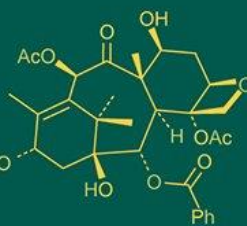
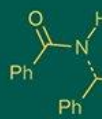
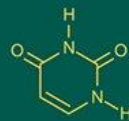
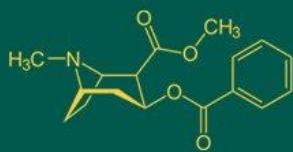


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Growth and physiological performance of grape cv. ManikChaman as affected by berry thinning, plant growth regulators and micronutrients

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Abstract

The seedless grape variety ManikChaman is an important cultivar in India, valued for its bold berry size and superior fruit quality, making it suitable for both domestic and export market. Despite its growing popularity, fruit quality from this region remains suboptimal. To address this issue, a study was conducted to examine the influence of berry thinning and the application of growth regulators and micronutrients on growth, yield and quality of ManikChaman grapes. The experiment included two factors: varying levels of berry thinning treatments and different treatment combinations involving plant growth regulators and micronutrients. Findings revealed that berry thinning was negatively correlated with vegetative growth and physiological characters. The growth regulators and micronutrients combination showed positive response. The most effective treatment was combined application of GA₃ (150 ppm), a micronutrient mixture consisting of ZnSO₄ at 3 g/L, FeSO₄ at 2 g/L, MnSO₄ at 2 g/L and boric acid at 1 g/L, along with CPPU (2 ppm) and brassinosteroids (0.5 and 1.0 ppm) at different growth stages.

Keywords: Grapes, berry thinning, growth regulators and micronutrients

Introduction

Grape (*Vitis vinifera* L.) is a major fruit crop grown in India, valued for its rich content of vitamins, minerals and phytochemicals with antioxidant and kidney-supporting potential. In India, the crop is predominantly grown under subtropical and tropical conditions, with cultivation reported about 1.75 lakh ha and production around 31.25 lakh tonnes with a productivity of 21.27 t/ha (Anon., 2024) [1]. India leads globally in grape productivity and ranks seventh in table grape exports, shipping 3.43 lakh tonnes valued for Rs. 3,460.70 crores, mainly to the EU, Netherlands, Russia, UK, Bangladesh and Germany. Approximately 75-80 percent of the produce is consumed as fresh, around 17-20 percent is converted into raisins and only about 1-2 percent is processed into juice or wine. Agronomic research also emphasizes that, despite being a temperate crop, grapes have acclimatized successfully under tropical conditions and that varietal improvement, canopy management and nutrient management play a vital role in sustaining yield and quality. Recent Indian investigations further suggest that foliar application of micronutrients and growth regulators significantly influence berry quality and productivity, reinforcing the need for precise crop management in India's evolving viticulture sector.

Grape cultivation is primarily concentrated in Maharashtra (67%) and Karnataka (28%). In Karnataka Vijayapura, Bagalkot, Belagavi, Koppal, Gadag and Raichur are the major grape growing districts. The quality of table grapes is typically evaluated based on bunch size, berry uniformity, symmetry and the distinctive color, flavor and texture of the variety. Grape quality is largely influenced by factors such as soil management, irrigation, fertilization, pruning and climate. Additionally, various other vineyard practices including bunch thinning, defoliation, application of growth regulators, girdling, micronutrient application and canopy management play a significant role in improving berry quality. Its production is driven by advanced key agronomic techniques such as berry thinning and the use of growth regulators like GA₃ (Gibberellic Acid), CPPU (Forchlorfenuron) and brassinosteroids, which play a crucial role in enhancing fruit quality.

Materials and Methods

The present investigation was conducted during 2023-25 at the Main Horticultural Research and Extension Centre, University of Horticultural Sciences, Bagalkot. The treatments were applied to eight-year-old grapevines grafted onto Dogridge rootstock and trained on a Y trellis system. The factorial randomized block design (FRBD) was used in this experiment with two factors: the first factor consisting of three treatments and the second factor consisting of four

treatments. Each treatment was replicated three times with five plants per treatments per replication were used. I Factor includes different berry thinning treatments such as 120 berries per bunch, 150 berries per bunch and control. The berry thinning was done at 3-4 mm berry size. Factor II includes different doses of GA₃ along with same micronutrients and growth regulators such as CPPU and brassinosteroids.

Module	GA ₃ Dose	Micronutrients (foliar spray per L)	CPPU	BRs	Application Stages
M ₁	GA ₃ 100 ppm	ZnSO ₄ 3 g + FeSO ₄ 2 g + MnSO ₄ 2 g + Boric Acid 1 g	2 ppm	0.5 & 1.0 ppm	10 ppm @ Parrot green stage (21 DAFP) 15 ppm @ Pre-bloom stage (23-25 DAFP) 40 ppm GA ₃ + micronutrients + CPPU + BR @ 3-4 mm berry size 35 ppm GA ₃ + micronutrients + CPPU + BR @ 6-7 mm berry size
M ₂	GA ₃ 120 ppm	ZnSO ₄ 3 g + FeSO ₄ 2 g + MnSO ₄ 2 g + Boric Acid 1 g	2 ppm	0.5 & 1.0 ppm	10 ppm @ Parrot green stage 15 ppm @ Pre-bloom stage 20 ppm @ 50% flowering stage 40 ppm GA ₃ + micronutrients + CPPU + BR @ 3-4 mm berry size 35 ppm GA ₃ + micronutrients + CPPU + BR @ 6-7 mm berry size
M ₃	GA ₃ 150 ppm	ZnSO ₄ 3 g + FeSO ₄ 2 g + MnSO ₄ 2 g + Boric Acid 1 g	2 ppm	0.5 & 1.0 ppm	10 ppm @ Parrot green stage 15 ppm @ Pre-bloom stage 20 ppm @ Pre-bloom stage (28-32 DAFP) 35 ppm @ 50% flowering stage 30 ppm GA ₃ + micronutrients + CPPU + BR @ 3-4 mm berry size 40 ppm GA ₃ + micronutrients + CPPU + BR @ 6-7 mm berry size
M ₄	GA ₃ 100 ppm				10 ppm @ Parrot green stage 15 ppm @ Pre-bloom stage 40 ppm GA ₃ dip @ 3-4 mm berry size 35 ppm GA ₃ dip @ 6-7 mm berry size

Observations on growth parameters were recorded by selecting five random canes per vine in each replication. The internodal length of the fruiting shoot was measured between the fourth and fifth nodes from the base using a 30 cm scale and expressed in centimeters (cm). Similarly, internodal girth was measured using verniercalipers at the same node positions and expressed in millimeters (mm). These measurements were recorded at 45 and 90 days after forward pruning (DAFP). Leaf chlorophyll content was assessed using a SPAD 502 chlorophyll meter, a non-destructive tool that measures leaf absorbance at two specific wavelengths. The fifth fully expanded leaf from the base of five physiologically matured leaves per vine was selected for SPAD measurements and the mean value was expressed as SPAD Chlorophyll Meter Reading. The Leaf Area Index (LAI) was measured using non-destructive method, a LAI-2200C Plant Canopy Analyzer, with the sensor calibrated prior to data collection. An above-canopy

reading was first taken in an open area to assess incident light, followed by four below-canopy readings at ground level around each plant, avoiding direct sunlight. The instrument automatically calculated LAI based on light attenuation and all readings were taken at a consistent time of day to minimize variability. Leaf area was initially measured using the linear method and expressed in square centimeters (cm²). These same leaves were then oven-dried at 60 °C until a constant weight was obtained and their dry weight was recorded in milligrams (mg). Specific Leaf Area (SLA) was calculated by dividing the leaf area by its corresponding dry weight and expressed in cm²/mg using the formula:

$$SLA = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf dry weight (mg)}}$$

Table 1: Internodal length (cm) of fruiting shoot at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Internodal length (cm) of fruiting shoots at 45 DAFP			Internodal length (cm) of fruiting shoots at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	5.72	5.68	5.70	5.91	6.18	6.05
B ₂ -150 berries/bunch	5.59	5.61	5.60	5.78	6.15	5.93
B ₃ -Control	5.51	5.45	5.48	5.73	5.86	5.80
S.Em ±	0.06	0.05	0.05	0.11	0.12	0.09
CD at 5%	NS	NS	NS	NS	NS	NS
Module (M)						
M ₁ -Module 1	5.47	5.57	5.52	5.58	5.90	5.70
M ₂ -Module 2	5.74	5.65	5.70	5.94	6.08	6.01
M ₃ -Module 3	5.78	5.82	5.80	6.13	6.53	6.33
M ₄ -Module 4	5.43	5.39	5.41	5.59	5.74	5.66
S.Em ±	0.07	0.06	0.05	0.13	0.12	0.11
CD at 5%	0.21	0.18	0.17	0.37	0.36	0.32
Interactions (B × M)						
B ₁ M ₁	5.56	5.53	5.55	5.81	5.97	5.89
B ₁ M ₂	5.88	5.76	5.82	5.95	6.16	6.06
B ₁ M ₃	5.92	5.94	5.93	6.43	6.74	6.58
B ₁ M ₄	5.50	5.52	5.51	5.75	5.84	5.80
B ₂ M ₁	5.39	5.31	5.35	5.53	6.03	5.78
B ₂ M ₂	5.71	5.60	5.65	5.89	6.30	6.10
B ₂ M ₃	5.79	5.80	5.80	5.96	6.50	6.23
B ₂ M ₄	5.50	5.51	5.50	5.58	5.75	5.62
B ₃ M ₁	5.35	5.38	5.36	5.44	5.69	5.57
B ₃ M ₂	5.64	5.59	5.61	5.97	5.79	5.88
B ₃ M ₃	5.65	5.72	5.69	6.01	6.34	6.17
B ₃ M ₄	5.41	5.70	5.56	5.50	5.63	5.57
S.Em ±	0.12	0.11	0.10	0.22	0.21	0.19
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1 ppm)
M ₃ -Module 3:	GA ₃ at150 ppm + micronutrients spray(ZnSO ₄ at3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at100 ppm

Table 2: Internodal girth (mm) of fruiting shoot at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Internodal girth (mm) of fruiting shoots at 45 DAFP			Internodal girth (mm) of fruiting shoots at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	6.26	6.31	6.28	6.39	6.55	6.47
B ₂ -150 berries/bunch	6.16	6.27	6.21	6.22	6.44	6.33
B ₃ -Control	6.06	5.99	6.02	6.20	6.25	6.22
S.Em ±	0.07	0.11	0.09	0.09	0.07	0.08
CD at 5%	NS	NS	NS	NS	NS	NS
Module (M)						
M ₁ -Module 1	6.07	5.95	6.01	6.16	6.23	6.19
M ₂ -Module 2	6.24	6.11	6.17	6.39	6.61	6.50
M ₃ -Module 3	6.42	6.51	6.46	6.59	6.71	6.61
M ₄ -Module 4	5.89	5.82	5.85	5.94	5.98	5.96
S.Em ±	0.08	0.14	0.11	0.11	0.08	0.11
CD at 5%	0.24	0.39	0.34	0.31	0.25	0.28
Interactions (B × M)						
B ₁ M ₁	6.28	6.06	6.17	6.03	6.18	6.10
B ₁ M ₂	6.20	6.07	6.13	6.64	6.67	6.65
B ₁ M ₃	6.54	6.52	6.53	6.76	6.80	6.78
B ₁ M ₄	6.01	6.04	6.02	6.14	6.11	6.12
B ₂ M ₁	5.95	5.54	5.74	5.96	6.14	6.05
B ₂ M ₂	6.18	5.86	6.02	6.86	6.36	6.61
B ₂ M ₃	6.29	6.36	6.32	6.67	6.46	6.56
B ₂ M ₄	5.75	5.47	5.61	5.87	5.86	5.86
B ₃ M ₁	5.97	6.24	6.10	6.10	6.37	6.23
B ₃ M ₂	6.34	6.41	6.37	6.26	6.80	6.53
B ₃ M ₃	6.44	6.65	6.54	6.71	7.08	6.90
B ₃ M ₄	5.90	5.96	5.93	5.82	5.97	5.90
S.Em ±	0.14	0.23	0.19	0.18	0.15	0.16
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at 100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at 120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1 ppm)
M ₃ -Module 3:	GA ₃ at 150 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at 100 ppm

Table 3: Chlorophyll content (SPAD values) at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Chlorophyll content (SPAD values) at 45 DAFP			Chlorophyll content (SPAD values) at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	36.13	37.81	36.97	39.78	41.14	40.46
B ₂ -150 berries/bunch	35.84	36.69	36.27	39.17	39.87	39.52
B ₃ -Control	35.00	36.15	35.58	39.06	39.72	39.39
S.Em ±	0.50	0.56	0.44	0.48	0.53	0.34
CD at 5%	NS	NS	NS	NS	NS	NS
Module (M)						
M ₁ -Module 1	34.59	36.39	35.49	38.57	39.45	39.01
M ₂ -Module 2	36.15	37.75	36.95	39.96	40.70	40.33
M ₃ -Module 3	37.78	37.96	37.87	40.44	41.78	41.11
M ₄ -Module 4	34.13	35.44	34.78	38.36	39.04	38.70
S.Em ±	0.58	0.65	0.51	0.56	0.61	0.40
CD at 5%	1.71	1.91	1.50	1.63	1.79	1.17
Interactions (B × M)						
B ₁ M ₁	35.12	37.28	36.20	38.85	39.65	39.25
B ₁ M ₂	36.54	38.20	37.37	39.93	41.46	40.69
B ₁ M ₃	39.01	38.78	38.90	41.01	43.01	42.01
B ₁ M ₄	33.88	36.98	35.43	39.32	40.42	39.87
B ₂ M ₁	35.05	36.21	35.63	37.96	38.87	38.41
B ₂ M ₂	36.06	37.34	36.70	40.57	40.00	40.28
B ₂ M ₃	36.50	38.35	37.42	40.31	41.47	40.89
B ₂ M ₄	35.76	34.87	35.32	37.83	39.13	38.48
B ₃ M ₁	33.60	35.69	34.64	38.27	38.59	38.43
B ₃ M ₂	35.85	37.71	36.78	39.40	40.63	40.01
B ₃ M ₃	37.81	36.76	37.29	40.01	40.85	40.43
B ₃ M ₄	32.75	34.46	33.60	38.57	38.80	38.68
S.Em ±	1.01	1.13	0.89	0.97	1.06	0.69
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1.0 ppm)
M ₃ -Module 3:	GA ₃ at150 ppm + micronutrients spray(ZnSO ₄ at3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at100 ppm

Table 3: Chlorophyll content (SPAD values) at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Chlorophyll content (SPAD values) at 45 DAFP			Chlorophyll content (SPAD values) at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	36.13	37.81	36.97	39.78	41.14	40.46
B ₂ -150 berries/bunch	35.84	36.69	36.27	39.17	39.87	39.52
B ₃ -Control	35.00	36.15	35.58	39.06	39.72	39.39
S.Em ±	0.50	0.56	0.44	0.48	0.53	0.34
CD at 5%	NS	NS	NS	NS	NS	NS
Module (M)						
M ₁ -Module 1	34.59	36.39	35.49	38.57	39.45	39.01
M ₂ -Module 2	36.15	37.75	36.95	39.96	40.70	40.33
M ₃ -Module 3	37.78	37.96	37.87	40.44	41.78	41.11
M ₄ -Module 4	34.13	35.44	34.78	38.36	39.04	38.70
S.Em ±	0.58	0.65	0.51	0.56	0.61	0.40
CD at 5%	1.71	1.91	1.50	1.63	1.79	1.17
Interactions (B × M)						
B ₁ M ₁	35.12	37.28	36.20	38.85	39.65	39.25
B ₁ M ₂	36.54	38.20	37.37	39.93	41.46	40.69
B ₁ M ₃	39.01	38.78	38.90	41.01	43.01	42.01
B ₁ M ₄	33.88	36.98	35.43	39.32	40.42	39.87
B ₂ M ₁	35.05	36.21	35.63	37.96	38.87	38.41
B ₂ M ₂	36.06	37.34	36.70	40.57	40.00	40.28
B ₂ M ₃	36.50	38.35	37.42	40.31	41.47	40.89
B ₂ M ₄	35.76	34.87	35.32	37.83	39.13	38.48
B ₃ M ₁	33.60	35.69	34.64	38.27	38.59	38.43
B ₃ M ₂	35.85	37.71	36.78	39.40	40.63	40.01
B ₃ M ₃	37.81	36.76	37.29	40.01	40.85	40.43
B ₃ M ₄	32.75	34.46	33.60	38.57	38.80	38.68
S.Em ±	1.01	1.13	0.89	0.97	1.06	0.69
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at 100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at 120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1.0 ppm)
M ₃ -Module 3:	GA ₃ at 150 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at 100 ppm

Table 4: Leaf area index (LAI) at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Leaf area index at 45 DAFP			Leaf area index at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	1.88	2.17	2.02	3.31	3.26	3.28
B ₂ -150 berries/bunch	1.79	2.02	1.91	3.29	3.18	3.24
B ₃ -Control	1.73	1.91	1.82	3.14	3.04	3.09
S.Em ±	0.05	0.07	0.04	0.13	0.06	0.07
CD at 5%	NS	NS	NS	NS	NS	NS
Module (M)						
M ₁ -Module 1	1.72	1.93	1.82	2.87	2.92	2.89
M ₂ -Module 2	1.81	2.04	1.93	3.47	3.36	3.41
M ₃ -Module 3	1.99	2.26	2.12	3.45	3.27	3.36
M ₄ -Module 4	1.69	1.91	1.80	3.00	2.89	2.95
S.Em ±	0.05	0.08	0.05	0.15	0.07	0.08
CD at 5%	0.14	0.24	0.13	0.45	0.21	0.24
Interactions (B × M)						
B ₁ M ₁	1.73	2.10	1.91	3.21	3.28	3.25
B ₁ M ₂	1.85	2.13	1.99	3.25	3.31	3.28
B ₁ M ₃	2.11	2.29	2.20	3.44	3.34	3.39
B ₁ M ₄	1.82	2.15	1.99	3.35	3.08	3.22
B ₂ M ₁	1.70	1.89	1.79	2.93	2.70	2.81
B ₂ M ₂	1.79	2.07	1.93	3.55	3.48	3.52
B ₂ M ₃	2.06	2.26	2.16	3.68	3.51	3.59
B ₂ M ₄	1.63	1.86	1.74	2.80	2.87	2.83
B ₃ M ₁	1.73	1.80	1.76	2.47	2.79	2.63
B ₃ M ₂	1.79	1.92	1.86	3.60	3.30	3.45
B ₃ M ₃	1.80	2.21	2.01	3.63	3.35	3.49
B ₃ M ₄	1.61	1.71	1.66	2.86	2.71	2.79
S.Em ±	0.08	0.14	0.08	0.26	0.13	0.14
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1.0 ppm)
M ₃ -Module 3:	GA ₃ at150 ppm + micronutrients spray(ZnSO ₄ at3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at100 ppm

Table 5: Specific leaf area (SLA) at 45 and 90 days after forward pruning as influenced by berry thinning, foliar application of growth regulators and micronutrients in grapes cv.ManikChaman

Treatment	Specific leaf area (cm ² /g) at 45 DAFP			Specific leaf area at (cm ² /g) at 90 DAFP		
	2024	2025	Pooled	2024	2025	Pooled
Berry thinning (B)						
B ₁ -120 berries/bunch	137.03	145.53	141.28	151.62	160.12	155.87
B ₂ -150 berries/bunch	139.69	146.49	142.59	164.66	174.46	169.56
B ₃ -Control	141.80	153.80	147.80	165.06	175.06	171.06
S.Em ±	5.65	5.60	5.64	4.65	4.26	4.45
CD at 5%	NS	NS	NS	13.65	NS	NS
Module (M)						
M ₁ -Module 1	140.76	150.86	145.81	165.31	175.41	170.36
M ₂ -Module 2	138.01	148.11	143.06	155.75	165.85	160.80
M ₃ -Module 3	121.10	131.20	126.15	148.90	159.00	153.95
M ₄ -Module 4	154.16	164.26	159.21	171.82	181.92	176.87
S.Em ±	6.51	6.48	6.50	5.30	5.37	5.33
CD at 5%	19.09	18.09	18.09	15.76	14.76	15.06
Interactions (B × M)						
B ₁ M ₁	139.41	147.91	143.66	165.50	174.00	169.75
B ₁ M ₂	135.17	143.67	139.42	143.38	151.88	147.63
B ₁ M ₃	116.69	125.19	120.94	129.11	137.61	133.36
B ₁ M ₄	156.87	165.37	161.12	168.51	177.01	172.76
B ₂ M ₁	139.74	149.54	144.64	166.31	176.11	171.21
B ₂ M ₂	143.83	153.63	148.73	164.04	173.84	168.94
B ₂ M ₃	113.91	123.71	118.81	157.66	167.46	162.56
B ₂ M ₄	149.29	159.09	154.19	170.62	180.42	175.52
B ₃ M ₁	143.14	155.14	149.14	164.13	176.13	170.13
B ₃ M ₂	135.03	147.03	141.03	159.84	171.84	165.84
B ₃ M ₃	132.70	144.70	138.70	159.93	171.93	165.93
B ₃ M ₄	156.32	168.32	162.32	176.33	188.33	182.33
S.Em ±	11.27	12.50	11.20	9.31	11.31	10.31
CD at 5%	NS	NS	NS	NS	NS	NS

NS :Non significant

DAFP: Days after forward pruning

M ₁ -Module 1:	GA ₃ at100 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₂ -Module 2:	GA ₃ at120 ppm + micronutrients spray (ZnSO ₄ at 3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BR (0.5 and 1 ppm)
M ₃ -Module 3:	GA ₃ at150 ppm + micronutrients spray(ZnSO ₄ at3 g/L + FeSO ₄ at 2 g/L + MnSO ₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm)
M ₄ -Module 4:	GA ₃ at100 ppm

Results and Discussion

The pooled data of berry thinning treatments revealed a non-significant difference with respect to all vegetative parameters on both stages, because it primarily affects fruit load and quality rather than vegetative growth. Leaf development and structure are largely established by these stages, resulting in minimal response to berry thinning. The module treatments showed a significant difference in the internodal length and girth of fruiting shoots at 45 and 90 DAFP (Days after forward pruning). Among the module treatments, Module 3 recorded the highest internodal length (5.80 cm at 45 DAFP and 6.33 cm at 90 DAFP) and girth (6.46 mm at 45 DAFP and 6.71 mm at 90 DAFP) of fruiting shoot, which was at par with Module 2 (internodal length :5.70 and 6.01 cm; internodal girth:6.17 mm and 6.50 mm). The lowest internodal length (5.41 and 5.66 cm) and girth (5.85 and 5.96 mm) of fruiting shoot was observed in Module 4 at same intervals. In this study, the increase in internodal length and girth was due to the higher levels of gibberellins (particularly additional application at prebloom stage), CPPU, brassinosteroids and micronutrients. This response is likely due to enhanced cell division and elongation triggered by gibberellic acid, which loosen the

cell wall by activating the modify enzymes such as expansin and cellulases (Richard, 2006) [5]. Brassinosteroids and CPPU also support stem elongation by regulating cell growth and boosting carbohydrate availability through the up regulation of extracellular invertase activity. The present results are in confirmation with the findings of Bhat *et al.* (2011) [3]. Manganese plays a vital role in nitrogen metabolism by activating enzymes responsible for nitrate reduction and amino acid synthesis. This, in turn, enhances protein and chlorophyll formation, leading to improved vegetative growth of the plant. Similar observations were reported by Shah *et al.* (2016) [6] in Flame Seedless.

The pooled data of module treatments showed a significant effect on chlorophyll content and LAI at both stages (Table 3 & 4). Among the module treatments, Module 3 recorded the highest chlorophyll content (37.87 and 41.11 SPAD values) and LAI ((2.12 and 3.42) followed by Module 2 (chlorophyll content: 36.95 and 40.33 SPAD values & LAI: 1.93 and 3.36), while the lowest SPAD values (34.78 and 38.70 SPAD values) and LAI (1.80 and 2.95) were observed in Module 4 at 45 and 90 DAFP, respectively. In the current study, higher amount of gibberellic acid, CPPU and brassinosteroids in combination with micronutrients

enhanced the chlorophyll content and LAI. This effect may be attributed to enhanced chlorophyll biosynthesis in leaves through the stimulation of cell division and elongation. Anand (2021) [2] reported that the application of GA₃ in combination with brassinosteroids increased chlorophyll content in grape cv. 2A clone. Further, micronutrients particularly iron play a vital role in chlorophyll biosynthesis, as it serves as a key component of enzymes such as ferrochelatase and δ -aminolevulinic acid synthase, which are involved in the formation of chlorophyll precursors. Iron also aids in electron transport during photosynthesis, thereby indirectly contributing to chlorophyll stability and function. These results are in accordance with the findings of Yogeesh (2005) [8] in grapes.

The module treatments revealed a significant influence on specific leaf area at both stages. Among the module treatments, Module 4 recorded the highest specific leaf area (159.21 cm²/g and 176.87 cm²/g), which was at par with Module 1 (145.81 and 170.36 cm²/g). The lowest SLA was observed in Module 3 (126.15 and 153.95 cm²/g) at 45 and 90 DAFP, respectively. This may be attributed to greater dry matter accumulation in leaves resulting from the combined application of growth regulators and micronutrients. The improvement is likely due to enhanced physiological efficiency and a strengthened source-sink relationship. The treatment also facilitated more efficient translocation of assimilates and photosynthates. As a result, overall plant growth and productivity was enhanced. Similar findings were reported by Omar and Aboryia (2000) [9] in Thompson Seedless and Khilari *et al.* (2020) [4] in Sahebi grapes. The interaction effect between berry thinning and module treatments on specific leaf area was found non significant at both 45 and 90 DAFP.

Conclusion

The results of this study concluded that different berry thinning was found non effective for vegetative and physiological traits. The higher concentration of GA₃, growth regulators (CPPU & BRs) and micronutrients module (GA₃ at 150 ppm + micronutrients spray (ZnSO₄ at 3 g/L + FeSO₄ at 2 g/L + MnSO₄ at 2 g/L + Boric acid at 1 g/L) + CPPU (2 ppm) + BRs (0.5 and 1.0 ppm) showed a notable effect on the growth and physiological parameters.

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