GROWTH PERFORMANCE OF GRAPEVINE (*Vitis vinifera L.*) VARIETIES WITH DIFFERENTIAL RESPONSE TO FOLIAR APPLICATION OF GIBBERELLIC ACID

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ABSTRACT

Grapevine (*Vitis vinifera* L.) cultivation in semi-arid regions like Northern Nigeria faces challenges related to suboptimal growth conditions, which can hinder early development and reduce crop yield potential. This study was conducted during the 2022 dry season at the Training and Research Farm of the Centre for Drylands Agriculture, Bayero University, Kano, to evaluate the effects of gibberellic acid (GA_3) on the early growth of three grapevine varieties: Black Hamburg, Muscat Alexandria, and Crimson Seedless. Gibberellic acid was applied at three concentrations: 0, 100, and 200 mgl^{-1}. The experiment was laid in a split-plot design, with grapevine variety assigned to the main plot and GA_3 concentration to the sub-plot, replicated three times. Vegetative growth data were collected at 3, 4, and 5 months after transplanting (MAT) and analyzed using SAS software. Results revealed that Black Hamburg showed superior growth performance in plant height, number of leaves per plant, leaf chlorophyll content, stem diameter, leaf area, and leaf area index, in comparison to Muscat Alexandria, and Crimson Seedless. Application of 200 mgl^{-1} GA_3 significantly enhanced all growth parameters measured compared to 100 mgl^{-1}, with the least growth observed in the control group (0 mgl^{-1}). Significant interactions were observed, particularly between Black Hamburg and 200 mgl^{-1} GA_3, which recorded the highest growth values. The study demonstrates that foliar application of GA_3 can enhance grapevine growth in the challenging environmental conditions of Northern Nigeria.

INTRODUCTION

Grapevine (*Vitis vinifera* L.) is a global fruit crop with approximately 80.1 million tons produced annually, significantly valued for its use in fresh consumption, juice production, and raisins. Its production is widespread, with varied climatic requirements that influence its growth, development, and yield. Grape being a semiarid subtropical crop, it requires warm and dry summer and cool winter, tolerating to thrives well in regions with a temperature ranges from 4.5^{0}C to 45^{0}C. Most of fruit drink industry heavily depends on the grape fruit juice, increased production of fruits, fruit size and fruit weight becomes a vital marketing parameter for commercial grape farmers. Improving grape production and fruit yield through chemical treatments would improve the economic benefits for both the farmers and the juice processors. In recent years, the application of plant growth regulators, particularly gibberellic acid (GA_3), has been explored as a means to enhance grapevine growth, fruit set, and overall productivity (Khan *et al*., 2015). Gibberellic acid is known to influence cell elongation, leaf expansion, and internode length, which can significantly improve vegetative growth and fruit quality in different crops (Eriksson *et al*., 2011). Several common promising chemicals that are widely used to improve fruit set, yield and fruit quality include micronutrients (zinc, and boron, iron,), plant growth regulators such as gibberellic acid (GA_3) and auxins, and carbohydrates such as sucrose (Lovatt, 2013). Gibberellins, as phytohormones, have an essential role in promoting the change from vegetative to reproductive development in angiosperms with key functions in flower development, fertilization and fruit development (Plackett and Wilson, 2016).

Foliar application of nutrient solutions or liquid fertilizer directly on the leaves encourages and enhances critical points in tree phenology, including flowering, fruiting and seed formation and this method have become an essential feature in the production of fruits for commercial purposes globally (Lovatt, 2013). Advantages of foliar fertilization include well time of application throughout the growing season, precision: spraying of requires quantities of nutrients appropriate to specific requirements, faster uptake of nutrients through foliage compared to soil, and quick correction of physiological disorders due to nutrient-deficiency (Ali *et al*., 2019; Amaro *et al*., 2020). Combination application of boric acid (BA) + GA + sucrose as foliar nutrients resulted to increase fruiting and fruit yield for various fruits trees (Perica *et al*., 2001; Ebeed and El-Migeed, 2005; Aliyu *et al*., 2011; Krishna *et al*., 2017; Souza *et al*., 2017). Use of GA as a foliar nutrient resulting in increased flower buds and fruiting has been stated for coffee plants in Nigeria (Rodrigues and Rodrigues, 2016). However, different concentration of GA via foliar applications have not been reported so far.

In Northern Nigeria, agriculture is the backbone of the economy, with a strong focus on cereal crops and livestock. However, there is growing interest in diversifying agricultural production by introducing high-value horticultural crops such as grapes. Northern Nigeria's semi-arid climate, characterized by hot days and cooler nights, presents a unique environment for grape production. With proper management, including the use of growth regulators like GA_3, grapevine cultivation could become a viable agricultural practice in the region (Abubakar *et al*., 2020). The foliar application of GA_3 offers the potential to overcome some of the region's key challenges, such as poor soil fertility and erratic rainfall, by promoting more vigorous growth and increasing tolerance to environmental stresses (Hameed *et al*., 2014). However, limited studies have been conducted on the effects of gibberellic acid on grapevine growth in Northern Nigeria, particularly regarding the region's suitability for different varieties. This study aims to explore the influence of foliar application of different concentrations GA_3 on the growth performance of various grapevine varieties, contributing to the knowledge base needed for the successful introduction of this crop in Northern Nigeria.

MATERIALS AND METHODS

The field experiment was conducted at the Training and Research Farm of the Centre for Drylands Agriculture, Bayero University, Kano, Nigeria (11° 58' N, 8° E, 475 m above sea level). Seedlings were propagated from cuttings of three grape vine varieties: Crimson Seedless, Muscat Alexandria, and Black Hamburg were raised in polythene seedling bags. Prior to transplanting, soil samples were randomly collected from the experimental site at a depth of 0-15 cm using a soil auger for routine analysis. The experimental field was prepared by clearing debris and harrowing to prevent waterlogging. Transplanting holes (40 cm^3) were dug at a spacing of 2.5 m within rows and 3.5 m between rows. Each hole was refilled with topsoil mixed with farmyard manure in a 3:1 ratio, and the soil around the transplanted vines was compacted. The young vines were supported with sticks for structural stability.

The experiment consisted of three concentrations of synthetic gibberellic acid (GA_3) application; 0, 100, and 200 mgl^{-1}, across the three grapevine varieties. The treatments were arranged in a split-plot design with three replications, where the grapevine varieties were assigned to the main plot and GA_3 concentrations to the subplots. GA_3 was applied as a foliar spray at 20 ml per vine using a knapsack sprayer in the late afternoon, starting one month after transplanting and continuing at monthly intervals. Control vines were sprayed with water, and each vine served as an individual plot unit. The vines were irrigated regularly using a drip irrigation system. Weeding was performed manually to maintain weed-free conditions. Farmyard manure was applied in a 90 cm radius around each vine at a rate of 15 kg per plant, and NPK fertilizer (15:15:15) was applied at a rate of 250 g per plant in five split doses at monthly intervals. Bamboo sticks, 2 m tall, were used to support the young vines. To control insect pests, the plots were sprayed with Imiforce (Imidacloprid) at 30 g per 15 liters of water using a knapsack sprayer. Fungal diseases were managed by applying a mixture of Carbendazim 12% and Mancozeb 63%, with spraying commencing two weeks after transplanting. Data on vegetative growth were collected as follows: Plant Height were Measured from the base of the plant to the uppermost leaf using a meter rule. Number of Leaves were determined by counting the number of leaves per plant. Chlorophyll Content were assessed using a SPAD-502 chlorophyll meter (Minolta). Stem Diameter were Measured using a digital vernier caliper. Leaf Area measured using a digital leaf area meter (YMJ-A Model) from three tagged plants and lastly Leaf Area Index (LAI) were Calculated as LA/GA, where LA represents leaf area and GA represents ground area. Data were collected at 3, 4, and 5 months after transplanting (MAT) and analyzed using analysis of variance (ANOVA), as described by Snedecor and Cochran (1967), with the help of SAS statistical software. The Student-Newman-Keuls (SNK) test was employed to compare treatment means at a 5% probability level.

RESULTS AND DISCUSSION

The soil sample from the study site was characterized as sandy loam with a slightly acidic pH of 5.97. Chemical analysis indicated high organic carbon, moderate nitrogen (0.048%), moderate available phosphorus (6.43 mg/kg), and low potassium content (0.19 cmol/kg). These characteristics provide a moderately fertile environment for grapevine growth, although the low potassium levels could be a limiting factor for optimal development, as potassium is crucial for fruit quality and plant vigor (Basiouny *et al*., 2016). Supplementary fertilization may be necessary to enhance overall grapevine productivity, hence, NPK 15:15:15 was supplied. The effect of gibberellic acid (GA_3) on the plant height of different grapevine varieties was significant (Table 1). Among the varieties, 'Black Hamburg' consistently exhibited the tallest plants, followed by 'Muscat Alexandria' and 'Crimson Seedless,' indicating a genetic advantage in height growth for 'Black Hamburg' under the trial conditions. The higher growth rate of 'Black Hamburg' may be attributed to its adaptability to the warm climate of northern Nigeria, as suggested by previous studies (Ahmed *et al*., 2012). In contrast, 'Crimson Seedless' produced the shortest plants, which could be linked to its late-maturing nature and reduced adaptability to the warmer climate, as corroborated by Michael (2010). The application of GA_3 significantly influenced plant height across all varieties, with the height increasing as GA_3 concentration increased. The highest plant were recorded with the 200 mgl^{-1} GA_3 treatment, while the control group exhibited the shortest plants. This suggests that GA_3 plays a critical role in enhancing vertical growth by promoting cell elongation and division (Amanda *et al*., 2020). The interaction between variety and GA_3 was significant, with 'Black Hamburg' treated with 200

mgl^{-1} GA_3 producing the tallest plants, while 'Crimson Seedless' in the control group had the shortest plants (Table 2). This supports findings by Ali *et al*. (2019), who reported that GA_3 application significantly increased the growth and development of grapevines.

Varietal differences were also significant in terms of leaf production, with 'Black Hamburg' producing the highest number of leaves, followed by 'Muscat Alexandria' and 'Crimson Seedless' (Table 1). The increased leaf count in 'Black Hamburg' may contribute to enhanced photosynthetic capacity and improved overall plant vigor. GA_3 application had a positive effect on the number of leaves, with the 200 mgl^{-1} GA_3 treatment resulting in significantly higher leaf counts compared to the control. This effect was more pronounced at 4 and 5 months after transplanting (MAT), with GA_3 promoting increased leaf production, likely due to its role in enhancing cell division and leaf area expansion (Magdalena *et al*., 2017). The interaction between variety and GA_3 concentration was significant, with 'Black Hamburg' treated with 200 mgl^{-1} GA_3 producing the highest number of leaves, while 'Crimson Seedless' in the control group produced the least (Table 2). This result aligns with previous studies, which have shown that GA_3 improves canopy development and overall vine productivity by increasing leaf number and area (Ali *et al*., 2019). The chlorophyll content of grapevine leaves varied significantly between the varieties, with 'Black Hamburg' consistently showing the highest chlorophyll content, followed by 'Muscat Alexandria' and 'Crimson Seedless' (Table 3). This suggests that 'Black Hamburg' has a greater photosynthetic potential, which could lead to enhanced growth and yield. GA_3 application significantly increased chlorophyll content, particularly at 4 and 5 MAT, with the 200 mgl^{-1} GA_3 treatment resulting in the highest chlorophyll levels. This increase in chlorophyll content may be linked to the ability of GA_3 to enhance photosynthetic efficiency by improving the activity of enzymes involved in carbon fixation (Amanda *et al*., 2020). A significant interaction between variety and GA_3 concentration was observed, with 'Muscat Alexandria' treated with 200 mgl^{-1} GA_3 producing the highest chlorophyll content, while 'Crimson Seedless' in the control group exhibited the lowest chlorophyll levels (Table 4). These findings support previous research by Magdalena *et al*. (2017), which reported that GA_3 application enhances photosynthesis and overall vine growth. The stem diameter of grapevines was significantly affected by varietal differences, with 'Black Hamburg' producing the widest stems, followed by 'Muscat Alexandria' and 'Crimson Seedless' (Table 3). A wider stem diameter is indicative of a stronger and more vigorous plant structure, which can support greater water and nutrient transport, contributing to overall plant health and productivity (Basiouny *et al*., 2016). GA_3 application had a similar effect, with the 200 mgl^{-1} treatment resulting in significantly wider stems than the control, further supporting the positive role of GA_3 in enhancing plant growth. The interaction between variety and GA_3 concentration was significant, with 'Black Hamburg' treated with 200 mgl^{-1} GA_3 producing the widest stems, while 'Crimson Seedless' in the control group had the smallest stems (Table 4). This interaction highlights the potential of GA_3 to improve structural growth in grapevines, particularly in varieties like 'Black Hamburg' that are more responsive to the hormone.

Leaf area and LAI were significantly affected by both variety and GA_3 application (Table 5). 'Black Hamburg' produced the largest leaf area and highest LAI, followed by 'Muscat Alexandria' and 'Crimson Seedless'. This suggests that 'Black Hamburg' has a greater photosynthetic surface area, which can enhance biomass accumulation and yield potential. GA_3 application significantly increased leaf area and LAI, with the 200 mgl^{-1} treatment producing the largest leaf areas and highest LAIs. This result is consistent with previous studies, which have shown that GA_3 promotes leaf expansion and enhances canopy development (Amanda *et al*., 2020). The interaction between variety and GA_3 concentration was significant, with 'Black Hamburg' treated with 200 mgl^{-1} GA_3 producing the largest leaf area and highest LAI, while 'Crimson Seedless' in the control group had the smallest leaf area (Table 6). These findings further confirm the positive role of GA_3 in enhancing vegetative growth, particularly in varieties like 'Black Hamburg', which are more responsive to its application. The results of this study align with previous findings, highlighting the potential of GA_3 to enhance grapevine growth and productivity through its action on cell division, elongation, and photosynthetic efficiency (Ali *et al*., 2019; Magdalena *et al*., 2017).

CONCLUSION

This study demonstrates the significant positive effects of GA_3 on the growth and development of grapevine varieties, particularly 'Black Hamburg', which consistently outperformed 'Muscat Alexandria' and 'Crimson Seedless' in terms of plant height, leaf number, chlorophyll content, stem diameter, and leaf area. The use of GA_3, especially at 200 mgl^{-1}, can substantially improve the vegetative growth and physiological efficiency of grapevines, making it a valuable tool for grapevine cultivation in warm climates like northern Nigeria. However, 'Crimson Seedless' showed less responsiveness to GA_3, indicating that this variety may require additional management practices or be less suitable for such environments without interventions. Future research should explore the long-term effects of GA_3 on yield and fruit quality to fully understand its impact on grapevine production.

Table 1: Effect of GA3 on Plant Height (cm) and Number of Leaves of Grapevine Varieties.

Treatment	**Plant Height (cm)**			**Number of Leaves Per Plant**		
	3	**4**	**5**	**3**	**4**	**5**
		MAT			**MAT**	
Variety (V)						
Black Hamburg	101.62^{a}	142.52^{a}	181.78^{a}	44.03^{a}	56.19^{c}	91.15^{a}
Muscat Alexandria	83.80^{b}	112.00^{b}	152.66^{b}	35.65^{b}	64.56^{b}	78.83^{b}
Crimson Seedless	63.26^{c}	96.48^{c}	120.63^{c}	36.56^{b}	71.79^{a}	74.30^{c}
P value	<0.0001	<0.0001	<0.0001	0.0010	<0.0001	0.0040
SE ±	2.362	3.046	3.114	0.833	0.673	2.246
GA_3 (G)						
0 mgl^{-1}	69.83^{c}	96.31^{c}	122.52^{c}	33.60^{b}	50.81^{c}	64.38^{c}
100 mgl^{-1}	83.87^{b}	120.00^{b}	155.07^{b}	40.04^{ab}	66.23^{b}	83.37^{b}
200 mgl^{-1}	93.98^{a}	134.69^{a}	177.48^{a}	42.59^{a}	75.50^{a}	96.53^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SE ±	1.148	1.292	2.389	0.449	0.614	0.845
Interaction						
V x G	0.0020	<0.0001	0.0380	<0.0001	0.1110	<0.0001

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK).

Table 2: Interaction between GA3 and Variety on Plant Height (cm) and Number of Leaves of Grapevine

	Plant Height (cm)									**Number of Leaves**					
	3 MAT			4 MAT			5 MAT			3 MAT			5 MAT		
GA_3 (mgl^{-1})	0	100	200	0	100	200	0	100	200	0	100	200	0	100	200
Black H.	85.50^{d}	104.32^{b}	115.04^{a}	120.90^{c}	149.80^{b}	156.80^{a}	148.10^{cd}	183.70^{b}	213.5^{a}	37.03^{de}	46.72^{b}	48.33^{a}	69.69^{e}	94.82^{b}	108.93^{a}
Muscat A.	69.78^{ef}	83.50^{d}	95.11^{c}	101.00^{d}	115.40^{c}	119.60^{c}	125.00^{e}	155.50^{c}	177.40^{b}	32.11^{f}	36.50^{e}	38.33^{d}	65.22^{e}	78.00^{d}	94.00^{b}
Crimson	54.22^{g}	63.78^{f}	71.78^{e}	81.20^{f}	101.20^{e}	107.00^{d}	94.4^{f}	126.00^{e}	141.40^{d}	31.67^{f}	36.89^{de}	41.11^{c}	58.22^{f}	77.28^{d}	86.67^{c}
SE±	2.866			3.551			4.058			1.047			2.544		

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK).

Table 3: Leaf Chlorophyll Content and Stem Diameter (mm) of Grapevine Varieties as Affected by Foliar Application of GA_3

	Leaf Chlorophyll Content			**Stem Diameter (mm)**		
	3	**4**	**5**	**3**	**4**	**5**
Treatment		**MAT**			**MAT**	
Variety (V)						
Black Hamburg	46.48^{a}	71.13^{a}	40.15^{b}	6.035^{a}	7.965	9.238^{a}
Muscat Alexandria	40.59^{b}	45.97^{b}	46.58^{a}	5.606^{b}	7.558	8.219^{c}
Crimson Seedless	34.92^{c}	37.66^{c}	37.87^{c}	5.060^{c}	7.286	8.586^{b}
P value	<0.0001	0.0020	0.0002	0.1070	0.1070	0.0015
SE ±	0.544	1.213	0.931	0.096	0.238	0.190
GA_3 (G)						
0 mgl^{-1}	36.16^{c}	41.64^{c}	37.51^{c}	4.930^{c}	6.724^{c}	7.742^{c}
100 mgl^{-1}	41.85^{b}	55.05^{ab}	42.08^{b}	5.727^{b}	7.782^{b}	8.877^{b}
200 mgl^{-1}	46.97^{a}	58.07^{a}	45.01^{a}	6.044^{a}	8.303^{a}	9.524^{a}
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SE ±	0.421	0.776	0.628	0.052	0.069	0.090
Interaction						
V x G	0.9310	<0.0001	<0.0001	0.0004	0.0010	0.0130

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK).

Table 4: Interaction between GA_3 and Varieties on Leaf Chlorophyll Content and Stem Diameter (mm) of Grapevine

	Leaf Chlorophyll Content									Stem Diameter (mm)					
	4 MAT			3 MAT			5 MAT			4 MAT			5 MAT		
GA_3 (mgl^{-1})	0	100	200	0	100	200	0	100	200	0	100	200	0	100	200
Black Hamburg	37.09^{d}	39.53^{cd}	40.59^{c}	5.43^{e}	6.24^{ab}	6.43^{a}	38.17^{d}	39.89^{d}	42.38^{c}	7.01^{de}	8.34^{ab}	8.54^{a}	8.14^{d}	9.37^{b}	10.20^{a}
Muscat Alexandria	38.42^{cd}	47.23^{b}	52.10^{a}	5.06^{f}	5.77^{d}	5.99^{bc}	40.60cd	46.90^{b}	52.24^{a}	6.56^{e}	7.74^{bc}	8.37^{a}	7.56^{e}	8.64^{cd}	9.56^{b}
Crimson Seedless	30.38^{e}	36.63^{d}	37.29^{cd}	4.30^{g}	5.17^{ef}	5.72^{c}	33.76e	39.44^{d}	40.40^{cd}	6.60^{e}	7.26^{cd}	7.99^{ab}	7.52^{e}	8.32^{d}	8.81^{c}
SE±		1.635			0.121			1.287			0.257			0.231	

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK).

Table 5: Effect of Foliar Application of GA_3 on Leaf Area (cm^2) and Leaf Area Index of Grapevine Varieties

	Leaf Area			Leaf Area Index		
Sampling period (MAT)	**3**	**4**	**5**	**3**	**4**	**5**
Variety (V)						
Black Hamburg	49.48^{a}	71.13^{a}	81.70^{a}	0.056^{a}	0.081^{a}	0.093^{a}
Muscat Alexandria	40.59^{b}	45.97^{b}	50.06^{b}	0.046^{b}	0.052^{b}	0.057^{b}
Crimson Seedless	34.92^{c}	37.66^{c}	39.89^{c}	0.040^{c}	0.043^{c}	0.045^{c}
P value	0.0040	0.0020	<.0001	0.0040	0.0020	<.0001
SE ±	1.929	3.671	2.442	0.0022	0.0042	0.0027
GA_3 (G)						
0 mgl^{-1}	36.16^{c}	41.64^{c}	47.04^{c}	0.041^{c}	0.047^{c}	0.054^{c}
100 mgl^{-1}	41.85^{b}	55.05^{b}	60.22^{b}	0.048^{b}	0.062^{b}	0.069^{b}
200 mgl^{-1}	46.97^{a}	58.07^{a}	64.39^{a}	0.054^{a}	0.066^{a}	0.073^{a}
P value	<.0001	<.0001	<.0001	<.0001	<0.0001	0.0017
SE ±	0.775	1.049	1.494	0.0009	0.0012	<.0001
Interaction						
V x G	0.00511	<.0001	<.0001	0.0501	<.0001	<.0001

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK).

	Leaf Area (cm^2)						Leaf Area Index					
	4			**5**			**4**			**5**		
GA_3 (mgl^{-1})	0	100	200	0	100	200	0			0	100	200
BH	50.46^{b}	79.67^{a}	83.26^{a}	59.25^{c}	90.03^{b}	95.82^{a}	0.058^{b}	0.091^{a}	0.095^{a}	0.068^{c}	0.103^{b}	0.109^{a}
MA	40.90^{b-f}	46.97^{b-d}	50.03^{bc}	45.91^{ef}	49.80^{de}	54.47^{cd}	0.046^{b-f}	0.054^{b-d}	0.057^{bc}	0.052^{ef}	0.057^{de}	0.062^{cd}
CS	33.55^{f}	38.50^{d-g}	40.93^{b-e}	35.96^{g}	40.84^{fg}	42.88^{ef}	0.038^{f}	0.044^{d-g}	0.047^{b-e}	0.041^{g}	0.047^{fg}	0.049^{ef}
SE±		3.959			3.229			0.0045			0.0037	

Means followed by the same letter(s) are not significantly different at 5% level of significance using Student Newman's Kleus (SNK). BH= Black Hamburg, MA= Muscat Alexandria and CS= Crimson Seedless

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