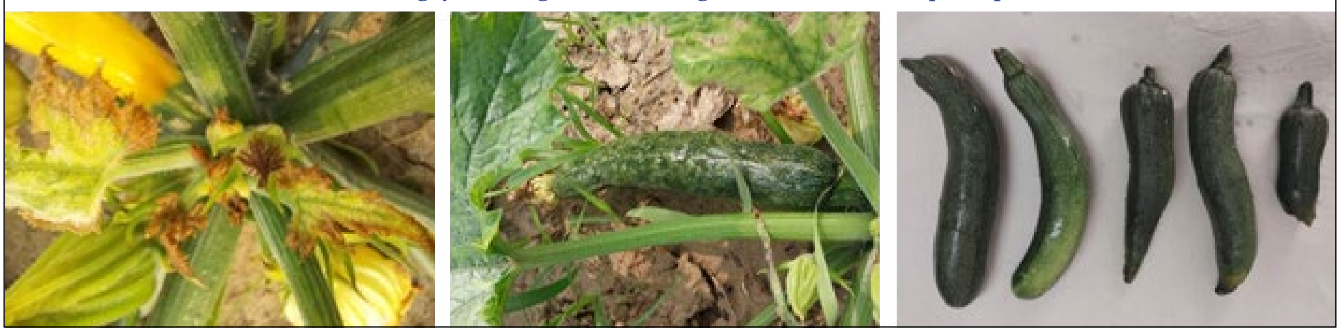
3.7. Phytotoxicity effects of biostimulant on summer squash hybrids

The highest dose of ECOHUME at 4 ml l^{-1} in case of T_5 exhibited clear phytotoxic effects on both hybrids of summer squash (presented in Table 7 and illustrated in Figure 2). Symptoms appeared soon after the first spray at 20 DAS, including stunted growth, leaf yellowing, and mottling, necrosis of leaves etc. These effects intensified following the second application at 40 DAS, leading to severe burning of leaves, floral buds, and abnormal fruits. In several cases, complete plant death occurred, resulting in near-total crop loss. These findings underscored that excessive biostimulant application, especially beyond optimal concentrations, could be detrimental and must be carefully managed. This finding was matched with the suggestions given by Cristofano et

Table 7: Phytotoxicity effects by ECOHUME biostimulant on summer squash hybrids

Treatment	Phyto-toxicity effect days after first spray (20 DAS)					Phyto-toxicity effect days after second spray (40 DAS)				
	1	3	5	7	10	1	3	5	7	10
T_1: Control										
T_5: ECOHUME at 4 ml l^{-1}			Stunting	Yellowing, leaf motling					Burning of leaves, buds, fruits	complete crop loss

Leaf motling, yellowing and stunted growth of summer squash plants



Burning symptoms of plants, fruit necrosis

Figure 2: Phytotoxicity effects by ECOHUME biostimulant on summer squash hybrids

al. (2021).

4. CONCLUSION

The ECOHUME at 2 and 1 ml l^{-1} were identified as the most effective doses for enhancing growth, flowering and yield of summer squash hybrids. Both hybrids responded positively, with green fruited hybrid outperforming yellow fruited in most of the parameters, especially yield while higher doses at 4 ml l^{-1} caused phytotoxic effects.

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