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EFFECT OF GIBBERELLIC ACID (GA_3) SPRAYING AND DIPPING ON GROWTH, YIELD AND NUTRITIONAL STATUS OF GRAPE (*VITIS VINIFERA* L.) IN TELANGANA INDIA

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ABSTRACT

The present investigation, conducted during 2024-2025 at the Grape Research Station, Rajendranagar and the Fruit Science Laboratory, PGIHS, SKLTSHU, evaluated the influence of gibberellic acid (GA_3) spraying and dipping on the growth, yield and nutritional status of three grape cultivars (Thompson Seedless, K.R. White and Flame Seedless). The experiment was laid out in a Factorial Randomized Block Design with three GA_3 application schedules, forming nine treatment combinations. Significant variation was observed among cultivars, schedules and their interactions. Thompson Seedless exhibited superior growth and yield attributes, including maximum rachis length, berry size and 100-berry weight, while K.R. White recorded the highest berry count and yield per vine. Among the application regimes, Schedule-2 consistently enhanced yield parameters. The interaction effect of Thompson Seedless with Schedule-2 (T_2) resulted in the highest bunch weight, berry weight, yield per vine, indicating optimal responsiveness to GA_3. Nutrient analysis after forward pruning revealed significant variation in nitrogen and potassium levels, with T_2 recording the highest potassium content, while phosphorus remained unaffected. Overall, Schedule-2 proved to be the most effective GA_3 application strategy and Thompson Seedless under Schedule-2 demonstrated the best performance across growth, yield and nutritional parameters. These findings highlight the importance of cultivar-specific GA_3 management for improving grape productivity and fruit quality under Telangana conditions.

***Keywords* :** Gibberellic acid (GA_3), spraying, dipping, rachis length, bunch weight, berry weight, yield attributes, nutrient analysis.

Introduction

Grapes (*Vitis vinifera* L.) are among the earliest domesticated fruit crops and hold significant importance in subtropical horticulture (Venkitasamy *et al.*, 2019). In India, grape cultivation has expanded steadily, with major production concentrated in Maharashtra, Karnataka, Andhra Pradesh and Telangana (Anonymous, APEDA, 2024; Anonymous, NHB, 2023). Among table grape cultivars, Thompson Seedless dominates commercial production due to its export potential, while Flame Seedless is gaining preference in markets demanding coloured grapes (Loay, 2007; Satisha *et al.*, 2021).

Grape quality is largely governed by berry size, cluster structure and biochemical composition, including sugars, acids and phenolic compounds (Conde *et al*., 2007). Grapes are also rich in vitamins, minerals and polyphenols such as resveratrol and flavonoids, which contribute to their antioxidant properties and associated health benefits (Bose, 2021; Singh *et al*., 2023; Arts and Hollman, 2005; Erdman *et al*., 2007; Xia *et al*., 2010; Doshi *et al*., 2015). However, the highly perishable nature of grapes and their sensitivity to biotic and abiotic stresses pose challenges to maintaining quality during handling and storage (Yahia *et al*., 2019).

Plant growth regulators, particularly gibberellic acid (GA_3), play a crucial role in improving berry enlargement, reducing cluster compactness and enhancing fruit quality in seedless cultivars (Korkutal *et al*., 2007; Dimovska *et al*., 2011). GA_3 application through spraying or bunch dipping at critical phenological stages has been widely adopted, though its effectiveness varies with cultivar, timing and environmental conditions (Abu-Zahra, 2013; Marzouk and Kassem, 2011). Given the increasing demand for high-quality export grapes and the climatic conditions of Telangana, optimizing GA_3 use is essential for improving productivity and marketability.

Therefore, the present study was conducted to evaluate the influence of GA_3 spraying and dipping schedules on growth, yield and nutritional status of major grape cultivars, with the goal of developing efficient and cultivar-specific management strategies under Telangana conditions.

Materials and Methods

The experiment was conducted from October 2024 to March 2025 at the Grape Research Station, Rajendranagar, Sri Konda Laxman Telangana Horticultural University, Hyderabad, India. The site is located at 17.87°N, 79.01°E and 542.8 m above sea level, characterized by red sandy loam (Alfisol) soils and a semi-arid tropical climate. The region receives an average annual rainfall of 511 mm, with mean maximum and minimum temperatures of 31.4 °C and 21.6 °C, respectively.

The study was conducted on uniform, eight-year-old vines of Thompson Seedless (C1), K.R. White (C2) and Flame Seedless (C3), spaced at 2.74 m × 1.52 m and trained on the Y-system. The experiment employed a Factorial Randomized Block Design (FRBD) consisting of three cultivars and three GA_3 application schedules, resulting in nine treatment combinations. Each treatment was replicated three times, with four vines per replication.

Gibberellic acid (GA_3) was applied through spraying and bunch dipping at concentrations ranging from 10 to 40 ppm, depending on treatment schedule. Applications were made at key phenological stages including the parrot green stage, 50–80% flowering and berry development stages (3–8 mm berry diameter).

- **Schedule 1:** All applications via spraying
- **Schedule 2:** Combination of spraying and dipping
- **Schedule 3:** Predominantly dipping applications

Nine treatment combinations were evaluated: T_1 (C_1S_1), T_2 (C_1S_2), T_3 (C_1S_3), T_4 (C_2S_1), T_5 (C_2S_2), T_6 (C_2S_3), T_7 (C_3S_1), T_8 (C_3S_2) and T_9 (C_3S_3).

Rachis length was measured in centimeters from the base to the tip using a calibrated scale for each replication. Berry length was recorded as the distance from the base to the tip of individual berries using a digital caliper, while berry diameter was measured at the widest point with the same instrument. The number of berries per bunch was determined by manually counting all berries in each sampled cluster. For 100-berry weight, a random sample of 100 berries collected from five bunches per replication was weighed using an electronic precision balance. Average bunch weight was obtained by weighing five to eight representative bunches per replication at harvest and expressing the mean in grams. Yield per vine was calculated by multiplying the total number of bunches per vine by the average bunch weight and the final value was expressed in kilograms per vine.

The analysis of petiole nutrients after forward pruning involved predigestion of 0.5–1.0 g plant material with concentrated HNO_3, followed by digestion using a diacid or triacid mixture until a clear residue was obtained. The residue was dissolved in 6N HCl, filtered and diluted to 100 ml to prepare the test solution. Nitrogen content was estimated through the Kjeldahl method, which included acid digestion with concentrated H_2SO_4 and a catalyst, followed by steam distillation and titration of the trapped ammonia against standard acid. Phosphorus was determined colorimetrically by reacting an aliquot of the digest with vanadate–molybdate reagent and measuring absorbance at 470 nm. Potassium was estimated using a flame photometer after appropriate dilution of the digest and concentrations were derived from a standard calibration curve.

Statistical Analysis

The observations on berry yield, physical characteristics and nutrient analysis were evaluated statistically using Analysis of Variance (ANOVA) appropriate for a Factorial Randomized Block Design (FRBD), as described by Panse and Sukhatme (1985). Data analysis was performed using OPSTAT software. Treatment effects were assessed through the F-test at the 5% significance level and whenever significant variation was detected, the critical difference (CD) at 5% was computed to facilitate mean comparison.

Results and Discussion

Application of GA_3 significantly enhances vegetative growth in grapes by promoting cell elongation and shoot development. GA_3 treatments improve berry size and cluster compactness, contributing to higher overall yield. Nutrient uptake, particularly of nitrogen, potassium, increases due to improved root activity under GA_3 influence. Overall, GA_3 positively affects both growth parameters and nutritional status, leading to superior quality grapes.

Length of the rachis (cm)

GA_3 applications significantly influenced rachis length across the cultivars Thompson Seedless, K.R. White and Flame Seedless. K.R. White recorded the longest mean rachis length (16.82 cm), on par with Thompson Seedless (16.51 cm), while Flame Seedless showed the shortest (14.90 cm). Among treatment schedules, Schedule-2 produced the maximum rachis length (17.43 cm), followed by Schedule-1 (15.96 cm) and Schedule-3 (14.84 cm). The interaction effect (C × S) was also significant, with T_2 (Thompson Seedless + Schedule-2) showing the highest rachis length (18.77 cm) and the lowest in T_9 (Flame Seedless + Schedule-3) at 13.50 cm.

The increase in rachis length under Schedule-2 can be attributed to GA_3 application at the parrot-green stage, particularly at 20 ppm, which promotes cell elongation and wider panicle spacing. GA_3 improves cell wall plasticity and converts starch to sugars, lowering water potential and enhancing water uptake, resulting in greater cell expansion. These findings agree with earlier reports by Dimovska *et al.* (2014) and Kumar *et al.* (2016).

Berry length (mm)

Berry length was significantly influenced by cultivars, with K.R. White (18.08 mm) recording the highest value, on par with Thompson Seedless (17.94 mm), while Flame Seedless showed the lowest (15.47 mm). Among GA_3 schedules, Schedule-2 produced the longest berries (17.78 mm), followed by Schedule-3 (17.13 mm), with Schedule-1 recording the minimum (16.58 mm). The C × S interaction was significant, with T_2 (Thompson Seedless + Schedule-2) giving the highest berry length (18.65 mm) and T_7 (Flame Seedless + Schedule-1) the lowest (14.66 mm). The increase in berry length is attributed to GA_3-induced cell division and enlargement after fruit set, consistent with earlier reports by Warusavitharana *et al.* (2008) and Kaplan *et al.* (2017).

Berry diameter (mm)

Berry diameter varied significantly among cultivars, with Flame Seedless showing the maximum (17.54 mm), followed by Thompson Seedless (14.87 mm) and K.R. White (14.08 mm). GA_3 schedules also influenced diameter, with Schedule-2 recording the highest (16.21 mm), followed by Schedule-3 (15.42 mm), while Schedule-1 showed the lowest (14.87 mm). The C × S interaction was significant, with T_8 (Flame Seedless + Schedule-2) producing the largest diameter (18.41 mm) and T_4 (K.R. White + Schedule-1) the smallest (13.61 mm). The increase in berry diameter is attributed to GA_3-induced cell division and later cell expansion driven by enhanced water and metabolite uptake, consistent with earlier findings by Richard (2006), Warusavitharana *et al.* (2008), Muhammad *et al*. (2009) and Nampila *et al*. (2010).

Number of berries per bunch

The number of berries per bunch varied significantly among cultivars, with K.R. White (132.08) recording the highest, on par with Flame Seedless (131.47), while Thompson Seedless showed the lowest (126.04). GA_3 scheduling also influenced berry number, with Schedule-2 (133.72) and Schedule-3 (130.97) performing better than Schedule-1 (124.89). The C × S interaction was non-significant. The increase in berry number is attributed to pre-bloom GA_3 application, which promotes inflorescence elongation and bud fertility, enhancing berry set. These results agree with earlier findings by Dimovska *et al.* (2011) and Dass and Randhawa (1972).

100 berry weight (g)

The 100-berry weight differed significantly among cultivars, with Thompson Seedless showing the highest weight (327.78 g), followed by K.R. White (288.56 g), while Flame Seedless recorded the lowest (257.67 g). GA_3 scheduling also influenced berry weight, with Schedule-2 producing the maximum (303.00 g) and Schedule-3 the minimum (279.56 g). The C × S interaction was significant, with T_2

(Thompson Seedless + Schedule-2) giving the highest weight (341.33 g) and T_9 (Flame Seedless + Schedule-3) the lowest (247.67 g). The increase in berry weight is attributed to GA_3-stimulated cell division, cell expansion, improved assimilate translocation and enhanced water uptake, aligning with the findings of Kim *et al.* (2008) and Kaplan *et al.* (2017).

Average bunch weight (g)

Average bunch weight varied significantly among cultivars, with K.R. White (406.36 g) recording the highest, on par with Thompson Seedless (393.61 g), while Flame Seedless showed the lowest (332.72 g). GA_3 scheduling also influenced bunch weight, with Schedule-2 producing the highest (399.33 g), followed by Schedule-3 (370.94 g) and Schedule-1 the lowest (362.42 g). The C × S interaction was significant, with T_2 (Thompson Seedless + Schedule-2) recording the maximum bunch weight (422.17 g) and T_7 (Flame Seedless + Schedule-1) the minimum (309.25 g). The increase in bunch weight is attributed to GA_3-enhanced rachis elongation, larger clusters and higher berry numbers, supported by efficient source-sink relationships and favorable growth conditions. These results align with findings of Kiran *et al.* (2018) and Nanjappanavar (2024).

Yield per vine (kg/vine)

Vine yield differed significantly among cultivars, with K.R. White (16.25 kg/vine) showing the highest yield, on par with Thompson Seedless (15.74 kg/vine), while Flame Seedless recorded the lowest (13.31 kg/vine). GA_3 scheduling also influenced yield, with Schedule-2 producing the maximum (15.97 kg/vine), followed by Schedule-3 (14.84 kg/vine) and Schedule-1 (14.50 kg/vine). The C × S interaction was significant, with T_2 (Thompson Seedless + Schedule-2) giving the highest yield (16.89 kg/vine) and T_7 (Flame Seedless + Schedule-1) the lowest (12.37 kg/vine). Yield improvement with GA_3 is attributed to increases in cluster weight, berry size and berry weight, along with reduced bunch compactness, as noted by Poudel *et al.* (2022). Enhanced cluster morphology, efficient assimilate production and improved physiological activity-supported by GA_3 and in some cases, brassinosteroids-contribute to better yield, consistent with Kumar *et al.* (2016), Warusavitharana *et al.* (2008), and Khalil (2020).

Nitrogen content in petiole (%)

Petiole nitrogen content did not vary significantly among cultivars. However, GA_3 scheduling had a significant effect, with Schedule-1 recording the highest nitrogen content (0.89%), on par with Schedule-2 (0.85%), while Schedule-3 showed the lowest (0.76%). The interaction effect (C × S) on petiole nitrogen content was non-significant.

Phosphorus content in petiole (%)

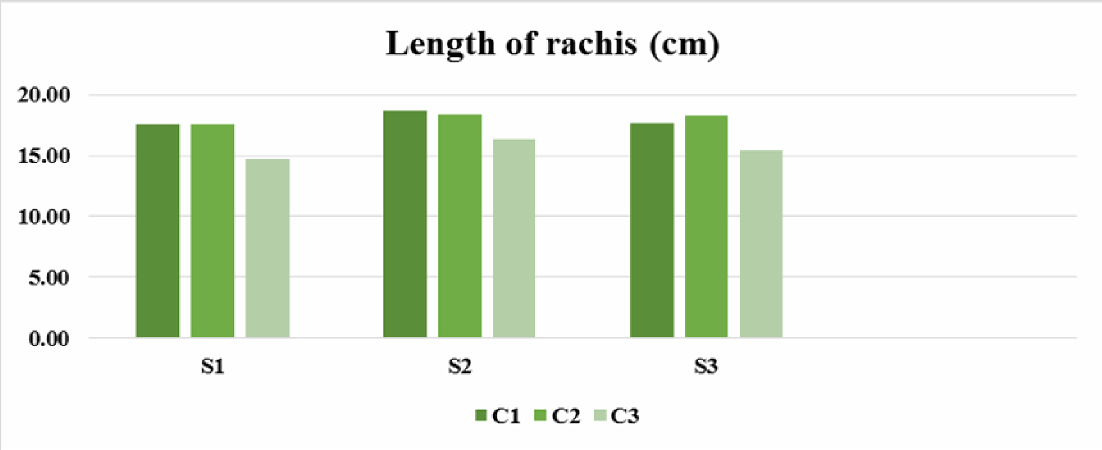
Phosphorus content in the petiole was not significantly influenced by cultivar, GA_3 application schedule, or their interaction. This indicates that phosphorus uptake and translocation remained unaffected by either genetic differences or GA_3 treatments under the conditions of this study. These results suggest that petiole phosphorus levels may be regulated independently of external gibberellin applications. Similar observations were reported by Bostrack *et al.* (1964), Strydom (2014) and Ali *et al.* (2018).

Potassium content in petiole (%)

Petiole potassium content varied significantly among cultivars, with K.R. White showing the highest value (1.19%), followed by Thompson Seedless (1.15%), while Flame Seedless recorded the lowest (1.09%). GA_3 scheduling also had a significant effect, with Schedule-2 producing the highest potassium content (1.29%), followed by Schedule-1 (1.08%) and Schedule-3 (1.06%). The C × S interaction was significant, with T_2 (Thompson Seedless + Schedule-2) recording the highest potassium level (1.35%) and T_7 (Flame Seedless + Schedule-1) the lowest (0.98%). These findings align with those of Stopinska (1986) and Nabil *et al.* (2023).

Table 1 : Effect of gibberellic acid (GA_3) spraying and dipping on length of the rachis (cm), berry length (mm), berry diameter (mm), in grape cv. Thomson Seedless, K.R. White, Flame Seedless.

	Length of the rachis (cm)				Berry length (mm)				Berry diameter (mm)			
	C1	**C2**	**C3**	**Mean**	**C1**	**C2**	**C3**	**Mean**	**C1**	**C2**	**C3**	**Mean**
S1	16.33^{b}	16.86^{b}	14.68^{c}	15.96^{b}	17.55^{b}	17.53^{b}	14.66^{e}	16.58^{c}	14.33^{e}	13.61^{f}	16.66^{c}	14.87^{c}
S2	18.77^{a}	17.02^{b}	16.51^{b}	17.43^{a}	18.65^{a}	18.40^{a}	16.29^{c}	17.78^{a}	15.71^{d}	14.52^{e}	18.41^{a}	16.21^{a}
S3	14.43^{cd}	16.57^{b}	13.50^{d}	14.84^{c}	17.64^{b}	18.30^{a}	15.46^{d}	17.13^{b}	14.57^{e}	14.12^{e}	17.56^{b}	15.42^{b}
Mean	16.51^{a}	16.82^{a}	14.90^{b}		17.94^{a}	18.08^{a}	15.47^{b}		14.87^{b}	14.08^{b}	17.54^{a}	
	C	**S**	**C x S**		**C**	**S**	**C x S**		**C**	**S**	**C x S**	
S.Em	0.172	0.172	0.299		0.088	0.088	0.152		0.084	0.084	0.145	
CD (5%)	0.517	0.517	0.895		0.262	0.262	0.455		0.251	0.251	0.435	



Cultivars : C1- Thompson seedless C2- K.R. White C3- Flame seedless
Schedules : S1- Schedule 1 S2- Schedule 2 S3- Schedule 3

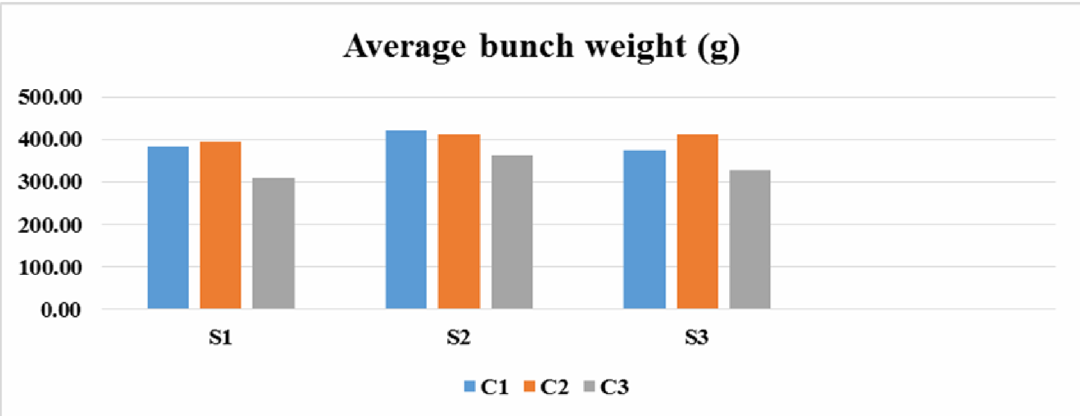
Fig. 1: Effect of gibberellic acid (GA_3) spraying and dipping on length of the rachis (cm)

Table: 2 Effect of gibberellic acid (GA_3) spraying and dipping number of berries per bunch, 100 berry weight (g) in grape cv. Thomson Seedless, K.R. White, Flame Seedless.

	Number of berries per bunch				100 berry weight (g)			
	C1	**C2**	**C3**	**Mean**	**C1**	**C2**	**C3**	**Mean**
S1	123.22	127.61	123.84	124.89^{b}	328.67^{b}	288.00^{e}	257.67^{h}	291.44^{b}
S2	129.37	136.03	135.77	133.72^{a}	341.33^{a}	300.00^{d}	267.67^{g}	303.00^{a}
S3	125.53	132.61	134.78	130.97^{a}	313.33^{c}	277.67^{f}	247.67^{i}	279.56^{c}
Mean	126.04^{b}	132.08^{a}	131.47^{a}		327.78^{a}	288.56^{b}	257.67^{c}	
	C	**S**	**C x S**		**C**	**S**	**C x S**	
S.Em	1.003	1.003	1.738		0.669	0.669	1.159	
CD (5%)	3.008	3.008	NS		2.006	2.006	3.474	

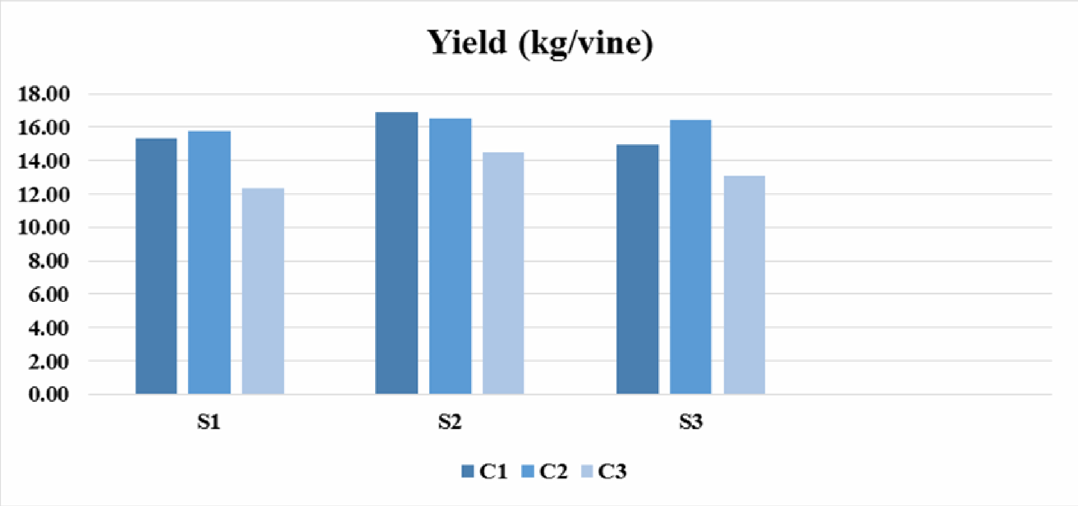
Table 3 : Effect of gibberellic acid (GA_3) spraying and dipping average bunch weight (g), yield (kg) in grape cv. Thomson Seedless, K.R. White, Flame Seedless.

	Average bunch weight (g)				Yield (kg/vine)			
	C1	**C2**	**C3**	**Mean**	**C1**	**C2**	**C3**	**Mean**
S1	383.92^{cd}	394.08^{bc}	309.25^{e}	362.42^{b}	15.36^{cd}	15.76^{bc}	12.37^{e}	14.50^{b}
S2	422.17^{a}	413.25^{ab}	362.58^{d}	399.33^{a}	16.89^{a}	16.53^{ab}	14.50^{d}	15.97^{a}
S3	374.75^{cd}	411.75^{ab}	326.33^{e}	370.94^{b}	14.99^{cd}	16.47^{ab}	13.05^{e}	14.84^{b}
Mean	393.61^{a}	406.36^{a}	332.72^{b}		15.74^{a}	16.25^{a}	13.31^{b}	
	C	**S**	**C x S**		**C**	**S**	**C x S**	
S.Em	4.492	4.492	7.781		0.180	0.180	0.311	
CD (5%)	13.468	13.468	23.327		0.539	0.539	0.933	



Cultivars : C1- Thompson seedless C2- K.R. White C3- Flame seedless
Schedules : S1- Schedule 1 S2- Schedule 2 S3- Schedule 3

Fig. 2: Effect of gibberellic acid (GA_3) spraying and dipping on average bunch weight (g)

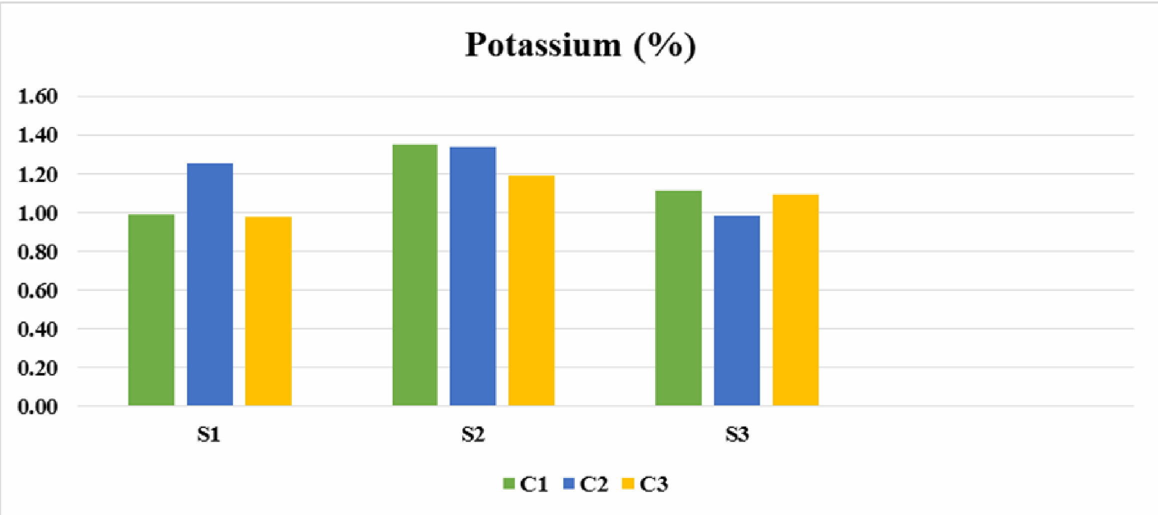


Cultivars : C1- Thompson seedless C2- K.R. White C3- Flame seedless
Schedules : S1- Schedule 1 S2- Schedule 2 S3- Schedule 3

Fig 3: Effect of gibberellic acid (GA_3) spraying and dipping on yield (kg/vine)

Table 4: Effect of gibberellic acid (GA_3) spraying and dipping on nitrogen, phosphorus, potassium (%) in petioles of grape cv. Thomson Seedless, K.R. White, Flame Seedless.

	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
S1	0.87	0.87	0.92	0.89[a]	0.20	0.17	0.22	0.19	0.99[f]	1.26[b]	0.98[f]	1.08[b]
S2	0.83	0.87	0.84	0.85[ab]	0.19	0.22	0.18	0.20	1.35[a]	1.34[a]	1.19[c]	1.29[a]
S3	0.78	0.75	0.76	0.76[b]	0.19	0.20	0.23	0.21	1.11[d]	0.99[f]	1.09[e]	1.06[b]
Mean	0.82	0.83	0.84		0.19	0.19	0.21		1.15[b]	1.19[a]	1.09[c]	
	C	S	C x S		C	S	C x S		C	S	C x S	
S.Em	0.032	0.032	0.056		0.013	0.013	0.023		0.002	0.002	0.004	
CD (5%)	NS	0.97	NS		NS	NS	NS		0.007	0.007	0.012	



Cultivars : C1- Thompson seedless C2- K.R. White C3- Flame seedless
Schedules : S1- Schedule 1 S2- Schedule 2 S3- Schedule 3

Fig. 4: Effect of gibberellic acid (GA_3) spraying and dipping on potassium (%)

Conclusion

The study demonstrated that GA_3 application significantly enhanced key growth, yield and nutrient attributes in the grape cultivars Thompson Seedless, K.R. White and Flame Seedless. Among the cultivars, K.R. White consistently performed best, recording superior rachis length, berry size, bunch weight and yield. Schedule-2 of GA_3 application emerged as the most effective, resulting in maximum berry dimensions, bunch weight, vine yield and higher potassium and nitrogen accumulation in petioles. GA_3-induced improvements were primarily attributed to enhanced cell division, cell enlargement, efficient assimilate translocation and better source-sink balance, ultimately improving cluster compactness, berry development and overall productivity. Nutrient analysis indicated significant effects on potassium and nitrogen but not on phosphorus, suggesting selective nutrient responsiveness to GA_3. Overall, the combined influence of cultivar characteristics and optimal GA_3 scheduling, particularly Schedule-2, proved most beneficial for improving growth, yield performance and nutrient status in grapevines.

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