EFFECT OF GIBBERELLIC ACID (GA_3) ON YIELD AND FRUIT QUALITY OF TABLE GRAPE VAR. HIMROD IN KATHMANDU VALLEY, NEPAL

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ABSTRACT

The experiment was conducted at Warm Temperate Horticulture Center, Kirtipur, Kathmandu, Nepal with an aim to improve the yield and fruit quality of seedless table grape var. Himrod. Different treatments of GA_3 (0 ppm,10 ppm, 20 ppm, 30 ppm, 40 ppm) were applied for two times on grape bunches after berry set. The quantitative and qualitative attributes of bunch and berry were recorded. Berry size, berry weight, berry volume, bunch weight and berry color were improved significantly in GA_3 treated grape bunches whereas TA was significantly decreased. The effect of GA_3 on berry diameter had significant impact on berry weight and berry volume, and thus in yield. As the yield of a vine is the product of bunch number and bunch weight, GA_3 influenced the current season bunch weight by improving the berry attributes, and also affected quality attributes of grape berries in var. Himrod.

Keywords: Berry, bunches, GA_3, PGR, quality

INTRODUCTION

Grape (*Vitis vinifera* L.) belonging to the family vitaceae, is one of the earliest fruit known since civilization, popular for its nourishing, delicious and refreshing fruits (Jegadeeswari *et al.*, 2010). Dahal *et al.* (2017) has stated that grape can be consumed in diversified forms viz. fresh fruit, drinks as juices, wines, beverages and medicines, and stored as raisin thus, grape has its identity as worldly fruit. It is one of the most precious fruit of the temperate regions, but successfully grown in the tropical and sub-tropical agro-climatic regions too. In Europe, grape is the major ingredient for preparation of wines of various brands from the medieval period but in African and Asian countries, grape is more preferred and consumed as fresh fruit or raisin (Chattopadhyay, 2012). In Nepal, grape cultivation was supposed to be started more than 70 years ago at the time of Rana regime (Dahal *et al.*, 2017). Atreya *et al.* (2015) mentioned the grape cultivation covered an area of about 20 ha with total fresh grapes production of around 76 tonnes annually in Nepal. In recent years, commercial vineyards are establishing which will certainly increase area and productivity of grapevine in Nepal. In Nepal, various table grape cultivars such as, 'Thompson seedless', 'Perlette', 'Himrod', 'Beauty Seedless', 'Steuben', 'Kyoho', 'Black Olympia' etc were subsequently introduced from Japan and India (Joshi, 1986).

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Among several imported varieties, 'Himrod' is considered one of the promising seedless variety, developed by crossing 'Thompson seedless' and 'Ontario' in State Agricultural Experiment Station, New York Botanical Garden (Maul *et al.*, 2020). 'Himrod' variety is one of the popular early ripening table grapes, grown in warm climate (Dahal *et al.*, 2017), which has attractive bunch color, excellent taste, firmness and of parthenocarpic nature (Maul *et al.*, 2020) but the small berry size is a distractive feature (Miyoshi *et al.*, 1997). For table grapes, berry size is one of the important criteria, influencing consumer's preference in the global market (Zoffoli *et al.*, 2009). Attractive visual features like bigger berry size, weight, proper shape, appropriate color development etc are vital for proper marketable quality and to fence higher price (Marzouk and Kassem, 2011).

Since 19th century, several cultural methods like girdling, pruning, berry thinning and spraying plant growth regulators (PGRs) have been used to improve quantitative and qualitative characteristics of grapes (May, 2004). Among these practices, PGRs application was considered effective in improving yield and quality of grape berries (Dokoozlian, 1998; Loubser and Wolf, 1994; Srivastava and Handa, 2005). In commercial grape cultivation, application of PGRs especially Gibberellic acid (GA_3) is popular for enhancement of vegetative growth parameters like bunch weight, berry length, berry diameter, berry weight and size etc. and qualitative characteristics like Total Soluble Solid (TSS) and Titratable Acidity (TA) in several table grape varieties including 'Thompson Seedless', 'Flame Seedless', 'Ruby Seedless', 'Sovereign Coronation', 'Italia' and so on (Dokoozlian, 1998; Ezzahouani *et al.*, 1985; Miele *et al.*, 2000; Reynolds and Savigny, 2004; Shaaban *et al.*, 1989). GA_3 is used widely for improving yield and fruit quality of grape when the inflorescence is about 8 cm length for bunch elongation, at full bloom stage for berry thinning, and at 4-10 mm berry size for berry enlargement; however, the specific stage of GA_3 treatment varies among cultivar, environment and the purpose of the treatment (Christensen, 2000; Dokoozlian, 1998; Hed *et al.*, 2011; Molitor *et al.*, 2012; Van Der Merwe, 2014). GA_3 can be applied either by spraying the entire vine or by localized spraying/dipping of the individual bunch at recommended phenological stage, definite dose, and specific environmental condition; as these criteria are sensitive to desired outcomes (Molitor *et al.*, 2012; Mullins *et al.*, 1992; Orth, 1990; Weaver and Pool, 1971).

With existing climatic suitability and assuring market, viticulture has tremendous possibilities in Nepal as the demand for fresh grapes is increased day by day due to increment in population, increased awareness and purchasing power of the individuals Thus, the major objective of this investigation was to identify appropriate dose of GA_3 for improving the yield and quality of seedless table grapes.

MATERIALS AND METHODS

The experiment was conducted in an established vineyard (>30 years old vines) of Warm Temperate Horticulture Centre (WTHC), Kirtipur, Kathmandu, Nepal from May, 2020 (Baisakh, 2077) to July, 2020 (Ashad, 2077). For experimental set up, the vines were arranged in a Randomized Complete Block Design (RCBD) having 5 treatments with 4 replications. Ten bunches of similar growth stage were tagged from a vine for treatment application, while other bunches of a vine were remained untouched. A vine was considered as a replicate. So, there were total 20 experimental vines of var. Himrod. Different concentrations of GA_3 (10 ppm, 20 ppm, 30 ppm, 40 ppm and control) were allocated as treatments. Two applications of GA_3 were carried out after berry set. The first application of GA_3 was carried out on 7th May, 2020 (25th Baisakh, 2077) when berries were approximately 4 to 5 mm in size (berries pepper corn size stage, bunches tending downwards; E-L 29 stage) (Coombe and Dry, 2004). The second application of GA_3 was carried out after a week of the first application on 15th May, 2020 (2nd Jestha, 2077). GA_3 was sprayed all over the selected grape bunches until the surface flow was noticed from bunches, by using fine nozzle of knapsack sprayer. Vine management practices were performed as standards followed by WTHC, Kirtipur, Kathmandu, Nepal. The quantitative and qualitative attributes were observed after single harvesting of the grape bunches on 6th July, 2020 (22nd Ashad, 2077). Ten grape bunches were selected randomly from each experimental unit for measurement of fruit quality parameters. Further, 10 berries (4 from top section, 4 from middle section and 2 from bottom section) were randomly picked from each bunch for parameters observation (May, 2004). For quantitative observation, berry diameter, berry weight, berry volume, bunch weight, bunch length and yield attributes were recorded. Bunch color, juice pH, Total Soluble Solid (TSS), Titratable Acidity (TA) and TSS/TA ratio were assessed for qualitative observation. Bunch color was analysed by image analysis of each bunch through 'ImageJ' software that identified the change in coloration of grape bunches and estimated area of light green region on grape bunches that signified veraison or maturity. Statistical analysis was performed by using data analysis tools like R Stat 4.0.4, GEN Stat (18th edition) etc. The data were subjected to Analysis of Variance (ANOVA), mean separation by Duncan Multiple Range Test (DMRT) at 5% level of significance, dispersion, correlation and regression analysis.

RESULTS AND DISCUSSIONS

BERRY AND BUNCH CHARACTERISTICS

Berry characteristics such as berry diameter, berry weight and berry volume; and bunch characteristics including bunch weight and bunch length were found substantially different between the treatments, recorded at harvest (Table 1, Figure 1).

Table 1. Effect of GA_3 on berry and bunch characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	Berry diameter (mm)	10 berry weight (g)	10 berry volume (ml)	Bunch weight (g)	Bunch length (cm)
10 ppm	16.88^{b}±0.29	30.55^{b}±1.48	29.35^{b}±1.19	400.68^{a}±36.36	20.35^{a}±0.63
20 ppm	17.63^{a}±0.25	34.93^{ab}±1.34	33.70^{a}±1.01	391.23^{a}±35.71	19.40^{ab}±0.34
30 ppm	17.90^{a}±0.11	36.22^{a}±0.84	34.88^{a}±1.04	364.89^{a}±52.54	19.47^{ab}±0.78
40 ppm	18.23^{a}±0.37	37.73^{a}±2.43	36.05^{a}±2.54	408.73^{a}±29.95	19.55^{ab}±0.45
Control	15.71^{c}±0.25	24.43^{c}±1.40	23.48^{c}±0.89	258.53^{b}±24.37	18.10^{b}±0.23
Grand mean	17.27	32.77	31.49	364.81	19.37
LSD	0.726***	4.589***	4.230***	61.34***	1.394*
CV (%)	2.7	9.1	8.7	10.9	4.7

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at $p \leq 0.001$; **at $p \leq 0.01$; *at $p \leq 0.05$; SEM = Standard error of mean; CV = Coefficient of variation.

Berry diameter, berry weight and berry volume were found to be increased with increasing concentrations of GA_3, the maximum at 40 ppm and the minimum in control treatment (Table 1). In cultivars like 'Thompson Seedless' and 'Flame Seedless', GA_3 application from 10 to 50 ppm concentrations caused significant increase in berry physical characteristics like width, weight, and volume (Dokoozlian *et al*., 2001; Elgendy *et al*., 2012; Marzouk and Kassem, 2011; Reynolds and Savigny, 2004). The presented data was identical with the results reported that frequent application of GA_3 had increased the berry width and berry weight on cv. Thompson Seedless (Fallahi *et al*., 1995; Hussein *et al*., 1998), 'Flame Seedless' (Marzouk and Kassem, 2002; Shehata and El-Barbary, 1996), 'Ruby Seedless' (Omar and El-Morsy, 2000) and several other grape cultivars (Ben-Arie *et al*., 1997; Dokoozlian and Peacock, 2001). Miyoshi *et al*. (1997) stated identical results that 50 ppm of GA_3 application at full bloom stage had considerably increased berry weight by 20% in var. Himrod in Kirtipur, Kathmandu, Nepal. GA_3 was supposed to have stimulating effect on cell elongation process (Lee and Han, 2004; Sachs and Weaver, 1968; Taiz and Zeiger, 1991) and biosynthesis of protein thereby, development of strong sink causing increment in water uptake followed by solute storage (Hale and Weaver, 1962; Zhenming*et al*., 2008) thus, causing enhancement on berry dimensions (Elgendy *et al*., 2012).

0 ppm of GA_3 (Control) | **10 ppm of GA_3** | **20 ppm of GA_3** | **30 ppm of GA_3** | **40 ppm of GA_3**

Figure 1. Images showing the differences in bunch architecture and berry sizes treated with different concentrations of GA_3 in WTHC, Kirtipur, Kathmandu, Nepal

Among the tested treatments, 40 ppm of GA_3 gave the highest bunch weight while the lowest was obtained in the control treatment. With respect to bunch length, there was no significant difference observed among the GA_3 treatments expect the control treatment. The lowest bunch length was obtained in the control treatment. In cultivars like 'Thompson Seedless' and 'Flame Seedless', GA_3 application from 10 to 40 ppm concentrations caused significant increase in bunch weight (Abd El-Wahab, 2006; Elgendy *et al.*, 2012; Navarro *et al.*, 2001). The increase in bunch weight was due to increase in berry weight and size by GA_3 treatment that caused acceleration on synthesis of carbohydrates and proteins thereby, more availability and mobilization of organic nutrients towards the bunches (Elgendy *et al.*, 2012). In case of bunch length, the obtained result was identical with research study by Lee and Han (2004) which mentioned that bunch length only varied significantly between the GA_3 treated and the control bunches in var. Kyoho.

YIELD ATTRIBUTES

There was substantial difference in bunch weights per vine between the treated and the control treatments, the maximum in 40 ppm of GA_3 and the minimum in control treatment (Table 2). Vines treated with 28 ppm of GA_3 resulted in higher yield in var. Thompson Seedless which was due to increment in berry and bunch weight by GA_3 application (Marzouk and Kassem, 2011). The bunch number per vine and potential yield per vine remained unaffected by the treatment application. There was large variation in bunch number per vine, as the grapevines of different age group were selected for treatment application due to fewer grapevines number in the research center. Also, only 10 bunches per vine were selected for treatment application, thus, the treatment difference was not that large enough to show the umbrella effect for a whole vine yield. Dokoozlian and Peacock (2001) mentioned similar results that bunch weight, yield per vine were not affected by 2 g/ha GA_3 treatments at different stages of bloom in cv. Crimson Seedless.

Table 2. Effect of GA_3 on yield and yield attributing characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	10 Bunch weight (kg/vine)	Bunch number (per vine)	Potential yield (kg/vine)
10 ppm	4.01^{a}±0.36	119±55 (5.45)	53.31±27.89 (4.52)
20 ppm	3.91^{a}±0.36	76±41 (4.93)	32.44±19.31 (3.98)
30 ppm	3.65^{a}±0.53	76±41(4.79)	30.77±16.59 (3.75)
40 ppm	4.09^{a}±0.30	56±14 (4.86)	23.27±6.88 (3.95)
Control	2.59^{b}±0.24	64±34 (4.84)	18.91±11.71 (3.48)
Grand mean	3.65	78 (4.97)	31.74 (3.93)
LSD	0.613***	98 $(1.136)^{ns}$	45.45 $(1.263)^{ns}$
CV (%)	10.9	81.5 (14.8)	92.9 (20.8)

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at p≤0.001; **at p≤0.01; *at p≤0.05; ns = non-significant; SEM = Standard error of mean; CV = Coefficient of variation. The numbers in parenthesis indicated (log x + 1) value to compensate the large difference among the treatments.

BERRY QUALITY ATTRIBUTES

In relation to bunch color, GA_3 treated bunches showed significantly higher area of light green region on bunches in comparison to the control treatment (Table 3), suggesting GA_3 promoted the maturity of grape berries (Abu-Zahra, 2010). Some variations were obtained in pH and TSS for grape juice, but both pH and TSS for different treatments did not varied significantly. However, the least pH and TSS values were obtained for the control grape berries. In case of TA and TSS/TA ratio, treated grape berries varied significantly from that of the control treatment, observing the maximum TA and minimum TSS/TA ratio in the control treatment as the juice contained the highest amount of organic acids among all the treatments.

GA_3 applied during or after flowering has resulted in higher color uniformity and early ripening of the berries (Marzouk and Kassem, 2002; Prasad and Pathak, 1975). GA_3 has been said to hasten the maturity of grape berries by affecting the berry qualities such as decreasing the TA content (Abu-Zahra, 2010). Avenant and Avenant (2005) had mentioned similar results that no significant difference in pH by GA_3 treatment in var. Red Globe. Lee and Han (2004) and Lee *et al.* (1997) stated that GA_3 treatment had very little effect on quality parameters thus, in GA_3 applied grape bunches, TSS was found to be equal or above in comparison to that of the control in var. Thompson Seedless (Abu-Zahra, 2010; Harrell and Williams, 1987) which was identical with results in var. Himrod. The amount of TA was decreased by 50 ppm GA_3 application in var. Thompson Seedless (Abu-Zahra, 2010). In cultivars like 'Thompson seedless' and 'Flame seedless', increase in GA_3 concentration caused gradual increase in TSS but decrease in TA (Elgendy et al., 2012; Shaaban et al., 1989); and increment in TSS/TA ratio (Elgendy et al., 2012; Tambe, 2002).

Table 3. Effect of GA_3 on quality characteristics (Mean ± SEM) of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

Conc. of GA_3	Bunch color (cm^2)	pH	TSS (^oBrix)	TA (%)	TSS/TA Ratio
10 ppm	$26.96^{a}\pm2.47$	3.26 ± 0.01	15.20 ± 0.37	$0.7345^{ab}\pm0.0339$	$21.06^{ab}\pm0.95$
20 ppm	$30.81^{a}\pm2.03$	3.25 ± 0.04	15.32 ± 0.35	$0.7108^{ab}\pm0.0522$	$22.48^{b}\pm1.84$
30 ppm	$30.61^{a}\pm2.62$	3.26 ± 0.04	15.12 ± 0.63	$0.6510^{b}\pm0.0421$	$23.50^{b}\pm2.14$
40 ppm	$25.46^{ab}\pm2.20$	3.24 ± 0.05	14.81 ± 0.69	$0.6849^{b}\pm0.0542$	$22.59^{b}\pm2.23$
Control	$20.30^{b}\pm1.29$	3.12 ± 0.04	14.72 ± 1.03	$0.8198^{a}\pm0.0759$	$18.43^{a}\pm2.02$
Grand mean	26.83	3.23	15.04	0.7202	21.61
LSD	6.580**	0.1187^{ns}	1.251^{ns}	0.1084*	3.479^{*}

Conc. of GA_3	Bunch color (cm^2)	pH	TSS (°Brix)	TA (%)	TSS/TA Ratio
CV (%)	32.1	2.4	5.4	9.8	10.4

Means followed by common letter(s) within a column do not differ significantly at ≤5 % level of significance by DMRT; LSD = Least significant difference; significance codes ***at p≤0.001; **at p≤0.01; *at p≤0.05; ns = non-significant; SEM = Standard error of mean; CV = Coefficient of variation.

RELATIONSHIP BETWEEN YIELD ATTRIBUTES

Berry diameter, berry weight, berry volume and bunch weight were found to be positively correlated but had negative correlation with TA (Table 4). Abu-Zahra (2010) reported the berry diameter had significant positive correlation with berry weight, bunch weight and bunch length in var. Thompson Seedless.

Table 4. Correlation coefficients between measured parameters of grapevine var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal, 2020.

	Berry diameter	10 berry width	10 berry volume	Bunch weight	Bunch length	PH	TSS	TA(%)	TSS/TA
Berry diameter	1								
10 berry width	0.9762	1							
10 berry volume	0.9589	0.9726	1						
Bunch weight	0.3926	0.3810	0.3736	1					
Bunch length	0.0562	0.0442	0.0102	0.5832	1				
PH	0.4522	0.4551	0.4182	0.3906	0.1573	1			
TSS	0.1899	0.1813	0.1430	0.2039	0.0608	0.576	1		
TA(%)	-0.4474	-0.4189	-0.4059	-0.3229	-0.0805	-0.434	-0.3141	1	
TSS/TA	0.4384	0.4108	0.3811	0.3148	0.0725	0.602	0.6072	-0.8903	1

As shown in Figure 2, 95.29% variation in berry weight was explained by berry diameter showing direct relationship. Hence, the effect of GA_3 on berry diameter had significant impact on berry weight and thus in berry yield.

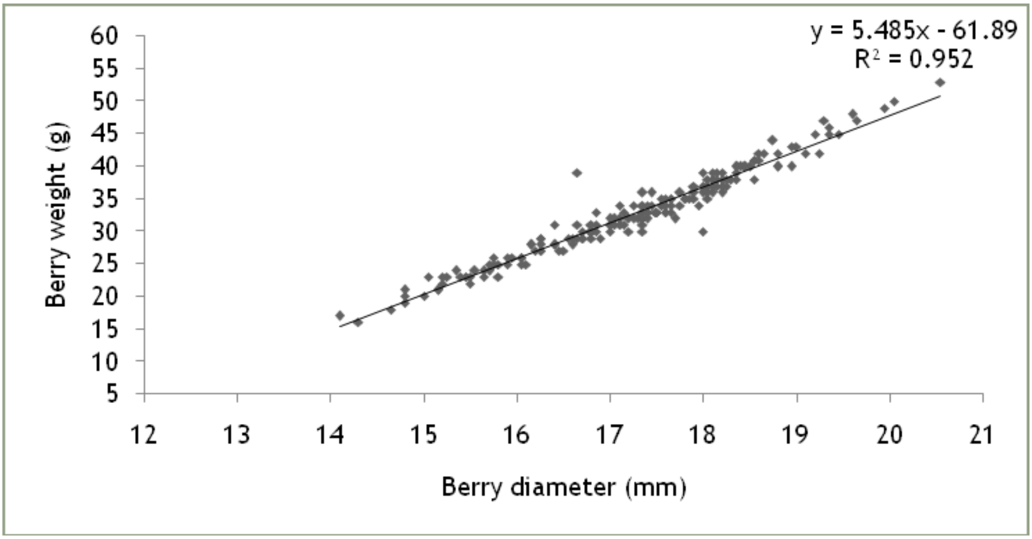

Figure 2. Linear regression showing the berry weight relation to berry diameter in WTHC, Kirtipur, Kathmandu, Nepal, 2020

On the basis of coefficient of determination (R^2), it was found that 79.06% variation in potential yield per vine was due to bunch number, while 57.20% variation in the potential yield per vine was explained by bunch weight. The potential yield per vine is the product of bunch number and bunch weight, hence GA_3 treatment was responsible for increase in bunch weight and thus in bunch yield. The qualitative observations, TSS and TA were negatively correlated. Similar result was obtained in research conducted by Bhullar and Dhillon (1977). TA values were correspondingly decreased with the increasing values of berry diameter. Richard (2006) reported GA_3 encourages growth by increasing plasticity of the cell wall followed by hydrolysis of starch into sugars which decreases the cell water potential thus, allowing entry of water in the cell that causes dilution of titratable acids as well as promotes cell elongation.

CONCLUSIONS

The yield attributes such as berry size, berry weight, berry volume, bunch weight and berry color were increased significantly in the GA_3 treated bunches compared to the control in Himrod variety of grapevine. However, the quality parameters did not differ significantly among the GA_3 treatments. TA was decreased significantly in GA_3 treated berries. The effect of GA_3 on berry diameter had significant impact on berry weight and berry volume, and thus in yield. This experiment was limited to application of GA_3 on bunches thus, further GA_3 applications is suggested in the whole grapevine, concerning variety, doses and number of GA_3 applications.

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