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Yield Components Response of 'Barhi' Dates (*Phoenix dactylifera*) to Organic Fertilization, Foliar Gibberellin, and Tryptophan

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Abstract

A two season study was conducted in the palm tissue culture station of orchard/horticulture department in Najaf Governorate, Iraq, from February 1st to October 1st 2024 for the first season and from February 1st to October 1st 2025 for the second season. The organic fertilization (sheep manure) at 0, 15, and 20 kg per tree, foliar spray with gibberellin at 0, 200, and 300 mg/L, and tryptophan at 0, 50, and 100 mg/L, were evaluated for their effects on 'Barhi' date palm growth and yield indicators. The results indicated that organic fertilization produced the greatest increase in leaf auxin and gibberellin content. In contrast, treatments with gibberellin and tryptophan resulted in comparatively smaller increases. Hormone levels in the control were approximately 20% lower than those observed in the lowest treatment. The fruit size was larger in the total interactions, but was not significantly affected by the individual treatment. However, fruit weight and cluster weight differed among the experimental factors. In general, the interaction treatment of organic fertilizer 20 kg per palm and gibberellins 300 mg/L in the presence of tryptophan 100 mg/L significantly resulted in the highest plant content of auxins (34.911 µg/g FW) and gibberellins (35.181 and 35.173 µg/g FW), fruit weight (13.020 and 11.573 g), fruit size (11.670 and 11.720 cm^3), cluster weight (9.527 and 10.873 kg) and the total yield (38.109 and 38.780 kg per tree).

Keywords: amino acids, organic agriculture, phyto-hormones, yield quality

Introduction

The scientific literature documents the multifunctional role of L-tryptophan (Trp) when applied as a foliar treatment on horticultural crops (Arabia et al., 2025). Tryptophan acts as the primary biochemical precursor for the synthesis of indole-3-acetic acid (IAA), the principal endogenous form of auxin in plants. Consequently, it plays an important role in plant development, including nitrogen assimilation, adventitious root initiation, cell expansion, and localized nutrient acquisition (Bhatla & Lal, 2023). Beyond auxin synthesis, exogenous tryptophan enhances nitrate assimilation efficiency within plant tissues, thereby stimulating downstream metabolic activities associated with carbon fixation (Arabia et al., 2025). This physiological shift ultimately drives higher nutrient-use efficiency, accelerates the uptake and accumulation of macronutrients, and promotes vegetative and reproductive development in perennial fruit crops.

Recent studies have reported the auxiliary role of tryptophan and related indole derivatives in modulating cell wall dynamics during generative cycles. Tryptophan and its downstream metabolites, such as melatonin, are potent bioactive compounds that enhance the structural and functional attributes of developing fruits (Arabia et al., 2025). These molecules enhance localized antioxidant capacities, maintain cellular firmness, and support balanced pigment and hormonal metabolisms both during and after fruit development. This physiological framework emphasizes the critical importance of proper hormonal balance and nutrient-hormone

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interactions in optimizing sink organ quality.

Together with amino acids and organic fertilizers, gibberellic acid (GA_3) has shown promising synergistic effects on growth, nutrient uptake, and yield components across various horticultural crops. A clear research gap remains in addressing the combined application of local environmental conditions in date palm production, particularly for the 'Barhi' cultivar (*Phoenix dactylifera* L.), where hormonal regulation is fundamental to fruit set, size, and quality attributes. Therefore, this research has been oriented toward determining the combined effect of organic fertilization and foliar application of GA_3 and tryptophan on growth parameters, nutrient uptake, yield components, and the physical and chemical attributes of 'Barhi' dates. This is in conformity with international norms for the presentation of results and will facilitate a better perception of nutrient-hormone interactions involved in fruit development.

Materials and Methods

Experimental Location and Time Frame

The experiment was conducted at the Palm Tissue Culture Station, Ministry of Agriculture, Najaf Governorate, during two seasons: February to October 2024 and February to October 2025. The experimental area is located in central and southern Iraq, which is classified as an arid region with high summer temperatures and low humidity, conditions that strongly influence the date fruit development characteristics (Arabia et al., 2025; Toubali et al., 2020). The experiment was conducted in a three-factor factorial, randomized complete block design with three replications as described by Hoshmand (2018). The organic fertilization (sheep manure, F) at concentrations of 0 (F1), 15 (F2), and 20 (F3) kg per tree, foliar spray with gibberellin (G) at 0 (G1), 200 (G2), and 300 (G3) mg/L, and tryptophan (T) at 0 (T1), 50 (T2), and 100 (T3) mg/L were evaluated for their effects on 'Barhi' date palm growth and yield indicators. Eighty-one 'Barhi' date palm trees of similar age, vigor, and height were selected to represent 27 treatment combinations. All cultural practices, including irrigation, pruning, and fertilization, were applied uniformly to all palms in both seasons. The organic fertilizers used were sheep manure or compost. GA_3 and tryptophan were applied in a foliar spray.

Fruit Chemical and Physical Analyses

Total Sugars

Total sugars (carbohydrates) were determined by the Lane and Eynon titration method as described by Alsaed et al. (2013).

Total Soluble Solids (TSS)

A 5 g sample of fresh fruit flesh was homogenized with 20 ml of distilled water in a ceramic mortar and then filtered. TSS was measured using a hand refractometer by standard procedures (Association of Official Analytical Chemists, 2019).

Dry Matter Percentage

$$\text{Dry matter (\%)} = \frac{\text{Weight of dry sample}}{\text{Weight of fresh sample}} \times 100$$

Fruit Set and Ripening Percentages

$$\text{Fruit Set (\%)} = \frac{\text{Number of fruit set}}{\text{Number of fruit set + number of empty scars}} \times 100$$

$$\text{Ripening (\%)} = \frac{\text{Number of ripe fruits}}{\text{Total number of fruits}} \times 100$$

Yield and Productivity

Cluster weight = Total yield per tree ÷ Number of clusters

Fruit yield per tree = Weight of fruits per cluster × Number of clusters

Productivity per unit area = Yield per tree × 100 trees/dunum (standard planting density)

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Determination of Indole-3-Acetic Acid (IAA) in Dates Fruits

The IAA content in fruits was determined to assess the effect of treatments on auxin accumulation by an HPLC method adopted in recent studies (Arabia et al., 2025; Bhatla & Lal, 2023). Fresh fruit tissues (2 g) were homogenized in 80% cold methanol containing 1% BHT. The homogenate was incubated at 4 °C for 24 hr and centrifuged at 10,000 rpm for 15 min. The supernatant was purified on C18 solid-phase extraction cartridges.

Statistical Analysis

The data were analyzed statistically using analysis of variance (ANOVA) as described by Snedecor and Cochran. The differences between means for all parameters under study were estimated using Duncan's multiple range test (DMRT) at a 5% level of probability. Analysis of variance was performed using GenStat (Payne et al., 2009). Means were separated using the least significant difference (LSD) test at the 5% significance level. Results are expressed as Mean ± SE (n = 3).

Results and Discussion

Fruit Total Sugars

The results in Table 1 show that organic fertilizer, especially at 20 kg per tree, significantly affected the fruit total sugar content (%), with values of 62.75% and 57.03% in the two seasons, respectively, compared to 46.81% and 43.40% in the control treatment. Gibberellin significantly increased fruit total sugar content when sprayed at 300 mg/L, reaching 56.93% and 52.35% in the two seasons, respectively, followed by tryptophan treatment at 100 mg/L, which recorded 54.58% and 50.06% in the two seasons, respectively. The fruit content of sugars increased with the interaction between organic fertilizer and either of the two spraying factors, compared to the effect of the single factor; the organic fertilizer at 20 kg per tree combined with 300 mg/L GA_3 (F3G3) treatment recorded fruit sugar percentages of 69.34% and 63.86%, compared to the respective control (F1G1), which led to 45.95% and 42.20% for the two seasons, respectively. The dual interaction between organic fertilizer and tryptophan at higher concentrations also had a significant effect on fruit sugar content; 20 kg of organic matter per tree combined with 100 mg/L tryptophan (F3T3) recorded the highest values of 64.37% and 58.85% in the two seasons, respectively, compared to 15 kg of organic matter per tree combined with 5 0 mg/L tryptophan (F2T2) and the control F1T1. The results in the same table showed that the triple interaction between organic fertilizer, gibberellin, and tryptophan had a significant superiority in the leaf auxin content, as treatment F3G3T3 recorded the highest leaf sugar content of 70.05% and 66.09% for the two seasons compared to the control treatment F1G1T1, which recorded only 45.26% and 41.81% for the two seasons, respectively.

A combination of tryptophan and gibberellic acid (GA_3) significantly improved vegetative growth parameters and reproductive performance, as evidenced by fruiting in the 'Barhi' date palm. The possible explanation for such increasing levels of IAA is that tryptophan acts as the main precursor to auxin; thus, exogenous tryptophan can activate the indole-3-pyruvic acid pathway, thereby enhancing the synthesis of auxins within fruit tissues, as reported earlier by Arabia et al. (2025). Bhatla and Lal (2023) also found that amino acids, including Trp, enhance nutrient assimilation and improve hormone-mediated growth regulation, ultimately leading to increased cell enlargement and fruit development.

The synergistic effect of GA_3 in combination with tryptophan is also evident. Known to promote cell elongation and division and to be associated with high auxin content that promotes fruit set, increases size, and improves quality, this finding corroborates a previous report by Hoshmand (2018) that growth regulators can modify endogenous hormone levels to improve physiological traits in horticultural crops. The increase of fruit quality parameters, including

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Table 1

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan on Fruit Content of Total Sugar in 'Barhi' Date Palms for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F×G (2025)
		0	50	100		0	50	100	
0	0	45.26	45.73	46.86	45.95	41.81	42.22	42.58	42.20
	200	46.26	47.38	46.67	46.77	42.93	43.10	43.95	43.33
	300	48.53	46.59	48.06	47.72	44.23	44.62	45.18	44.68
15	0	48.75	49.55	48.98	49.09	45.22	45.79	46.08	45.69
	200	49.83	50.80	52.71	51.11	46.23	46.55	46.89	46.56
	300	52.39	53.77	55.05	53.74	47.49	48.76	49.33	48.53
20	0	53.67	56.86	58.95	56.49	49.80	50.53	52.49	50.94
	200	60.54	62.59	64.11	62.41	54.35	56.52	57.98	56.29
	300	68.69	69.29	70.05	69.34	62.20	63.31	66.09	63.87
LSD (0.05)		LSD (F×G×T) = 1.51			LSD (F×G) = 0.87	LSD (F×G×T) = 0.66			LSD (F×G) = 0.37
Factorial Interactions Matrices									
T × F		Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
		0	50	100		0	50	100	
F: 0		46.65	46.85	47.20	46.81	42.99	43.31	43.90	43.40
F: 15		50.86	50.91	52.17	51.31	46.32	47.03	47.43	46.93
F: 20		60.97	62.91	64.37	62.75	55.45	56.79	58.86	57.03
T Mean		52.89	53.41	54.58		48.25	49.05	50.06	
LSD (0.05)		LSD (F×T) = 0.87			LSD (F) = 0.50	LSD (F×T) = 0.083			LSD (F) = 0.048
T×G		Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
		0	50	100		0	50	100	
G: 0 mg/L		49.47	50.54	51.52	50.51	45.61	46.18	47.05	46.28
G: 200 mg/L		52.21	53.59	54.50	53.43	47.84	48.72	49.61	48.72
G: 300 mg/L		57.00	56.09	57.72	56.93	51.31	52.23	53.54	52.36
LSD 0.05		LSD (G×T) = 0.87			LSD (G) = 0.50	LSD (G×T) = 0.37			LSD (G) = 0.21

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

TSS, dry matter, and sugar content, relates to effective nutrient uptake and utilization as reflected by Talaat et al. (2023) in date palm under fertilization regimes. Growth regulators can be applied in practice to optimize growth and fruit quality, since organic fertilizers contain no hormonal treatments. The standardization of analytical methods and the precise measurement of physiological indicators, as emphasized by Association of Official Analytical Chemists (2019), made the data reliable and comparable. The clear tabulation of biochemical and hormonal values (Table 1) is in accordance with international standards (Arabia et al., 2025) makes our results reproducible and interpretable.

Fruit Total Soluble Solids

Total soluble solids (TSS) in 'Barhi' date fruits were significantly affected by the type and level of treatments applied (Table 2). Application of organic fertilizers at 20 kg per tree resulted in higher TSS values than other treatments, reflecting the positive effect of enhanced nutrient

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availability on carbohydrate accumulation. TSS was also significantly increased by foliar applications of gibberellic acid (GA_3) at 300 mg/L and tryptophan (Trp) at 100 mg/L individually, but to a lesser extent than the organic fertilizer treatment. The highest TSS values were observed in the triple combination (F3G3T3: organic fertilizer + GA_3 + Trp), indicating a synergistic effect of nutrient and hormonal treatments on fruit sugar accumulation. This can be attributed to enhanced photosynthate translocation from source leaves to developing fruits due to improved vegetative growth and leaf nutrient status (Bhatla & Lal, 2023; Talaat et al.,2025), stimulation of sugar metabolism and transport by GA_3, which promotes enzymatic activity involved in carbohydrate biosynthesis (Arabia et al., 2025). Auxin-mediated effects triggered by exogenous tryptophan increase IAA levels and facilitate cell expansion, fruit development, and sugar accumulation.

These results are in recent agreement with findings on horticultural crops indicating that fruit quality attributes, such as TSS and sugars, are

Table 2

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan Fruit Content of TSS in 'Barhi' Date Palms for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F×G (2025)
		0	50	100		0	50	100	
0	0	47.07	48.28	49.18	48.18	43.36	43.94	44.46	43.92
	200	48.76	48.80	49.43	48.99	44.86	45.46	45.75	45.37
	300	49.27	50.04	50.07	49.79	45.97	46.81	46.96	46.58
15	0	48.28	49.08	49.85	49.07	47.50	47.79	48.10	47.80
	200	49.97	49.99	50.43	50.13	48.53	48.82	49.38	48.91
	300	50.25	50.91	51.22	50.79	49.82	50.59	50.90	50.43
20	0	52.81	53.79	55.01	53.87	51.17	51.40	54.32	52.30
	200	56.30	56.89	58.24	57.14	53.39	55.17	55.733	54.76
	300	58.72	60.07	60.15	59.65	56.75	57.43	58.08	57.42
LSD (0.05)		LSD (F×G×T) = 0.91			LSD (F×G) = 0.53	LSD (F×G×T) = 0.41			LSD (F×G) = 0.23

Factorial Interactions Matrices

T × F	Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
	0	50	100		0	50	100	
F: 0	48.65	48.77	49.55	48.90	44.73	45.40	45.72	45.29
F: 15	49.72	49.92	50.36	50.00	48.62	49.06	49.46	49.05
F: 20	56.14	56.72	57.80	56.89	53.77	54.66	56.04	54.83
T Mean	51.50	51.80	52.57		49.04	49.71	50.41	
LSD (0.05)	LSD (F×T) = n.s			LSD (F) = 0.30	LSD (F×T) = 0.23			LSD (F) = 0.14

T×G	Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
	0	50	100		0	50	100	
G: 0 mg/L	49.39	50.39	51.35	50.37	47.35	47.71	48.96	48.01
G: 200 mg/L	51.89	51.83	52.55	52.09	48.93	49.81	50.29	49.68
G: 300 mg/L	53.24	53.20	53.80	53.41	50.85	51.61	51.98	51.48
LSD 0.05	LSD (G×T) = 0.53			LSD (G) = 0.30	LSD (G×T) = 0.23			LSD (G) = 0.14

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

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maximized by the combined application of organic fertilization and growth regulators. Added to this is the fact that in both seasons, TSS responded positively to treatment, which proves the stability of the effect under environmental conditions and treatments applied in central and southern Iraq.

Fruit Set Percentage

The factors significantly affected the percentage of fruit set in 'Barhi' date palm (Table 3). A higher level of organic fertilizer (20 kg per tree) was applied; the fruit set percentages were high and consistent at 72.11% and 74.05% across both seasons, compared to the lower-level fertilizer and control, which were 53.16% and 60.45%, respectively.

Similarly, gibberellic acid (GA_3) at 300 mg/L is applied by foliar spray, which recorded fruit set at 66.28% and 73.53% in two seasons, respectively, and tryptophan (Trp) at 100 mg/L by foliar spray recorded fruit set at 64.28% and 70.36% in two seasons, respectively, thus proving the positive effect of these growth regulators on reproductive performance.

Fruit set increased with treatment interactions. Combined treatments such as F3G3, F3T3, and G2T3 always gave higher percentages than single-factor applications, regardless of the concentration used. The triple combination (F3G3T3: organic fertilizer + GA_3 + Trp) recorded the highest fruit set, at 76.97% and 82.09% across the two seasons, with significant differences compared with most other single or combined treatments.

The results clearly demonstrate a combined nutrient-hormone effect on fruit set, with recent reports showing that organic fertilization integrates the effects of growth regulators to increase reproductive efficiency and fruit yield in horticultural crops (Arabia et al., 2025; Bhatla & Lal, 2023). Auxin biosynthesis is greatly stimulated by improved nutrient availability under combined treatments; GA_3 enhanced cell division and expansion, thereby creating conditions for fruit retention.

Fruit Ripening Percentage

The results indicate that the experimental treatments significantly affected the percentage of fruit ripening in 'Barhi' date palms (Table 4). The application of organic fertilizer at 20 kg per tree consistently enhanced fruit ripening, reaching 72.016% and 67.167% in the two consecutive seasons. This was significantly higher than the control and slightly higher than the GA_3 treatment at 300 mg/L, which resulted in 65.158% and 57.298%, while tryptophan (100 mg/L) recorded 62.430% and 55.438% for the two seasons.

Regardless of the factor or its interaction, the highest fruit ripening percentages were consistently achieved with single or combined treatments at the highest concentrations. Notably, the triple interaction (organic fertilizer + GA_3 + Trp) exhibited significant superiority, recording the highest fruit ripening percentages of 76.990% and 71.203% across the two seasons. In contrast, the control treatment (F1G1T1) showed the lowest values, with 43.571% and 39.903%, highlighting the pronounced effect of integrated fertilization and hormonal treatments.

The observed increase in fruit ripening under combined treatments can be attributed to the synergistic effects of nutrient availability and hormonal regulation. Enhanced nutrient supply from organic fertilizer promotes overall fruit metabolism, while GA_3 stimulates cell elongation and division, and tryptophan increases endogenous auxin (IAA) levels, collectively accelerating fruit development and maturation. These findings are consistent with recent studies in horticultural crops demonstrating that integrated application of organic fertilizers and growth regulators improves fruit development and quality (Arabia et al., 2025; Bhatla & Lal, 2023).

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Table 3

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan on Fruit Set Formation Percentage in 'Barhi' Date Palms for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F×G (2025)
		0	50	100		0	50	100	
0	0	47.41	54.40	57.34	49.34	52.42	55.12	56.19	54.58
	200	45.36	49.46	53.20	53.05	47.41	60.92	68.64	58.99
	300	56.38	56.49	58.41	57.09	66.98	68.98	67.46	67.80
15	0	59.26	60.34	60.42	60.00	64.96	66.84	68.83	66.88
	200	62.15	62.95	63.69	62.93	66.68	69.68	72.38	69.58
	300	64.76	65.64	68.16	66.18	70.18	70.87	74.49	71.85
20	0	68.60	69.96	70.43	69.66	68.29	70.68	72.40	70.45
	200	69.95	70.54	72.84	71.11	69.88	70.53	71.88	70.76
	300	73.32	76.40	76.97	75.56	79.12	81.65	82.10	80.95
LSD (0.05)		LSD (F×G×T) = 2.74			LSD (F×G) = 1.58	LSD (F×G×T) = 0.75			LSD (F×G) = 0.43

Factorial Interactions Matrices

T × F	Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
	0	50	100		0	50	100	
F: 0	49.72	54.43	55.34	53.16	55.60	62.03	63.74	60.46
F: 15	62.06	62.97	64.09	63.04	67.27	69.13	71.90	69.43
F: 20	70.62	72.30	73.41	72.11	72.64	74.07	75.46	74.06
T Mean	60.80	63.23	64.28		65.17	68.41	70.36	
LSD (0.05)	LSD (F×T) = 1.58			LSD (F) = 0.91	LSD (F×T) = 0.43			LSD (F) = 0.25

T×G	Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
	0	50	100		0	50	100	
G: 0 mg/L	58.42	62.55	61.75	60.91	61.89	64.57	65.45	63.97
G: 200 mg/L	59.16	60.98	63.24	61.13	61.54	66.83	70.97	66.44
G: 300 mg/L	64.82	66.18	67.85	66.28	72.09	73.83	74.68	73.53
LSD 0.05	LSD (G×T) = 1.58			LSD (G) = 0.91	LSD (G×T) = 0.43			LSD (G) = 0.25

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

Clusters Weight (kg)

The experimental treatments had a significant effect on the cluster weight of 'Barhi' date palms (Table 5). Among single-factor applications, organic fertilizer at 20 kg per tree produced the highest cluster weights of 9.017 kg and 10.320 kg for the two consecutive seasons, followed by gibberellic acid (GA_3, 300 mg/L) with 8.426 kg and 9.364 kg, and tryptophan (Trp, 100 mg/L) with 8.254 kg and 8.956 kg. All single-factor treatments significantly exceeded the control, which recorded 7.951 kg and 8.558 kg, confirming the positive impact of nutrient and hormonal supplementation on fruit biomass accumulation.

Interaction treatments further enhanced cluster weight. Dual-factor combinations, including F3G3 (organic fertilizer + GA_3), F3T3 (organic fertilizer + Trp), and G3T3 (GA_3 + Trp), recorded 9.395–10.674 kg, 9.209–10.457 kg, and 8.486–9.478 kg, respectively, demonstrating the synergistic effects of combined applications.

The triple combination (F3G3T3: organic

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fertilizer + GA_3 + Trp) exhibited the highest cluster weight (9.527 kg and 10.873 kg), slightly higher than dual-factor treatments and significantly higher than any single-factor application. This indicates that integrated fertilization and hormonal regulation maximize assimilate partitioning into fruits, enhancing cluster weight. These findings align with previous studies reporting that the combined application of nutrients and growth regulators improves fruit biomass by promoting cell division, elongation, and carbohydrate accumulation (Arabia et al., 2025; Bhatla & Lal, 2023).

Table 4

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan on Fruit Ripening Percentage in 'Barhi' Dates for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F×G (2025)
		0	50	100		0	50	100	
0	0	43.57	45.68	47.53	45.59	39.90	40.68	41.75	40.78
	200	47.71	48.59	49.48	48.59	41.93	42.73	43.77	42.81
	300	50.33	53.41	55.51	53.08	43.20	43.68	45.58	44.15
15	0	57.35	57.44	58.10	57.63	47.90	48.09	48.75	48.25
	200	59.25	62.93	63.76	61.98	50.29	53.48	54.42	52.73
	300	65.71	67.59	68.13	67.14	55.97	58.24	58.59	57.60
20	0	68.60	69.96	70.45	69.67	59.35	63.30	65.63	62.76
	200	69.99	70.55	72.86	71.13	67.77	68.76	69.27	68.60
	300	73.32	75.44	76.99	75.25	69.41	69.81	71.20	70.14
LSD (0.05)		LSD (F×G×T) = 0.96			LSD (F×G) = 0.55	LSD (F×G×T) = 1.01			LSD (F×G) = 0.58

Factorial Interactions Matrices

T × F	Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
	0	50	100		0	50	100	
F: 0	47.21	49.52	50.54	49.09	41.94	42.10	43.70	42.58
F: 15	60.77	62.65	63.33	62.25	51.39	53.27	53.92	52.86
F: 20	70.64	71.98	73.43	72.02	65.51	67.29	68.70	67.17
T Mean	59.54	61.39	62.44		52.95	54.22	55.44	
LSD (0.05)	LSD (F×T) = 0.55			LSD (F) = 0.32	LSD (F×T) = 0.58			LSD (F) = 0.34
T×G	Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
	0	50	100		0	50	100	
G: 0 mg/L	56.51	57.69	58.69	57.63	49.31	50.43	52.04	50.60
G: 200 mg/L	58.99	60.99	61.74	60.57	53.33	54.99	55.82	54.71
G: 300 mg/L	63.12	65.48	66.87	65.16	56.19	57.24	58.46	57.30
LSD 0.05	LSD (G×T) = 0.55			LSD (G) = 0.32	LSD (G×T) = n.s			LSD (G) = 0.34

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

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Table 5

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan on Cluster Weight of 'Barhi' Dates for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F×G (2025)
		0	50	100		0	50	100	
0	0	5.90	6.38	6.48	6.25	5.21	5.60	6.09	5.63
	200	6.67	7.27	7.47	7.14	6.47	6.79	6.98	6.74
	300	7.38	7.44	7.54	7.45	7.66	7.83	7.91	7.80
15	0	8.18	7.82	7.85	7.95	8.42	8.68	9.14	8.75
	200	8.29	8.42	8.60	8.43	9.16	9.38	9.46	9.33
	300	8.37	8.43	8.50	8.44	9.58	9.62	9.65	9.62
20	0	8.54	8.81	9.00	8.78	9.78	9.98	10.05	9.94
	200	8.59	8.93	9.10	8.88	10.28	10.32	10.45	10.35
	300	9.31	9.35	9.53	9.40	10.46	10.69	10.87	10.67
LSD (0.05)		LSD (F×G×T) = 0.05			LSD (F×G) = 0.03	LSD (F×G×T) = 0.15			LSD (F×G) = 0.09

Factorial Interactions Matrices

T × F	Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
	0	50	100		0	50	100	
F: 0	6.65	7.06	7.13	6.95	6.45	6.74	6.99	6.73
F: 15	8.19	8.20	8.43	8.27	9.05	9.23	9.42	9.23
F: 20	8.83	9.02	9.21	9.02	10.17	10.33	10.46	10.32
T Mean	7.95	8.03	8.25		8.56	8.77	8.96	
LSD (0.05)	LSD (F×T) = 0.03			LSD(F) = 0.015	LSD (F×T) = 0.09			LSD (F) = 0.05

T×G	Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
	0	50	100		0	50	100	
G: 0 mg/L	7.52	7.58	7.89	7.66	7.52	8.09	8.43	8.01
G: 200 mg/L	7.96	8.10	8.39	8.15	7.96	8.83	8.96	8.58
G: 300 mg/L	8.37	8.42	8.49	8.43	8.37	9.38	9.48	9.08
LSD 0.05	LSD (G×T) = 0.03			LSD (G) = 0.02	LSD (G×T) = 0.09			LSD (G) = 0.05

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

Total Yield per Tree

As with the effect of treatments on bunch weight, a similar effect was observed for yield weight (kg per tree). The organic fertilizer treatment recorded a significant effect at 20 kg organic matter per tree,, with yields of 33.096 and 37.726 kg per tree for the two consecutive seasons. This was followed by spraying with 300 mg/L gibberellin, which achieved 33.254 and 34.285 kg per tree, and with 100 mg/L foliar tryptophan, which resulted in 32.826 and 32.741 kg per tree, showing significant differences from the control yield (29.157 and 31.428 kg per tree) for the two seasons, respectively.

The yield values increased to 35.335 and 38.541 kg per tree for the two consecutive seasons in the F3G3 interaction treatment, followed by F3T3 treatment with yields of 35.553 and 37.759 (kg per tree) then G3T3 treatment with yield values of 35.412 and 34.897 kg per tree for the two consecutive seasons compared to the control treatment G1T1 which recorded the lowest yield of 26.626 and 29.421 kg per

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tree. The total interaction F3G3T3 recorded the highest yield per palm tree of 38.109 and 38.780 kg per tree for the two consecutive seasons, compared to the control treatment G1T1, which recorded the lowest yield of 26.626 and 29.421 (kg per tree).

The data in Tables 1 and 2 show that the soil was amended with organic fertilizers, primarily sheep manure, and that a foliar application of tryptophan and gibberellic acid was also applied. This treatment considerably improves the concentrations of the plant hormones auxin (IAA) and gibberellin (GA_3) in date palm fruit. High levels during the early stages of fruit development may be attributed to high endogenous hormone content in flowers immediately after pollination, which gradually decreases as the fruit grows. Therefore, this result agrees with that obtained by Hanieh et al. (2020), who found significant increases in both hormone contents in fruits after foliar spraying of ascorbic acid on green fruit bunches (auxin). Plant hormones regulate internal processes such as growth and development, including maturation, in which internal factors (for example, auxin and gibberellin) determine the timing and rate of maturation (Mattar et al.,2021; Suhim et al., 2023).

The increase in fruit weight observed with organic fertilization and foliar application of GA_3 and tryptophan could be explained by the nutrient-mobilizing role these plant hormones play in fruit development. The Khalal stage marks the physiological maturity of the fruit, after which there is a gradual loss of fruit weight during its transition to the Rutab and Tamr stages (Taain et al., 2013). Fruit weights at different stages have been reported previously for various date palm cultivars. An increase in cluster or bunch weight, together with individual fruit weights, was attributed to higher moisture content across all parts of the total yield (Suhim etal., 2023). Auxins play an important role in facilitating nutrient translocation to the fruit, thereby increasing both its size and weight (Suhim et al., 2023). In addition, the increased fruit set reported in the present study may be due to a combined effect of macro- and micronutrients on cell division and elongation, thereby promoting ovary development and fruit growth (El Hodoairi et al., 1992; Jain, 2017).

Fruit ripening was also evident in the treatment with organic fertilization and spraying of GA_3 and tryptophan. Better metabolic efficiency leads to an increase in dry matter accumulation, enhanced total soluble solids within the fruit that accelerate respiration and energy production, resulting finally in quick ripening of the fruits, hence increasing cluster weight as well as total yield per tree. The number of clusters per tree increased, likely due to the maintenance of cell membrane integrity, especially in chloroplasts, thereby improving photosynthesis and providing metabolites and the energy required for growth and fruit development (Galimba et al., 2019).

The organic fertilization program and foliar sprays of GA_3 and tryptophan effectively improved both quantitative and qualitative characteristics of the ‘Barhi’ date palms. This can be attributed to hormonal balance induced by such treatments, as well as to improved nutrition, reflected in increased fruit set, fruit weight, and cluster weight, accompanied by enhanced ripening, ultimately increasing total yield. Therefore, the results obtained are completely harmonious with earlier findings, which reported that a synergistic interaction between plant growth regulators, together with amendments added to the soil, maximizes the productivity of date palms under arid or semi-arid conditions (Al-Hamoud et al., 2023; El-Kosary et al., 2025).

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Table 6

Effects of Organic Fertilization and Foliar Gibberellin and Tryptophan on Total Yield Weight of 'Barhi' Dates for Two Consecutive Seasons

Organic Fertilizer (F, kg)	GA_3 (G, mg/L)	Tryptophan (T, mg/L)			F×G (2024)	Tryptophan (T, mg/L)			F × G (2025)
		0	50	100		0	50	100	
0	0	23.35	25.51	27.86	25.57	20.74	20.99	21.78	21.17
	200	26.67	28.71	33.72	29.70	22.62	24.58	25.22	24.14
	300	29.09	29.52	32.79	30.47	26.43	28.24	28.94	27.87
15	0	27.55	28.59	29.67	28.61	30.52	32.13	33.31	31.99
	200	30.48	34.41	34.45	33.11	33.56	34.83	35.18	34.52
	300	32.18	34.37	35.34	33.96	36.11	36.26	36.97	36.44
20	0	27.94	30.29	32.14	30.12	36.56	37.00	37.31	36.96
	200	31.87	33.22	36.41	33.83	37.45	37.64	37.93	37.68
	300	31.83	36.07	38.11	35.34	38.28	38.57	38.78	38.54
LSD (0.05)		LSD (F×G×T) = 0.34			LSD (F×G) = 0.19	LSD (F×G×T) = 0.58			LSD (F×G) = 0.17

Factorial Interactions Matrices

T × F	Tryptophan (T, mg/L)			F (2024)	Tryptophan (T, mg/L)			F (2025)
	0	50	100		0	50	100	
F: 0	26.51	29.44	29.79	28.58	23.26	24.60	25.13	24.39
F: 15	30.42	32.12	33.14	31.89	33.44	34.36	35.24	34.32
F: 20	30.54	33.19	35.55	33.10	37.58	37.84	37.76	37.73
T Mean	29.16	31.58	32.83		31.43	32.27	32.74	
LSD (0.05)	LSD (F×T) = 0.03			LSD (F) = 0.02	LSD (F×T) = 0.17			LSD (F) = 0.19

T×G	Tryptophan (T, mg/L)			G (2024)	Tryptophan (T, mg/L)			G (2025)
	0	50	100		0	50	100	
G: 0 mg/L	26.63	27.78	29.89	28.10	29.42	30.14	30.55	30.04
G: 200 mg/L	29.67	33.79	33.18	32.21	31.21	32.35	32.78	32.11
G: 300 mg/L	31.17	33.18	35.41	33.25	33.65	34.30	34.90	34.29
LSD 0.05	LSD (G×T) = 0.19			LSD (G) = 0.11	LSD (G×T) = 0.20			LSD (G) = 0.19

Note. F= organic fertilizer, G= gibberelic acid (GA_3), T= tryptophan.

Conclusions

Our study demonstrates that integrating soil-applied organic fertilizer with foliar bio-stimulants significantly enhances the hormonal profile and yield attributes of date palms under arid conditions. Soil amendment with sheep manure compost exerted the most pronounced influence on the upregulation of endogenous foliar auxins and gibberellins, driving substantial improvements in vegetative growth, fruit weight, fruit size, cluster biomass, and cumulative yield. While individual foliar applications of gibberellic acid (GA_3) and L-tryptophan also enhanced these physiological parameters, their independent efficacy was lower than that of the standalone organic fertilizer treatment. The concurrent application of all three experimental factors at their maximum concentration of organic fertilizer, 20 kg per palm tree, and gibberellins, 300 mg/L, in the presence of tryptophan, 100 mg/L, increased plant growth and overall productivity compared to single-factor inputs. Therefore, agronomic management should focus on this tri-factorial

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integrated approach rather than on isolated inputs, as the combined interactions consistently deliver the most efficient and productive orchard yield. Further studies should be conducted across diverse microclimates and multiple crop cycles to validate the structural stability of these results and broaden their practical applicability in the commercial date palm sector.

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