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Yield and quality enhancement as influenced by pre-harvest nutrient spray in grapes (*Vitis vinifera* L.) var. Muscat Hamburg by adopting double pruning and double cropping system under Cumbum Valley condition

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Abstract
An experiment was conducted to assess the effect of pre-harvest treatments on biometrical, physio-chemical and shelf life in grapes variety Muscat Hamburg. The experiment was conducted in randomized block design with 14 treatments (T_1 ($Ca(NO_3)_2$ 0.5%), T_2 ($Ca(NO_3)_2$ 1.0%), T_3 (KNO_3 0.5%), T_4 (KNO_3 1.0%), T_5 ($CaCl_2$ 0.5%), T_6 ($CaCl_2$ 1.0%), T_7 (sulphate of potash (SOP) 0.5%), T_8 (SOP 1.0%), T_9 (T_1+T_3), T_{10} (T_2+T_4), T_{11} (T_5+T_7), T_{12} (T_6+T_8), T_{13} (water spray) and T_{14} (control)) in two replications and imposed at berry development and veraison stage. The data revealed that T_{12} showed the highest values for bunch weight, fruit yield vine^{-1}, berry diameter, berry weight, seed weight, berry firmness, juice recovery, TSS, total sugars, reducing sugars, non-reducing sugars, shelf life, petiole potassium and berry potassium with the least berry cracking, berry shattering, PLW and berry rotting. While T_{14} showed the lowest values for yield and quality parameters. The treatment T_{11} recorded the highest anthocyanin and total phenols content. T_{10} expressed the maximum nitrogen content in petiole, whereas T_8 recorded the highest petiole phosphorus. The petiole calcium was more in T_6. The highest petiole magnesium was found in T_3.

Keywords: Enhancement, influenced, Muscat Hamburg, *Vitis vinifera* L.

Introduction
The grapes (*Vitis vinifera* L.) is the most promising fruit crop grown widely in tropical and subtropical regions in the world and belongs to the family Vitaceae. Globally, it is mostly cultivated in the temperate climate regions and preponderance of produce is being used for wine making. India has the highest productivity of among the grape growing countries in the world. The total area is 0.13 million hectares which covers about 2.01% of the total area with an annual production of 2.95 million tonnes (NHB 2019). Grapes is cultivated in an area of about 2,184 ha in Theni district of Tamil Nadu. Out of this area, Muscat Hamburg (Panneer) is grown in 2000 ha and remaining 184 ha occupies seedless varieties. In Tamil Nadu, Cumbum valley is a major growing belt for grapes production. The soil and climatic conditions prevailed in the Cumbum Valley is highly congenial for the harvest of grapes throughout the year, while in most of the other growing states, the season ends with summer. The grapes grown in this region is harvested two times in a year or five times in two years by staggered pruning practices. The average productivity of grapes is 29.20 tonnes per hectare in Cumbum Valley whereas the world and Indian average is 9 and 25 tonnes per hectare respectively. There are many factors like soil, climate, variety, rootstock, nutrition, irrigation, maintenance, pruning etc., which influence the yield and quality of grapes (Swathi *et al.*, 2019) [35]. Among the various factors, nutrient management plays an important role and it determines the yield, quality and storability of grapes. In Tamil Nadu, grapes growers are facing lot of problems like uneven colour development, berry cracking, berry shattering, price fluctuation and various pest and diseases attacks. Of which berry cracking, berry shattering and uneven colour development may result in reduction of yield, quality, shelf life and marketability. The berry cracking is normally linked to rainfall events and calcium content which prevails during harvest season. Calcium showed an increasing trend up to veraison stage thereafter decreased (Amiri *et al.*, 2009) [4] and application of $CaCl_2$ during berry development stage induced considerable increase of calcium content in berries, while the postharvest calcium application was less effective (Miceli *et al.*, 1999) [24]. So, application at berry development and veraison

stage is optimum because application of nutrients to the leaves and cluster favours absorption within two days due to frequent stomatal opening.

Potassium is an essential major nutrient required for plant growth and development and plays a vital role in various activities *viz.*, berry sugar accumulation, protein synthesis, osmoregulation, photosynthetic activity, berry water relation, long distance transport of sugars, enzyme activation, charge balance, disease resistance, abiotic stress tolerance and mitigating senescence (Arora *et al.*, 2006, Geny *et al.*, 2005) [5, 17]. Potassium application increased both the colour and polyphenolic content (Mohammed *et al.*, 1993). Calcium (Ca) is essential for cell division, cell elongation, structure and permeability of cell membrane (Demarty *et al.*, 1984) [12]. It acts as a secondary messenger in many signaling pathways under biotic and abiotic stress condition. Calcium regulates the flesh firmness, ethylene production, ripening of fruits and stimulates colour development in grapes. High concentration of calcium contributes to delay senescence of grapes (Fortes *et al.*, 2015, Dodd *et al.*, 2010) [16, 13]. Calcium involved in biosynthesis of anthocyanin promotes the expression of anthocyanin structural genes (Gollop *et al.*, 2002, Xu *et al.*, 2014) [18, 36]. Both potassium and calcium were applied as foliar spray for quick nutrients supply to grapevine and to alleviate the nutrient deficiencies related with K and Ca (Dris and Niskanen 1996) [14]. Many studies showed that the pre-harvest spray of calcium and potassium on grapes as single nutrient increased the yield and physicochemical attributes but studies were lacking in combination of both especially in Muscat Hamburg variety of grapes. With this back ground, pre-harvest treatments with potassium and calcium based nutrients alone and in combination were given as spray at berry development and veraison stage to elucidate the effect on yield, quality and shelf life of grapes.

2. Materials and Methods

2.1 Plant material, vineyard site

An investigation was conducted in two different seasons, *viz.*, Season I (May, 2019 to September, 2019) and Season II (December, 2019 to April, 2020) at Grapes Research Station, Anaimalayanpatty, Rayappanpatty, Theni in four years old Muscat Hamburg grafted on dogridge rootstock and grape vineyard trained under bower system with the spacing of 3.0 × 2.0 m under Cumbum Valley condition.

2.2 Experimental details

Field experiment was laid out in randomized block design (RBD) with 14 treatments *viz.*, T_1($Ca(NO_3)_2$ @ 0.5%), T_2 ($Ca(NO_3)_2$ @ 1.0%), T_3 (KNO_3 @ 0.5%), T_4 (KNO_3 @ 1.0%), T_5 ($CaCl_2$ @ 0.5%), T_6 ($CaCl_2$ @ 1.0%), T_7 (sulphate of potash (SOP) @ 0.5%), T_8 (SOP @ 1.0%), T_9 ($Ca(NO_3)_2$ @ 0.5% + KNO_3 @ 0.5%), T_{10} ($Ca(NO_3)_2$ @ 1.0% + KNO_3 @ 1.0%), T_{11} ($CaCl_2$ @ 0.5% + SOP @ 0.5%), T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%), T_{13} (water spray) and T_{14} (control) and two replications. Six grapevine plants were used for the study under each replication.

2.3 Yield parameters

Yield parameters *viz.*, number of bunches vine^{-1}, individual bunch weight (g), fruit yield vine^{-1} (kg), berry diameter (g), berry weight (g), bunch volume, number of seeds berry^{-1} and individual seed weight (mg) were calculated. Representative random samples of ten bunches per replication were collected to calculate the yield parameters.

2.4 Quality and biochemical parameters

Skin thickness of berries was measured by using digital vernier caliper. The juice was extracted from grape berries by using electric juicer and expressed in per cent. The berry firmness was measured with the help of standard penetrometer. The total soluble solids were calculated by using hand refractometer (0-32 per cent range). Titrable acidity was determined by titrating the fruit sample against 0.1N NaOH (Ranganna 1986) [27]. Total sugar content was estimated by the anthrone method suggested by Hedge and Hofreiter (1962) [19]. Reducing sugar content was analysed by Nelson- Somogyi (1952) [32] method. The anthocyanin content was quantified by the procedure described by Swain and Hillis (1959) [34]. The total phenols content was estimated with Folin-Ciocalteu reagent as suggested by Bray and Thorpe (1954) [9].

$$\text{Berry cracking} = \frac{\text{Number of cracked berries in a bunch}}{\text{Total number of berries in a bunch weight}} \times 100$$

2.5 Shelf Life

Shelf life was determined by taken number of days from harvest to retain their appearance and fit for consumption without any decay and expressed in days. The berry shattering was calculated by measuring the weight of shattered berries from each bunch and dividing them by total weight of the same bunch and given as percentage.

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial bunch weight} - \text{Final bunch weight}}{\text{Initial bunch weight}} \times 100$$

$$\text{Berry rotting (\%)} = \frac{\text{Weight of rotted berries}}{\text{Total bunch weight}} \times 100$$

2.6 Petiole nutrient analysis

The total nitrogen content in petiole was estimated by Micro kjeldahl method (Humphries 1956) [20]. Phosphorus was determined by Vanado molybdo phosphoric yellow colour method (Piper 1966) [26]. The potassium content in petiole was estimated by flame photometry method as suggested by Sumner (1944) [33], whereas calcium and magnesium content of petiole were analysed by the procedure described by Sumner (1944) [33].

2.7 Statistical analysis

The data were subjected to statistical scrutiny by (Panse and Sukhatme 1985) [25]. The pooled analysis over seasons was used to check the existence of treatment x season interactions. The pooled ANOVA and critical difference at 5 percent level of significance were calculated.

3. Results

3.1 Effect of pre-harvest treatments on yield attributes

Pre-harvest treatment of calcium and potassium on various yield parameters were recorded and presented in table 1. The pooled analysis of yield parameters from different treatments showed significant variations. The experimental results showed the highest values for yield parameters *viz.*, number of berries bunch^{-1} (93.95), individual bunch weight (286.77 g), fruit yield (14.31 kg vine^{-1}), estimated yield (20.43 t ha^{-1}), berry diameter (17.37 mm), individual berry weight (4.08 g), hundred berry weight (386.70 g), bunch volume (307.12 cc)

and individual seed weight (7.44 mg) were registered in the treatment T_{12} (calcium chloride @ 1.0% + sulphate of potash @ 1.0%). While the treatment T_{14} (control) showed the lowest values for yield parameters *viz.*, number of berries bunch^{-1} (81.46), individual bunch weight (242.80 g), fruit yield (11.99 kg vine^{-1}), estimated yield (17.12 t ha^{-1}), berry diameter (13.87 mm), individual berry weight (3.16 g), hundred berry weight (310.07 g), bunch volume (250.73 cc) and individual seed weight (6.27 mg). All the treatments showed non-significant effect on number of seeds per berry in both seasons.

Table 1: Pooled mean analysis of pre-harvest treatments on yield parameters of grapes var. Muscat Hamburg

Treatments	Treatment combinations	Number of bunches vine^{-1}	Number of berries bunch^{-1}	Individual bunch weight (g)	Fruit yield (kg vine^{-1})	Fruit yield (t ha^{-1})	Berry diameter (mm)	Individual berry weight (g)	100 berry weight (g)	Bunch volume (cc)	No. of seeds berry^{-1}	Seed weight (mg)
T_1	$Ca(NO_3)_2$ @ 0.5%	49.99	82.55	254.16	12.70	18.32	15.36	3.42	342.25	265.96	1.71	6.44
T_2	$Ca(NO_3)_2$ @ 1.0%	49.12	86.57	261.31	13.01	18.70	16.38	3.64	358.62	274.13	1.54	6.77
T_3	KNO_3 @ 0.5%	49.01	84.25	259.03	12.94	18.47	15.86	3.57	332.90	267.18	1.65	6.76
T_4	KNO_3 @ 1.0%	49.29	87.33	269.02	13.57	19.38	16.73	3.77	354.83	280.77	1.53	7.10
T_5	$CaCl_2$ @ 0.5%	49.77	82.41	259.96	12.41	17.72	15.36	3.54	335.05	260.12	1.72	6.69
T_6	$CaCl_2$ @ 1.0%	49.39	86.61	269.98	12.88	18.39	16.28	3.70	353.43	271.71	1.56	6.85
T_7	Sulphate of Potash @ 0.5%	49.27	85.11	264.94	13.06	18.65	15.93	3.62	344.72	276.33	1.79	6.83
T_8	Sulphate of Potash @ 1.0%	49.73	88.98	276.50	13.76	19.64	17.13	3.88	362.69	291.71	1.70	7.14
T_9	$CaNO_3$ @ 0.5% + KNO_3 @ 0.5%	48.28	88.49	270.99	13.09	18.69	16.40	3.69	343.83	283.83	1.74	7.01
T_{10}	$CaNO_3$ @ 1.0% + KNO_3 @ 1.0%	49.71	91.00	283.67	14.11	20.15	17.20	3.97	370.30	302.51	1.54	7.24
T_{11}	$CaCl_2$ @ 0.5% + SOP @ 0.5%	49.24	88.63	276.14	13.34	19.05	16.37	3.76	358.60	291.17	1.68	7.14
T_{12}	$CaCl_2$ @ 1.0% + SOP @ 1.0%	48.93	93.95	286.77	14.31	20.43	17.37	4.08	386.70	307.12	1.64	7.44
T_{13}	Absolute Control (Water spray)	49.83	81.91	244.58	12.31	17.58	14.07	3.20	310.96	252.79	1.48	6.30
T_{14}	Control	49.37	81.46	242.81	11.99	17.12	13.87	3.16	310.07	250.73	1.44	6.27
	SE(d)	-	3.89	4.81	0.41	0.57	0.56	0.12	8.76	6.89	-	0.18
	CD (0.05)	NS	7.95	9.76	0.83	1.19	1.15	0.25	17.79	14.00	NS	0.39

3.2 Effect of pre-harvest treatments on quality and bio chemical parameters

Various quality and biochemical parameters were recorded and presented in table 2 and 3. Based on pooled mean analysis, T_{12} (calcium chloride @ 1.0% + sulphate of potash @ 1.0%) registered more values for berry firmness (0.59 kg/cm^2), skin thickness (0.20 mm) and skin/pulp ratio (0.144). The highest value for juice recovery (70.18%) was registered in T_{10} (calcium nitrate @ 1.0% + potassium nitrate @ 1.0%). Whereas control (T_{14}) recorded the lowest berry firmness (0.37 kg/cm^2) and juice recovery (52.95%). The lowest skin thickness (0.12 mm) and skin/pulp ratio (0.100) were observed in T_{13} (water spray). The next best treatment was T_{10} (calcium nitrate @ 1.0% + potassium nitrate @ 1.0%) for all the quality parameters in both the seasons. The pre-harvest treatment T_{12} (calcium chloride @ 1.0% + sulphate of potash @ 1.0%) expressed the maximum values for total soluble solids (23.03 ^{0}brix) with minimum acidity (0.52%). Total sugars (17.14%), sugar/acid ratio (33.34), reducing sugars (15.73%) and non-reducing sugars (1.41%) were also found to be higher in the treatment T_{12}. Whereas the treatment T_{14} (control) recorded the lowest values for total soluble solids (19.63 ^{0}brix), total sugars (13.19%), sugar/acid ratio (17.73), reducing sugars (12.51%) and non-reducing sugars (0.68%). The next best treatment was T_{10} (calcium nitrate @ 1.0% + potassium nitrate @ 1.0%) for all the quality parameters. T_{11} (calcium chloride @ 0.5% + sulphate of potash @ 0.5%) scored the highest values for anthocyanin (66.28 mg 100 g^{-1}) and total phenols content (1607.68 mg GAE^{-1}). While the T_{14} had the lowest anthocyanin content (42.93 mg 100g^{-1}) and total phenols (1020.63 mg GAE^{-1}) along with highest acidity (0.75%).

Table 2: Pooled mean analysis of pre-harvest treatments on quality and biochemical parameters in grapes var. Muscat Hamburg

Treatments	Treatment combination	Berry firmness (kg/cm^2)	Berry cracking (%)	Skin thickness (mm)	Skin/ pulp ratio	Juice recovery (%)	TSS (^{0}brix)	Acidity (%)	Sugar / acid ratio
T_1	$Ca(NO_3)_2$	0.48	6.41	0.15	0.125	59.58	20.99	0.64	21.99
T_2	$Ca(NO_3)_2$	0.54	4.22	0.18	0.134	63.06	21.39	0.61	24.03
T_3	KNO_3 @ 0.5%	0.45	6.15	0.14	0.113	61.72	21.10	0.62	23.53
T_4	KNO_3 @ 1.0%	0.40	6.34	0.16	0.107	67.99	21.58	0.57	27.72
T_5	$CaCl_2$ @ 0.5%	0.50	5.40	0.15	0.138	58.33	21.35	0.64	22.29
T_6	$CaCl_2$ @ 1.0%	0.58	4.85	0.19	0.131	63.23	22.11	0.60	24.59
T_7	Sulphate of Potash @ 0.5%	0.48	7.67	0.15	0.115	60.87	21.79	0.60	24.88

T_8	Sulphate of Potash @ 1.0%	0.44	5.72	0.14	0.110	65.92	22.67	0.55	30.88
T_9	$CaNO_3$ @ 0.5% + KNO_3 @ 0.5%	0.46	5.56	0.16	0.114	65.67	21.77	0.60	25.68
T_{10}	$CaNO_3$ @ 1.0% + KNO_3 @ 1.0%	0.53	6.42	0.18	0.134	70.18	22.60	0.55	31.31
T_{11}	$CaCl_2$ @ 0.5% + SOP @ 0.5%	0.50	7.21	0.19	0.115	63.32	22.27	0.57	28.34
T_{12}	$CaCl_2$ @ 1.0% + SOP @ 1.0%	0.59	3.64	0.20	0.144	69.59	23.03	0.52	33.34
T_{13}	Absolute Control (Water spray)	0.39	8.81	0.12	0.100	53.37	19.89	0.74	18.20
T_{14}	Control	0.37	13.19	0.13	0.101	52.95	19.63	0.75	17.73
	SE(d)	0.09	0.79	0.018	0.024	3.15	0.56	0.017	1.21
	CD (0.05)	0.20	1.68	0.037	0.029	6.38	1.17	0.038	2.50

Table 3: Pooled mean analysis of pre-harvest treatments on biochemical parameters and shelf life in grapes var. Muscat Hamburg

Treatments	Treatment combination	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Anthocyanin (mg 100 g^{-1})	Total phenols (mg GAE^{-1})	Shelf life (days)	PLW (%)	Berry shattering (%)	Berry rotting (%)
T_1	$Ca(NO_3)_2$	13.99	13.17	0.86	48.65	1295.29	5.66	9.05	7.12	4.09
T_2	$Ca(NO_3)_2$	14.48	13.58	0.94	53.79	1455.63	4.56	8.09	5.99	3.29
T_3	KNO_3 @ 0.5%	14.41	13.40	1.01	46.44	1214.60	5.17	9.58	8.96	4.64
T_4	KNO_3 @ 1.0%	15.70	14.58	1.12	55.22	1348.27	5.42	10.25	7.27	4.02
T_5	$CaCl_2$ @ 0.5%	13.99	13.18	0.80	53.20	1222.44	5.64	8.83	6.52	3.37
T_6	$CaCl_2$ @ 1.0%	14.48	13.59	0.87	64.66	1414.41	6.80	7.78	4.57	3.19
T_7	Sulphate of Potash @ 0.5%	14.80	13.85	0.95	53.12	1316.34	5.66	10.56	9.06	4.96
T_8	Sulphateof Potash @ 1.0%	16.76	15.58	1.19	53.25	1424.40	5.93	9.04	7.43	4.55
T_9	$CaNO_3$ @ 0.5% + KNO_3 @ 0.5%	15.11	14.05	1.06	55.43	1255.05	6.09	9.46	8.96	4.82
T_{10}	$CaNO_3$ @ 1.0% + KNO_3 @ 1.0%	16.93	15.61	1.33	54.61	1507.33	6.33	8.67	6.07	3.57
T_{11}	$CaCl_2$ @ 0.5% + SOP @ 0.5%	16.07	14.97	1.10	66.28	1607.14	6.21	8.28	8.03	3.69
T_{12}	$CaCl_2$ @ 1.0% + SOP @ 1.0%	17.14	15.73	1.41	61.07	1501.44	7.05	6.98	4.39	3.06
T_{13}	Absolute Control (Water spray)	13.38	12.63	0.75	44.50	1021.85	4.91	12.33	15.62	7.30
T_{14}	Control	13.19	12.51	0.68	42.93	1020.63	4.79	13.31	15.90	7.60
	SE (d)	0.51	0.52	0.07	6.13	15.37	0.19	1.18	0.43	1.37
	CD (0.05)	1.05	1.06	0.14	12.43	31.42	0.41	2.40	0.88	1.81

3.3 Effect of pre-harvest treatments on shelf life

Pre-harvest spray of calcium and potassium on various yield parameters were recorded and presented in table 3. The shelf life (7.05 days) was maximum in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) followed by T_6 (calcium chloride @ 1.0%) with the value of 6.80 days and minimum shelf life (4.79 days) was found in T_{14} (control). T_{12} expressed the minimum berry shattering (4.39%), physiological loss in weight (6.98%) and berry rotting (3.06%), whereas T_{14} showed the maximum berry shattering (15.90%), physiological loss in weight (13.31%) and berry rotting (7.60%).

3.4 Effect of pre-harvest treatments on petiole nutrient contents

The results indicated that T_{10} ($Ca(NO_3)_2$ @ 1.0% + KNO_3 @ 1.0%) had the maximum value for petiole nitrogen (1.61%). Among the various treatments imposed, T_8 (SOP @ 1.0%) recorded the highest petiole phosphorus (0.54%), whereas T_6 (calcium chloride @ 1.0%) scored the lowest values for petiole nitrogen (1.26%) and petiole phosphorus (0.29%). T_{12} exhibited more petiole potassium, while the lowest petiole potassium (1.41%) were scored in T_2 ($Ca(NO_3)_2$ @ 1.0%). The petiole calcium (2.28%) was higher in T_6 ($CaCl_2$ @ 1.0%). While the petiole calcium was lesser (1.45%) in T_{14} (control). T_3 (KNO_3 @ 1.0%) recorded the highest petiole magnesium (0.45%), whereas T_{10} showed the lowest petiole magnesium content (0.21%).

4. Discussion

4.1 Yield attributes

The data illustrated that T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) had the highest number of berries $bunch^{-1}$ and it was significantly different from all other treatments. The variation in number of berries $bunch^{-1}$ might be due to the leaves retention, better food supply, proper cane maturity, berry size, berry diameter and disease resistance. The treatment T_{12} also scored the maximum values for bunch weight, hundred berry weight and fruit yield. The yield enhancement might be attributed due to the higher nutrient supplement (28% Ca, 50% K and 18% S) which increased the availability of nutrients in petiole and berry thereby more retention of healthy leaves with higher photosynthetic and assimilation rate. These findings were corroborated with the earlier works of Bonomelli and Ruiz (2010), Ciccarese *et al.*, (2013) [8, 11].

T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) also had maximum individual berry weight, berry firmness, bunch volume and berry diameter. This might be due to the positive influence of potassium and calcium on cell division, cell elongation,

calcium deposition, berry turgor, osmotic pressure and strengthening of cell wall. The pre-harvest treatments increased the calcium and potassium content in both the petiole and berries, which may improve berry characteristics by various physiological processes. The similar findings were reported by Ciccarese *et al.,* (2013) [11] in Italia grapes, Karimi (2017) [22] in Sultana grapes and Arora *et al.,* (2006) [5] in Perlette grapes.

4.2 Quality and biochemical parameters

In the present investigation, T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) registered more skin thickness of berries which may be due to calcium supplement. The increase in berry skin thickness and firmness may be attributed due to the positive effect of the calcium on cell wall stability by enhancing the cell wall thickening though accumulation of calcium salts deposition in the middle lamella (Cabanne and Doneche (2003) [10]. These findings were in accordance with the earlier reports of Ahmadi *et al.,* (2017), Biradarpatil *et al.,* (2015) [2, 7].

Potassium plays a vital role in sugar accumulation, photosynthetic activity, berry water relations, transport of sugars and mitigating senescence (Arora *et al.,* 2008). In the present study, the total soluble solids (TSS) was high in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%). The increased total soluble solids might be due to the positive effect of potassium on sugar accumulation. Owing to the positive effect of sugar transport, berry water relation in grapes and lower organic acids accumulation resulted in higher TSS. The similar results were confirmed with the findings of Arora *et al.,* (2006) [5] in Perlette grapes and Karimi (2017) [22] in Sultana grapes. Reduction in acidity as a result of potassium application with the lowest acidity was recorded in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%). The same findings were also reported by Al-Qurashi and Awad (2013) [3] in El-Bayadi grapes and Abd El-Razek *et al.,* (2011) [1] in Crimson seedless.

The highest total sugars reducing sugars and non-reducing sugars were recorded in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%). The increased total sugars in berries may be due to the hydroxylation of starch into simple sugars and translocation of sugar from source to sink (Biradarpatil *et al.,* 2015, Scavroni *et al.,* 2018) [7, 30]. The maximum anthocyanin and total phenols were observed in T_{11} ($CaCl_2$ @ 0.5% + SOP @ 0.5%). Calcium and potassium treatments increased the TSS, which may improve anthocyanin accumulation by activating transcription factors. The results were in accordance with the earlier findings of Scavroni *et al.,* (2018) [30] in Ruby grapes, Martins *et al.,* (2020) [23] and Zhu *et al.,* (2019) [38] in Manicure finger grapes.

4.3 Shelf life

The shelf life of berries was greater in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) than other treatments. Whereas the T_{11} ($CaCl_2$ @ 0.5% + SOP @ 0.5%) registered the least physiological loss in weight. Calcium is involved in linkage of the middle lamella, which binds cells together and increases cell wall thickening and thus helped in maintenance of shelf life and it also reduces the decay incidence and rachis browning (Sandhu *et al.,* 1989) [29]. The results were confirmed with the earlier findings of Miceli *et al.,* (1999) [24], Sabir and Sabir (2017) [28].

In this investigation, T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) showed the minimum, berry shattering, physiological loss in weight and berry rotting. This may be due to the positive effect of calcium on controlling postharvest gray mold and rachis browning (Sandhu *et al.,* 1989) [29] and improving the postharvest berry quality (Fortes *et al.,* 2015) [16]. Pre and postharvest application of potassium salts which inhibiting the development of gray mold as reported by Youssef and Roberto (2014) [37] in Italian grapes and Feliziani *et al.,* (2013) [15] in Thompson Seedless grapes. Earlier studies showed that the pre-harvest calcium sprays on Asgari grapes increased the berry firmness and decreased the berry shattering per cent (Amiri *et al.,* 2009) [4]. These findings were confirmed with the findings of Biradarpatil *et al.,* (2015) [7] in Sonaka grapes, Bakshi *et al.,* (2013) [6] in strawberry, Al-Qurashi and Awad (2013) [3] in EI- Bayadi grapes.

4.4 Petiole nutrient content

In this experiment, T_{10} ($Ca(NO_3)_2$ @ 1.0% + KNO_3 @ 1.0%) expressed the maximum nitrogen content in petiole. In grapes, the mineral elements accumulation and absorption were affected by various factors *viz.* cultivar, rootstock, climate, soil, transport system, osmotic pressure, vapour pressure, transpiration and phenological stage of berry development (Cabanne and Doneche 2003) [10]. Whereas T_8 (SOP @ 1.0%) recorded the highest petiole phosphorus. The potassium content in the petiole was high in T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%). The petiole calcium content was more in T_6 ($CaCl_2$ @ 1.0%). The pre-harvest treatment T_3 recorded the highest petiole magnesium. The increased nutrient content in petiole might be due to adequate nutrient supplement (28% Ca, 50% K and 28.5% N), better absorption and favorable seasonal environment condition. Calcium content of berry showed a steady upward trend from veraison to harvest. Potassium accumulation was slow during the pre-veraison phase, but increased to 3.5 times during post-veraison stage (Rogiers *et al.,* 2000). These findings were in confirmation with the works of Amiri *et al.,* (2009) [4], Ibacache and Sierra (2009), Schreiner and Scagel (2017) [21, 31].

5. Conclusion

From the present investigation, it is highlighted that the yield, quality and shelf life of grapes var. Muscat Hamburg were enhanced by pre-harvest application of calcium and potassium. T_{12} ($CaCl_2$ @ 1.0% + SOP @ 1.0%) showed the superior results in terms of bunch weight, fruit yield, berry diameter, berry weight, berry firmness, juice recovery, TSS, total sugars, reducing sugars, non-reducing sugars, berry cracking, shelf life, petiole potassium and berry potassium content. T_{12} also recorded the lowest values for berry shattering, PLW and berry rotting. The pre-harvest treatment T_{11} ($CaCl_2$ @ 0.5% + SOP @ 0.5%) recorded the lowest highest anthocyanin and total phenols content. Hence the treatment T_{12} can be recommended for commercial exploitation in grapes.

6. References

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