INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
20–0278/202x/00–0–000–000
DOI: 10.17957/IJAB/15.1552
http://www.fspublishers.org

Full Length Article

Post-Bloom Applied Moringa Leaf Extract Improves Growth, Productivity and Quality of Early-Season Maturing Grapes (*Vitus vinifera*)

Ahmad Sattar Khan[1*], Muhammad Ibrahim[1], Shahzad Maqsood Ahmed Basra[2], Sajid Ali[3], Munawar Hussain Almas[4], Muhammad Azam[1], Raheel Anwar[1] and Mahmood Ul Hasan[1]
[1]*Institute of Horticultural Sciences, University of Agriculture Faisalabad, 38040, Pakistan*
[2]*Department of Agronomy, University of Agriculture Faisalabad, 38040, Pakistan*
[3]*Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, 60800, Pakistan*
[4]*Directorate of Floriculture (T&R), Punjab, Lahore, Pakistan*
[*]For correspondence: ahmad_khan157@yahoo.com
Received 19 February 2020; Accepted 26 June 2020; Published ______________

Abstract

Moringa (*Moringa oleifera* Lam.) is known to be a rich source of endogenous plant growth regulators and mineral elements with potential to improve plant growth. This study was performed in a commercial vineyard to evaluate the effect of exogenously applied moringa leaf extract (MLE) (3% MLE) at different phenological stages (*i.e.* flowering, berry setting and premature stages of grapevine) on growth, productivity and physico-chemical berry quality of important early-season maturing commercial table grapes cultivars (*viz.* 'Cardinal', 'Flame Seedless', 'King's Ruby', 'NARC Black' and 'Perlette'). Untreated vines were kept as control. Data were collected regardring leaf nutrient contents, vine vegetative and reproductive growth, organoleptic and physico-chemical qualitative characters of berries. Irrespective to the cultivars, foliar applied MLE showed a significant improvement in leaf potassium, iron and zinc contents, cane length, leaf size, berry set, berries per cluster, rachis length, cluster size, cluster weight, berry size and berry weight. The highest increase of yield was observed in grapes cv. 'Perlette' (32.1%) followed by 'NARC Black' (30.3%), 'Cardinal' (28.8%), 'Flame Seedless' (27.3%) and 'King's Ruby' (11.9%). MLE application also reflected a significant improvement in total soluble solids (TSS), TSS: titratable acidity ratio, total phenolic contents, vitamin C as well as reducing, non-reducing and total sugar percentages in berry juice of all studied grapes cultivars. In conclusions, 3% MLE can be efficiently applied on grapevines at post-bloom stages (flowering, berry setting and premature growth phases) to improve their vegetative and reproductive growth as well as physico-chemical berry quality. Grapes cvs. 'Perlette', 'NARC Black' and 'Cardinal' showed better response to 3% MLE sprays, as compared to 'King's Ruby' and 'Flame Seedless'. © 2020 Friends Science Publishers

Keywords: Berry quality; Grapes; Growth; Moringa; Physico-chemical quality; Yield

Introduction

Grapes (*Vitis vinifera* L.) have been cultivated since long for consumption as fresh, dried, and also as wine. Presently, about 47.3% of grape production is used for wine production, 35% is consumed as fresh fruit; while, 8% is used as dried fruit in the world (OIV 2017). The grapes are important source of antioxidants and biologically active dietary compounds. The most important biochemically active component of grapes is resveratrol which has certain health-promoting benefits (Shrikhande 2000; Yadav *et al.* 2009). Grapes are also a decent source of minerals such as cobalt (Co), iron (Fe), potassium (K), magnesium (Mg), and phosphorus (P) as well as vitamins like K, B1, B2, B6, and C (Anonymous 2018).

Grapes is an important fruit occupying an area of 7.5 million ha with 75.8 million tones production across the world (FAO 2016). In Pakistan, the production of grapes has been observed to be 0.065 million tonnes from an area of 0.0162 million ha with 3.98 t ha^{-1} average yield (FAO 2016). Presently, only European table grapes are being cultivated at commercial scale throughout temperate regions in the country including Gilgit-Baltistan, Balochistan and some area of Khyber Pakhtunkhwa (GOB 2016; Khan *et al.* 2011). The cultivars found in the country include 'Haita', 'Kishmishi', 'Shundokhani', 'Sahibi', 'Shekhali', 'King's Early', 'Cardinal', 'Anab-e-Shahi', 'Black Prince', 'Gold', 'Dehkani', 'Shamas Guru', 'Thompson', 'Perlette', 'Red Globe', 'Cardinal', 'King's Ruby', 'NARC Black', 'Crimson', 'Flame', 'Sultana' and 'Muscatil' (Aujla *et al.*

To cite this paper: Khan AS, M Ibrahim, SMA Basra, S Ali, MH Almas, M Azam, R Anwar, MU Hasan (202x). Post-bloom applied moringa leaf extract improves growth, productivity and quality of early-season maturing grapes (*Vitus vinifera*). *Intl J Agric Biol* 00:000–000

2011; Khan *et al.* 2011; Anonymous 2017). Earlier, the cultivation of grapes at commercial scale was restricted only to Balochistan and some area of Khyber Pakhtunkhwa because during summer season monsoon rains in Punjab result in attack of fungal diseases and rottening of berries. Researchers have evaluated different indigenous and exotic germplasm to identify early-season maturing grapes cultivars which could escape these rains and mature before the onset of rainy season for commercial production in the monsoon regions of central Punjab such as 'King's Ruby', 'NARC Black' and 'Perlette' (Khan *et al.* 2011; PARC 2018).

Growth and development of grapevine and grape berries quality are influenced by many internal and external factors such as cultivar, exposure to sun light, temperature, humidity, soil, nutrition and hormonal regulation (Conde *et al.* 2007). Both macro and micro-nutrients affect the yield and quality related features of grapes (Usha and Singh 2002). Various physiological functions such as development of flower, berry, and seed, setting of fruit, length of cluster, compactness of bunch, physical and chemical attributes of berry are regulated by many internal plant growth substances. Such variables can also be regulated by foliar application of plant growth regulators (PGRs), though, the effects may contrast with the variation in concentration, application time, growth stage and vine age (Farooq and Hulmani 2000; Korkutal *et al.* 2008; Shah *et al.* 2015).

Moringa oleifera known as 'Drumstick Tree' exhibits outstanding health promoting benefits (Mishra *et al.* 2011) and rich source of various phytochemicals (Leone *et al.* 2015), plant growth regulator cytokinin (zeatin), macro and micro-nutrients, phenolics, antioxidants, carotenoid, vitamins and ascorbates (Foidl *et al.* 2001; Aslam *et al.* 2005; Yasmeen *et al.* 2014). It has been found that on dry weight basis its leaves contained 27.5 mg kg^{-1} cytokinins, 15.9 mg kg^{-1} auxins, 16.8 mg kg^{-1} gibberellins and 10.5 mg kg^{-1} abscisic acid (Abusuwar and Abohassan 2017). Due to presence of the above-mentioned compounds, the foliar application of MLE has been reported to promote growth and development of various agronomic and horticultural crops (Foidl *et al.* 2001; Nasir *et al.* 2016, 2018, 2020). Exogenous application of MLE significantly improved growth, quality, and yield characters of plum (Thanaa *et al.* 2017), pear (El-Hamied and El-Amary 2015) and orange (El-Enien *et al.* 2015) fruit. Similarly, 'Kinnow' mandarin trees treated with 0.3% MLE in combination with, K and Zn at fruit set stage showed significantly higher productivity and with better fruit quality (Nasir *et al.* 2016, 2018, 2020).

Presently, the excessive and frequent use of chemical inputs such as fertilizers and PGRs has increased the consumer awareness for their hazardous effects (Helmy *et al* 2015). There is now a growing demand for availability of relatively eco-friendly, affordable, easily accessible, and naturally available resources for improving crop growth, productivity and quality (Rashid *et al.* 2018). To the best of our knowledge, at present no information is available about the influence of exogenous application of MLE on growth, productivity, and quality of grapes. Therefore, present study investigated the effect of foliar application of MLE at various phenological stages on grapevine growth, productivity, and berry quality of five early-season maturing commercial table grapes cultivars grown under the subtropical climatic conditions.

Materials and Methods

Plant material

Four years old, five commercial grapes (*Vitis vinifera* L.) cultivars *viz.* 'Cardinal', 'Flame Seedless', 'King's Ruby', 'NARC Black' and 'Perlette' propagated asexually (through cuttings) and grown in uniform condition at Rana Abdul Qayyum's Commercial Grape Vineyard, 41 R.B., Rohrhi-Wala (31°38'59.8"N; 73°25'28.4"E), Tehsil Sangla, District Nankana Sahib, located about 55 km east to Faisalabad were selected for this experiment. These vines trained on permanent support as Four Arm Kniffin System (with 3.4 m × 3.4 m row and 2.1 × 2.1 m plant distance) were treated with uniform standard commercial cultural practices such as pruning, fertilizer application, irrigation, weeding, insect-pest and disease management.

Experimental treatments

For MLE, the fresh leaves after harvest were kept overnight at -20°C before grinding for their leaf extract (Nasir *et al.* 2016). MLE solution (3%) was prepared by mixing 300 mL of MLE with 10 L of distilled water. Foliar spray of 3% MLE was applied to all grape cultivars at three phonological growth stages (*i.e.*, at bloom, berry set and premature stages) using hand sprayer thoroughly until drops run-off from the leaves. The experiment was designed as two factors (treatments and cultivars) factorial arrangements under RCBD. Single vine was used as experimental unit, replicated thrice.

Determination of leaf nutrients

At harvest 40–50 healthy uniform leaves (along with petiole) apparently free from any symptoms of disease or insect pest were harvest from each experimental unit at random to determine the leaf nutrient status. After proper washing and drying, grinded leaf powder was used for further analysis. Leaf nitrogen (N) was estimated on micro kjeledhal apparatus, P on spectrophotometer and K on flame photometer prescribed by Chapman and Parker (1961) as per cent dry weight. Whereas, leaf Fe, manganese (Mn) and zinc (Zn) were estimated by following the protocol described in AOAC (2000) on atomic absorption spectrophotometer. Before the determination of leaf P, K, Fe, Mn and Zn wet digestion were done following the detailed procedure used earlier by Khan *et al.* (2015) and expressed as mg kg^{-1} DW.

Vegetative and reproductive growth

For the study of growth behavior, five uniform and health canes per experimental vine were selected and tagged. Data regarding cane length (cm), leaf size (cm^2), No. of leaves per cane, berry set percentage (%), berry drop percentage (%), total no. of berries per cluster, rachis length (cm), cluster weight (g), cluster size (cm^2), berry weight (g), berry size (mm^2), total clusters per vine (No.), yield per vine (kg), yield per acre (kg) were recorded by using the method described by Khan *et al.* (2012).

Berry quality parameters

For chemical analysis of fresh grapes berry (randomly selected 250 berries per experimental unit), juice was extracted manually by using muslin cloth. Berry juice pH was taken by digital pH meter (HI 98107, Hanna Instruments, Mauritius). A digital refractometer (RX-5000 Atago, Japan) was used for determining TSS as expressed in ºBrix. Method described by Khan *et al.* (2011) was used to estimate the titratable acidity (%) and different forms of sugars (total, reducing and non-reducing sugars) in grape berry juice. Calculation of TSS:TA ratio was done by dividing TSS with the TA percentage. Ascorbic acid contents (Vitamin C) in grape berry juice was estimated by adopting the process described by Khan *et al.* (2011) and were expressed as mg 100 g^{-1} FW. Assay reported by Brand-Williams *et al.* (1995) was used to estimate the total antioxidants in grapes berry juice by 2, 2-diphenyl-1picrylhydrazyl radical (DPPH) assay and were expressed as % inhibition. Total phenolics contents (TPC) in grapes juice were estimated using the Folin–Ciocalteu (FC) technique defined by Ainsworth and Gillespie (2007) and were expressed as mg GAE 100 g^{-1} FW.

Statistical analysis

Data were evaluated statistically by using software Statistix 8.1 and Least Significant Difference (LSD) test was applied to differentiate means by using the differences among different means at $P \leq 0.05$.

Results

Leaf mineral contents

Foliar application of MLE to the grapevine cultivars did not show significant effect on leaf N, P and Mn contents (Table 1). However, these mineral concentrations were higher in MLE-treated vine as compared to leaves of untreated vines. This impact of MLE on leaf N, P and Mn may be ascribed to very lower concentration present in the MLE which remain unaffected to improve their endogenous level. Exogenously applied MLE (3%) significantly increased leaf K, Fe and Zn contents as compared to untreated control.

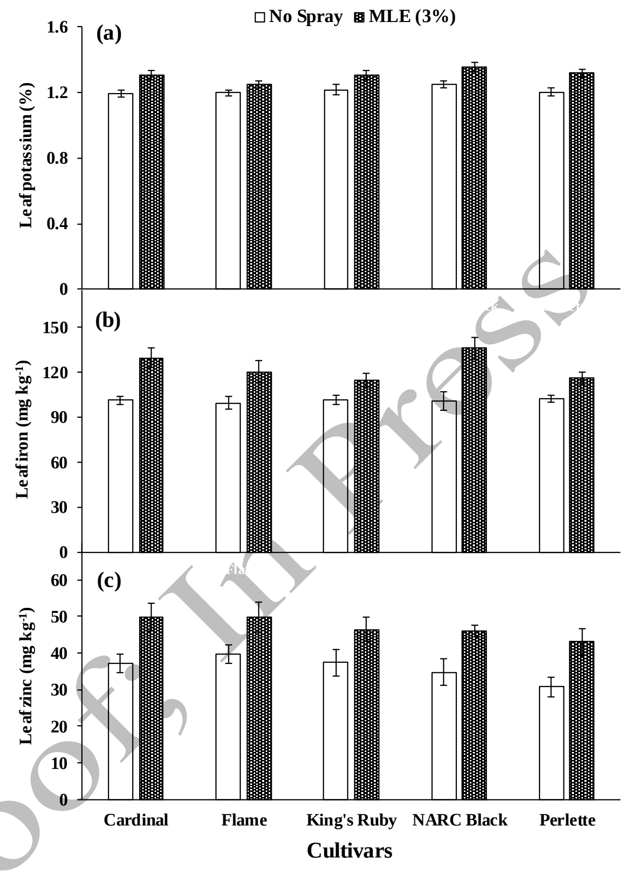

Fig. 1: Effect of foliar application of MLE (3%) on leaf K (**a**), Fe (**b**) and Zn (**c**) contents of grapes cultivars. Vertical bars indicate ± SE of means. n = 3 replicates

Application of MLE showed highest leaf K (1.36%) and Fe (136 mg kg^{-1}) contents in leaves of grapes cv. 'NARC Back' compared to untreated control (Fig. 1a–b); while, maximum increase in Zn levels (from 30.7 to 43 mg kg^{-1}) in leaves of 'Perlette' (Fig. 1c).

Vegetative and reproductive growth

The number of leaves per cane was not significantly affected by application of MLE (3%) on grapes cultivars. The exogenous spray of MLE (3%) on grapevines at various growth phases (at bloom + fruit set + premature stages) significantly improved leaf size of all cultivars. Highest leaf size was observed in 'NARC Black' (112.3 cm^2 *vs.* 79.7 cm^2 of untreated) and least increase in 'Flame' (176.9 cm^2 *vs.* 170.5 cm^2) of untreated, respectively (Table 1). Likewise, after foliar applied MLE (3%), grapevines exhibited positive significant impact on the cane length and rachis length (Table 2). Highest increase of cane length with application of MLE treatment was found in grapes cv. 'Perlette' (25.6%) followed by 'NARC Black' (19.2%), 'Flame' (18.2%), 'Cardinal' (7.9%) and 'King's Ruby' (6.8%).

Table 1: Effect of foliar application of MLE (3%) on leaf N, P, Mn contents, no. of leaves and leaf size of grapes cultivars

Cultivars	Leaf N (%)		Leaf P (%)		Leaf Mn (mg kg^{-1})		Leaves per cane (No.)		Leaf size (cm^2)	
	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray
'Cardinal'	2.68	2.80	0.34	0.36	180.00	188.00	43.76	47.60	140.01	175.71
'Flame Seedless'	2.68	3.03	0.35	0.37	187.33	196.33	102.77	106.52	170.49	176.88
'King's Ruby'	2.68	2.68	0.36	0.37	200.67	208.33	109.31	116.82	183.21	190.19
'NARC Black'	2.80	2.92	0.37	0.38	190.33	196.00	67.73	69.80	79.66	112.31
'Perlette'	2.45	2.57	0.36	0.37	204.67	209.33	76.00	84.40	181.80	216.30
LSD ($P \leq 0.05$)										
Treatments	NS		NS		NS		NS		13.100	
Cultivars	NS		NS		12.095		11.714		20.713	
Treatments x cultivars	NS		NS		NS		NS		NS	

n = 3 replicates, NS = non-significant

Table 2: Effect of foliar application of MLE (3%) on cane length, rachis length and berry components of grapes cultivars

Cultivars	Cane length (cm)		Rachis length (cm)		Berries per cluster (No.)		Berry size (mm^2)		Berry weight (g)	
	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray
'Cardinal'	87.27	94.13	18.60	21.70	181.95	240.20	247.55	318.25	3.69	3.92
'Flame Seedless'	106.11	125.41	18.08	19.00	281.66	293.22	236.31	246.01	2.07	2.21
'King's Ruby'	90.75	96.94	18.81	24.10	339.35	363.11	255.70	290.51	2.27	2.42
'NARC Black'	112.20	133.77	14.00	17.57	94.07	112.60	256.55	309.58	2.45	2.88
'Perlette'	108.53	136.27	21.20	25.73	423.27	514.33	200.22	223.54	1.59	1.95
LSD ($P \leq 0.05$)										
Treatments	7.3807		1.5301		22.527		11.800		0.1680	
Cultivars	11.670		2.4193		35.618		18.657		0.2656	
Treatments x cultivars	NS		NS		NS		26.385		NS	

n = 3 replicates, NS = non-significant

The grapes reproductive characters varied with the cultivar but application of moringa exogenously on grapevines showed promising improvement in reproductive characters such as rachis length, reduced berry drop and increased berry set, berries per cluster, berry size, berry weight, cluster size, cluster weight and ultimately yield of all the studied cultivars. Exogenously applied 3% MLE significantly improved the rachis length of grapevine cultivars (Table 2). The highest increase in rachis length was observed in 'King's Ruby' (28.1%) and lowest in 'Flame Seedless' (5.1%) as compared to untreated vines. Berry set on the clusters of grapes was significantly enhanced by MLE (3%). Maximum increase of berry set percentage was found in 'Cardinal' (39.2% compared to 30.7%) and followed by 'NARC Black' (50.5% compared to 41.9) and 'Perlette' (51.8% compared to 45.8%) (Fig. 2a). On the other hand, MLE (3%) treatment at three growth phases significantly reduced the berry drop from the clusters of grapes as compared to untreated vines. 'Cardinal' revealed up to (24.9%) less berry drop than the vines without treatment followed by 'Perlette' (24.3%), 'NARC Black' (16.9%), 'King's Ruby' (6.5%) and 'Flame Seedless' (1.9%) (Fig. 2b).

There was highly significant variation in number of berries per cluster, berry size and berry weight among the cultivars (Table 2). As well as, exogenous applied MLE significantly improved berry characters as compared to control without any treatment. The berries per cluster increased from (4.1%) to (32%) in 'Flame Seedless' and 'Cardinal', respectively. Whereas, 'Perlette', 'NARC Black' and 'King's Ruby' had shown an increase of berries per cluster (21.5%), (19.7%) and (7%), respectively as

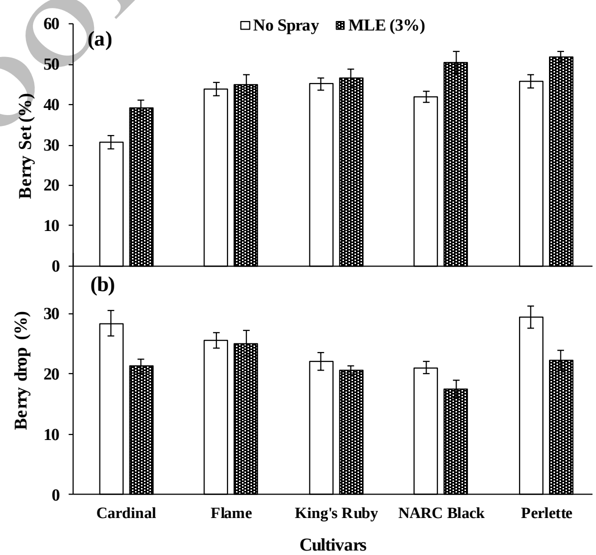

Fig. 2: Impact of foliar application of MLE (3%) on berry set (**a**) and berry drop (**b**) percentage of grapes cultivars. Vertical bars indicate ± SE of means. n = 3 replicates

compared to untreated vines. As MLE spray increased berry set and reduced berry drop percentage, it ultimately led to an increase in the number of berries which reached to harvest maturity and thereby increased yield. In response to MLE 'Cardinal' showed highest (28.6%) increase in berry size (318.3 mm^2 compared to 247.6 mm^2 of untreated vines) (Table 2). 'Perlette' had highest and 'Cardinal' had lowest significant increase in berry weight upon exogenous application of MLE (3%) as compared to its corresponding

Table 3: Effect of foliar application of MLE (3%) on yield components of grapes cultivars

Cultivars	Clusters per vine (No.)		Cluster size (cm^2)		Average cluster weight (g)		Yield (kg $vine^{-1}$)		Yield (tones ha^{-1})	
	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray	No spray	MLE spray
'Cardinal'	31.00	31.33	170.50	217.23	267.33	341.73	8.33	10.72	11.6	15.0
'Flame Seedless'	43.67	48.33	147.90	158.79	339.44	389.77	14.88	18.94	20.8	26.4
'King's Ruby'	43.33	42.67	160.62	172.10	353.58	404.00	15.55	17.41	21.7	24.3
'NARC Black'	63.33	65.00	101.55	126.20	117.87	149.93	7.48	9.74	10.4	13.6
'Perlette'	61.33	64.00	225.25	275.42	423.07	538.67	26.01	34.35	36.3	47.9
LSD ($P \leq 0.05$)										
Treatments	NS		14.466		28.620		2.5056		1415.7	
Cultivars	7.1318		22.872		45.253		3.9617		2238.4	
Treatments x cultivars		NS	NS		NS		NS		NS	

n = 3 replicates, NS = non-significant

untreated vines.

Exogenous application of MLE did not show any significant effect on number of clusters per vine (Table 3). However, MLE applied at flowering, berry setting and premature stages significantly improved cluster size, cluster weight and ultimately yield. Amon cultivars, minimum increase of cluster size was evident in 'King's Ruby' (7.15%) followed 'Flame Seedless' (7.4%) and maximum increase was in 'Cardinal', 'NARC Black' and 'Perlette' (27.4, 24.3 and 22.3%, respectively). Maximum increase in cluster weight was observed in cv. 'Cardinal' followed by 'Perlette', 'NARC Black', 'Flame Seedless' and 'King's Ruby' cvs., as compared to untreated vines. MLE (3%) had also a remarkable significant impact on the yield of grapes per vine. The highest increase of yield per vine was observed in 'Perlette' (32.1%) followed by 'NARC Black' (30.3%), 'Cardinal' (28.8%), 'Flame Seedless' (27.3%) and 'King's Ruby' (11.9%) as compared to their corresponding untreated vines (Table 3).

Berry quality

Foliar application of MLE 3% solution did not show any significant impact on the colour and flavor berries. However, berry texture, taste and overall acceptability exhibited significant improvement with MLE application in all cvs. (Table 4). Exogenous application of MLE significantly improved TSS and TSS: TA ration and reduced TA of all the grapevines cvs. Highest TSS (10.9%) was observed in 'NARC Black' and lowest value of TSS was recoded in 'Flame Seedless' (4.6%) compared their respective berries harvested from untreated vines (Fig. 3b). Similarly, MLE application significantly improved the TSS: TA ratio of berries harvested form treated than untreated vines (Fig. 3c). Whereas, MLE effectively reduced the acidity in grapes at harvest. The 'Perlette' showed (21.7%) less TA than the untreated control vines followed by 'King's Ruby' (19.51%), 'NARC Black' (15.2%), 'Flame Seedless' (11.2%) and 'Cardinal' (8.6%) cvs. (Fig. 3a).

Foliar application of MLE showed significantly improved total, reducing and non-reducing sugar percentage of grape berry juice. These sugars also varied significantly among cultivars. 'NARC Black' had highest (20.1%) and 'Flame Seedless' (14.8%) had lowest significant increase in

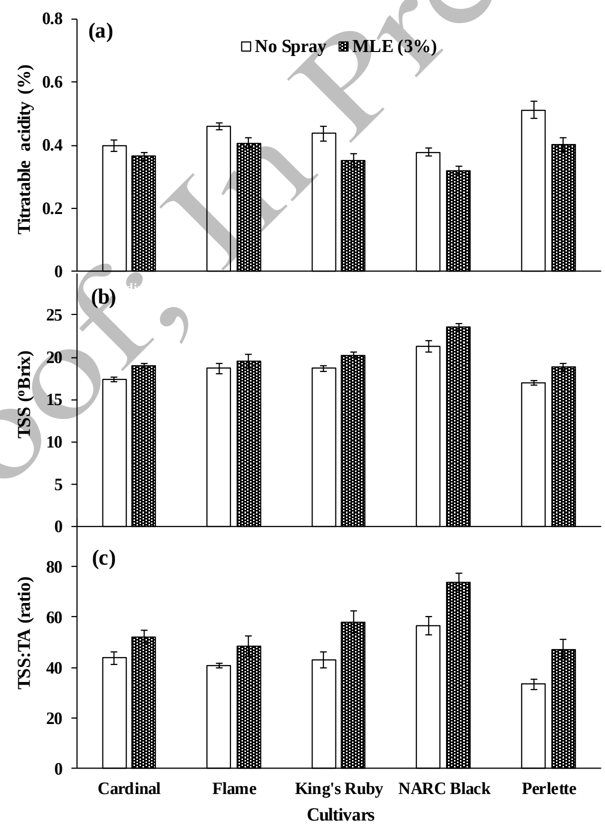

Fig. 3: Effect of foliar application of MLE (3%) on TA (**a**), TSS (**b**) and TSS:TA ratio (**c**) of berry juice of grapes cultivars. Vertical bars indicate ± SE of means. n = 3 replicates

total sugar contents in grape juice upon exogenous application of 3% MLE (Fig. 4a). However, foliar application of MLE showed non-significant results with respect to pH and total antioxidant contents of grapes berry juice (Table 5). Though, pH and total antioxidant contents of grape berry juice somewhat varied among the cultivars. 'NARC Black' had shown the highest (53.4%) inhibition and 'Perlette' (41.7%) inhibition of total antioxidant contents in juice of berries collected from untreated grapevines. On an average, irrespective of cvs. application of MLE improved the level of total antioxidants of grapes

Table 4: Effect of foliar application of MLE (3%) on organoleptic characters of different grape cultivars

Cultivars	Colour (score)		Texture (score)		Taste (score)		Flavour (score)		Overall acceptability (score)	
	No Spray	MLE (3%)	No Spray	MLE (3%)	No Spray	MLE (3%)	No Spray	MLE (3%)	No Spray	MLE (3%)
'Cardinal'	6.53	6.67	5.80	6.53	6.00	6.60	5.87	6.20	6.47	7.07
'Flame Seedless'	5.27	5.60	5.07	5.20	5.13	5.53	5.07	5.40	5.67	6.13
'King's Ruby'	5.73	5.93	5.07	5.73	5.20	5.53	5.87	6.00	5.60	6.10
'NARC Black'	6.13	6.33	6.40	7.53	6.13	7.40	6.13	6.13	6.80	7.60
'Perlette'	6.87	7.13	5.93	6.93	6.13	7.20	5.67	6.00	6.60	7.27
LSD ($P \leq 0.05$)										
Treatments	NS		0.4089		0.2948		NS		0.2211	
Cultivars	0.3819		0.6466		0.4662		0.5447		0.3496	
Treatments x Cultivars	NS		NS		NS		NS		NS	

n = 3 replicates, NS = non-significant

Table 5: Effect of foliar application of MLE (3%) on pH and total antioxidant contents of berry juice of different grape cultivars

Cultivars	pH		Total antioxidant (% inhibition)	
	No Spray	MLE (3%)	No Spray	MLE (3%)
'Cardinal'	3.05	3.18	43.56	49.49
'Flame Seedless'	2.91	3.04	52.73	54.18
'King's Ruby'	3.03	3.07	49.66	51.04
'NARC Black'	3.24	3.32	53.39	55.01
'Perlette'	2.81	2.90	41.73	45.86
LSD ($P \leq 0.05$)				
Treatments	NS		NS	
Cultivars	0.2169		6.88	
Treatments × Cultivars	NS		NS	

n = 3 replicates, NS = non-significant

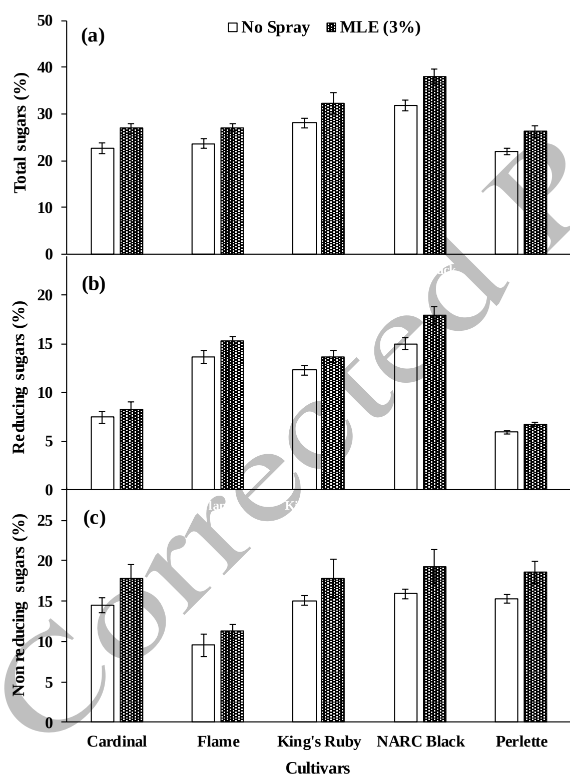

Fig. 4: Effect of foliar application of MLE (3%) on total (**a**), reducing (**b**) and non-reducing (**c**) sugar percentages of berry juice of grapes cultivars. Vertical bars indicate ±SE of means. n=3 replicates

berries in contrast to untreated control.

Exogenously applied MLE significantly improved berry juice Vitamin C and total phenolic contents (TPC). Highest increase in Vitamin C contents was recorded in cv. 'Cardinal' (12.82 mg 100 mL^{-1}) compared to untreated vines (10.1 mg 100 mL^{-1}) which was about 27.3% increase followed by 'Perlette' were (10.9 9.2 mg 100 mL^{-1} compared to 9.2 mg 100 mL^{-1} of untreated vines) which was (20%) increase; whereas, least 8.3% increase in Vitamin C contents was observed in cv. 'King's Ruby' (Fig. 5a). Irrespective of cvs., grapes harvested from MLE sprayed vines exhibited 1.1-fold to 1.3-fold higher TPC, as compared to untreated control. Among grapes cvs., cv. 'NARC Black' treated with MLE showed highest (302 mg GAE 100 g^{-1}) about 1.3-fold increase in the TPC as compared to control (Fig. 5b).

Discussion

In current study, vines sprayed with MLE showed higher levels of macro and micronutrients as compared to control. Moringa is found to be rich in minerals including K, Fe and Zn (Nasir *et al.* 2016). These might be used as an important mineral supplement as an alternate to chemical forms of these elements for crop improvement (Aslam *et al.* 2005). The accumulation of mineral nutrients including K and Fe in rocket plants were significantly higher in the plants treated with aqueous extracts of both leaf and twig extracts of moringa (Abdalla 2013). Similarly, MLE increased leaf K percentage contents of 'Navel' orange trees (El-Enien *et al.* 2015). Earlier exogenous application of seaweed extract was found to enhance the leaf Zn content of the grapes (Sabir *et al.* 2014). Likewise, MLE treated vines exhibited expanded leaf size in all cultivars in contrast with non-

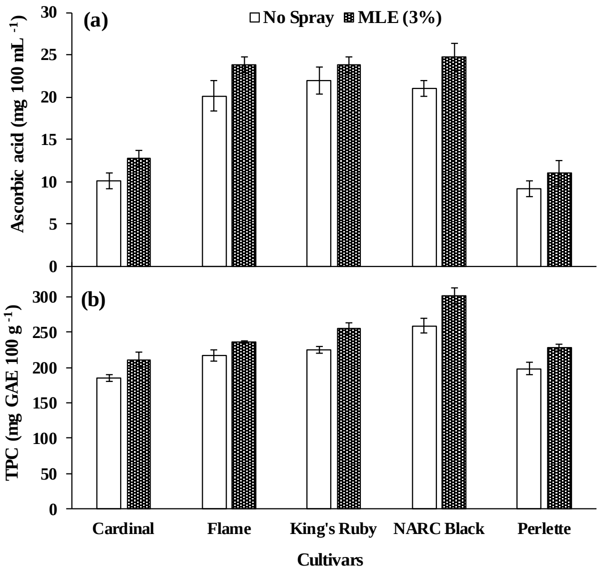

Fig. 5: Effect of foliar application of MLE (3%) on ascorbic acid (**a**) and total phenolic (**b**) contents of berry juice of grapes cultivars. Vertical bars indicate ± SE of means. n = 3 replicates

treated vines (Table 1). Similarly, it has been reported reported that seed soaking in MLE + foliar spray of MLE on common bean (*Phaseolus vulgaris* L.) cv. Bronco significantly improved their leaf area (Rady and Mohamed 2015). The improvement in cane length and rachis length of grape cultivars under study which might be due to the availability of plant growth hormones (such as zeatin) and mineral elements found abundantly in moringa leaves, which play important role in cell division and cell elongation that lead to promote the growth of plants and can be used in agriculture industry (Ashfaq *et al.* 2012). *Phaseolus vulgaris* L. plants treated as seed soaking by salicylic acid + foliar spray with MLE were found to significantly increase shoot length (Rady and Mohamed 2015).

Reproductive growth showed significant improvement in MLE treated vines (Table 2–3). This increase can be ascribed to the improved hormonal and mineral nutrient status of treated plants (Ashfaq *et al.* 2012). Earlier, grapevines sprayed with *Ascophyllum nodosum* marine-plant extract and PGR (brassinosteroids) significantly improved their rachis length (Norrie and Keathley 2006). Such increase in fruit set may be owed to the balanced nutritional properties whereas, berry drop may be due to the imbalance of nutrients in the grapevine. As MLE is found to rich source of important macro and micro elements, growth stimulators, amino acids, carbohydrates and proteins, its foliar application might have elevated the nutritional properties of grape and consequently increased berry set and reduced berry drop. In agreement to this, in a study the application of growth promoting compounds on grapes has improved fruit set, reduced premature berry drop and improved bunch parameters (Farooq and Hulmani 2000). As *M. oleifera* leaves are high in zeatin (cytokinin) (Ashfaq *et al.* 2012) the effect of MLE supports the fact that fruit size increases with cell division and cell enlargement and may be attributed to that cytokinins (Santner *et al.* 2009). Likewise, moringa extract treatment has significantly increased fresh fruit weight 'Kinnow' mandarin (Nasir *et al.* 2016) and plum (Thanaa *et al.* 2017).

The PGRs can be used to increase yield per unit area of a plant because they are responsible for changing the patterns of growth and development as in present study (Table 3). MLE has been found to contain considerable amounts of indole-3-acetic acid, gibberellins, zeatin (natural cytokinin) and abscisic acid (Rady and Mohamed 2015). These growth hormones influence yield remarkably. Similarly, MLE has been reported to have increased the yield of crops like onion, tomato, peanut, sugar cane and corn (Foidl *et al.* 2001), navel orange (El-Enien *et al.* 2015), pear (El-Hamied and El-Amary 2015) and plum (Thanaa *et al.* 2017). Plant growth regulators are found to be effective in improving grape quality and thereby making it acceptable for the consumers. MLE having plant growth promoting properties had also improved the grape qualitative characters. Similarly, grapevine treatment with IAA, GA_3 and zeatins improved the quality variables of 'Superior Seedless' table grapes (Jalil *et al.* 2017). ABA enhanced cluster attractiveness, colour and visual liking of grapes (Reynolds *et al.* 2016).

Moringa is wonder plant with unique nutritional profile significantly affect biochemical quality of fruits and vegetables. Vines sprayed with MLE showed higher concentration of biochemical quality attributes as compared to control (Fig. 2). Application of PGRs and nutrient elements improve the TSS percentage in the plants. MLE applied on orange trees had significantly increased juice TSS (El-Enien *et al.* 2015). Accumulation of sugar and acidity levels is inversely proportional to each other. As MLE increased the TSS and sugar contents in grape berry juice it correspondingly reduced the TA percentage. Accordingly, foliar spray of MLE on the 'Hollywood' plum trees significantly reduced the TA as compared to untreated trees (Thanaa *et al.* 2017). In coincidence to our results regarding sugars (Fig. 4), MLE had significant positive influence on the total sugar contents of 'Le-Conte' pear (El-Hamied and El-Amary 2015). The reducing sugar contents of the berries harvested from the vines treated with MLE were more than control (Fig. 4b). The highest and lowest percent increase in the reducing sugar contents of berry juice were in the 'NARC Black' had (19.30%) and 'Cardinal' (10.15%), respectively in comparison with their untreated ones. MLE (3%) had a significant positive impact on non-reducing percentage of grape juice of all the cultivars (Fig. 4c).

MLE application significantly improved ascorbic acid and phenolic contents of table grapes (Fig. 5a–b). Accordingly, when common bean (*Phaseolus vulgaris*) plants, pepper (*Capsicum annuum* L.) plants and plum trees were treated with MLE, it resulted in significantly higher vitamin C contents (Thanaa *et al.* 2017). Phenolic compounds play an important role in grape organoleptic properties. MLE when applied in combination with, K and Zn applied on 'Kinnow' mandarin resulted in significantly higher total phenolic contents (Nasir *et al.* 2016). Foliar spray of MLE significantly increased TPC of spinach leaves (Aslam *et al.* 2016).

Conclusion

Grapes cvs. 'Perlette', 'NARC Black' and 'Cardinal' showed best response to MLE sprays as compared to 'King's Ruby' and 'Flame Seedless'. Thus, exogenous application of MLE can be efficiently applied on grapevines at flowering, berry setting and premature growth phases to improve its vegetative, reproductive growth as well as physico-chemical quality features.

Acknowledgments

We are grateful to Rana Abdul Qayyum, the owner of Commercial Grape Vineyard, 41 R.B., Rohrhi-Wala for providing grapevines to conduct this research trial.

Author Contributions

A.S. Khan and S.M.A. Basra conceived the idea and planned the study. M. Ibrahim conducted the research trial. All authors equally contributed in providing critical feedback for analysis, editing, commenting, revising and approving the manuscript without conflict of interest.

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