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The Influence of Summer Pruning and Alternative Fungicides on Yield Quality and Powdery Mildew Progression of Black Monukka Grapevine

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Abstract: The application of spraying some mineral fertilizers viz, potassium bicarbonate ($KHCO_3$) and sodium bicarbonate ($NaHCO_3$) as alternative fungicides, alone or accompanied with summer pruning of shoots and leaves were studied on Black Monukka grapevine. The field trial was conducted for two successive seasons (2018 and 2019), comprised six treatments to improve yield quality and productivity along with limiting the powdery mildew disease progression. All treatments exhibited an improvement in all growth parameters and disease reduction. Results indicated that the combined application of spaying potassium bicarbonate and summer pruning was significantly the most effective treatment in increasing all growth parameters and net yield. In addition of reducing the incidence and severity of powdery mildew disease and yield compensation was achieved by an increase in the cluster weight and response to a reduction in the infected berries per cluster.

Key words: Black Monukka · Potassium bicarbonate · Sodium bicarbonate · Powdery mildew · Summer pruning

INTRODUCTION

Grapevine (*Vitis vinifera* L.) is one of the most economically important and widespread fruit crops in the worldwide. Grape powdery mildew disease is caused by the fungus *Erysiphe necator* Schwein, which has a narrow host range attacking only grapevine and a few related species. Powdery mildew disease of grapevine is the most common disease and widespread in the world [1].

Grapevine canopy managements can cause modifications in the grape quality and composition and can be an effective way to limit the powdery mildew disease progression through modifying the canopy microclimate [2]. Summer pruning is among these cultural practices used to reach this objective. In this way, applied different levels of summer pruning in addition to spraying some minerals can improve the quality and productivity of Black Monukka grapevine.

Powdery Mildew disease on grapes requires dry, overcast conditions rather than free moisture for its active growth. Hence, the proper canopy management practices and modifying the canopy microclimate are two essential factors to limit the powdery mildew propagation. High temperatures that do not harm the plant can harm the fungus; spores and mildew colonies can be killed at extended durations of temperatures above 33°C. The fungus is destroyed completely when air temperatures rise above 35°C for 12 hours or more if colonies are directly exposed to UV light [3]. Growth and reproduction by powdery mildew pathogens are generally inhibited by decreasing relative humidity [4]. Light intensity is the primary factor, which limits powdery mildew growth development [5].

Summer pruning is a cultural technique, which drives vine vigor to ensure fruit quality and plant vegetative balance. While summer pruning such as Shoot thinning and removal of basal leaves is the most expensive cultural operation, it helps to improve the microclimate in the canopy, promotes good ripening of the grapes and creates less suitable conditions for the development of pathogens [6].

Shoot thinning is the elimination of double, weaker and sterile shoots and it is very important to aerate the canopy, improve the growth of remaining shoots and adjust cluster numbers. There may be an advantage with shoot thinning in vigorous vines to reduce shoot crowding and thus increase light exposure of the remaining shoots. Shoot removal early in the season also

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reduces the impact of powdery mildew by helping to minimize early spore production. Therefore, shoot thinning should be performed when shoot length reaches 25-30 cm when it is possible to define which shoots have bunches in good position and which are well located as pruning material for the next year [7].

The removal of basal leaves around the clusters is widely adopted to improve grape quality and to reduce the incidence of fungal infection. As leaves are the main source for photosynthates translocated to the cluster, particularly during the early stages of its development, it should be applied at Veraison [8]. Additionally, it was mentioned by Bedrech and Mostafa [9] that shade should be avoided by reducing the number of crowded leaves.

Various bicarbonate salts are suggested as a good option to control powdery mildew. Bicarbonate salts are considered as good alternative control options, because they have fungicidal properties with a very low toxicity profile. Potassium bicarbonate was more effective in the control of powdery mildew than bicarbonate alone [10]. Efficacy of bicarbonate against powdery mildew has been proven in various crops, including grape powdery mildew (*Uncinula necator*) [11].

Sodium bicarbonate has been shown to inhibit fungal pathogens of fruits, field crops, vegetables and ornamentals [12]. The pH-altering effects of Sodium bicarbonate control powdery mildew fungi, not killing the spores, but interrupting the life cycle through inhibition of germination

The overall goal of this research was to evaluate and investigate the effectiveness of potassium bicarbonate, sodium bicarbonate and some summer pruning practices as alternatives to synthetic fungicides as well as the concomitant effects thereof on yield without any negative effect on cluster characteristics.

MATERIALS AND METHODS

The present work was performed during two successive seasons 2018 and 2019 in a vineyard located at Cairo-Alexandria Desert Road. Ten years-old Black Monukka grapevines grown in a sandy soil and trellised by Spanish parron shaped-system were used in this investigation. The vineyard is spaced 2 x 3 m and cane pruned (8 canes X 12 buds/cane along with 8 renewal spurs with 2 buds each) during the second week of January with a vine load of 96 buds. Vines were irrigated through drip irrigation system. Ninety vines were chosen for this study (6 treatments x 3 replicates x 5 vines / replicate). The vines were uniform in vigor and received common horticultural practices.

Summer pruning treatment was applied after the berry setting, where all lateral shoots and primary leaves (beginning from the base of the shoot to the node opposite to the top cluster, leaving the leaf opposite to the cluster on each shoot) are removed.

Alternative fungicides viz., Sodium and potassium bicarbonate were applied as a foliar application as a preventive scheme of weekly spray application, the first on the 2nd of April 2018 and a curative/preventive scheme imposed when the first powdery mildew incidence was observed, the first application on the 16th of April 2018; followed by a weekly spray application scheme [13].

The treatments were applied on both seasons of the study as follows:

- Control
- Potassium bicarbonate at 5 g/l.
- Sodium bicarbonate at 5 g/l.
- Summer pruning (shoot thinning and leaf removal).
- Potassium bicarbonate + Summer pruning.
- Sodium bicarbonate + Summer pruning.

Microclimatic Data Beneath the Vine Canopy: Data of microclimate was taken inside the vine canopy for each treatment and was recorded weekly during the growing period as follow:

- Canopy temperature.
- Relative humidity.
- Sunlight intensity.

They were measured on three levels lower, middle and upper branches using "Scheduler Plant Stress Monitor", Standard Oil Engineered Materials Co., Ohio, USA. All the above-mentioned measurements were used by the microprocessor of the apparatus to calculate the average of canopy microclimate in order to find the relationship between the microclimate and the macroclimate in this area.

Yield:

- Yield/vine (Kg).
- Average cluster weight (kg).
- Number of infected berries.
- Severity of infection %.
- The net yield (kg).

Chemical Characteristics of Berries: Representative random samples of 15 clusters /treatment (5 cluster from

each replicate) were collected when clusters reached their full color and total soluble solids reached about 18-20, according to Badr and Ramming [14].

The Following Determinations Were Carried Out:

- Refractometric total soluble solids (TSS %) and titratable acidity as gram of tartaric acid per 100 ml of juice and TSS / acid ratio [15].
- Total anthocyanin in berry skin (mg/100g) using spectrocolourimeter at 250 nm according to Yilidz and Dikmen [16].

Morphological Measurements:

- Leaf area (cm^2): Samples of leaves from the basal 5^{th} and 7^{th} leaf of the fruiting shoot were randomly collected for each treatment for leaf area determination at harvest (using leaf area meter, Model CI 203, U.S.A.).
- Shoot length (cm): it was determined by measuring the fruiting shoots.

Powdery Mildew Disease Assessment: No fungicides were applied and disease powdery mildew level was recorded four to seven days after the appearance of the first disease symptoms.

Severity of infection was recorded at the end of each season by dividing Average number of berries / clusters by Average number of infected berries/cluster multiplied by 100.

$$\text{Severity of infection \%} = \frac{\text{Number of infected berries}}{\text{Total no. of berries/cluster}} \text{x} 10$$

Statistical Analysis: A randomized complete block design was used in this experiment. Means representing the effect of the tested treatments were compared by the New L.S.D. method at 0.05 according to Snedecor and Cochran [17].

RESULTS AND DISCUSSION

Microclimatic Data Beneath the Vine Canopy

Canopy Temperature (°C): The measured air temperature inside the canopy is significantly different between treatments as shown in Figure (1); the highest temperature was recorded in the summer pruned treatments especially when it is combined with the foliar application of potassium carbonate. Defoliation and shoot thinning has a great effect on changing the microclimate inside the canopy which in turn has a negative effect on the propagation of Powdery Mildew. It was found that high temperatures that do not harm the plant can harm the fungus; spores and mildew colonies can be killed at extended durations of temperatures above 33°C. The fungus is destroyed completely when temperatures rise above 35°C for 12 hours or more if colonies are directly exposed to UV light [3]

Relative Humidity (%): Relative humidity percent is higher in the dense canopies of the control and single treatments of Potassium and Sodium bicarbonate vines than the pruned treatments (Figure 2). Humidity can build up slightly in dense canopies and contribute to fungal disease as wind speed is reduced. These results were in harmony with those obtained by Zahavi, *et al*. [18] who found that highest germination rates were observed at 75 to 85% relative humidity.

Sunlight Intensity (1000 Lux): The data presented in in Figure (3) shows the light intensity at the vines canopy as affected by various treatments. Leaf removal and shoot thinning led to an increase in light intensity inside the canopy of the vines. The highest light intensity in the canopy was recorded by the pruned treatments in both seasons, in comparison with the control and the unpruned treatments which limits the propagation of powdery Mildew disease. These results are similar to those of Zahavi, *et al*. [18] who suggested that high light intensity is the primary factor, which limits powdery mildew growth development. Tomasi *et al.* [19] report a temperature difference of 8°C or more in grape berries from the same cluster, both directly exposed to sunlight or not. Shoot thinning and/or leaf removal decrease foliage density and encourage light and air penetration into the canopy also facilitates more desirable shoot spacing along canes and cordons and more even leaf area distribution in the canopy, thus improving penetration into the fruiting zone [20].

Yield

Yield per Vine (kg), Cluster Weight (Kg), Number of Infected Berries, Severity of Infection % and Net Yield (kg): It is evident from the data in table (1) that the pruned treatments were found to be significantly effective in increasing grapevine yield comparing with the unpruned ones. In previous study, it was found that the combined treatment of Potassium bicarbonate and summer pruning gave the highest values due to the role of Potassium bicarbonate in controlling some key diseases, which facilitate crop growth, improve yield and quality [21].

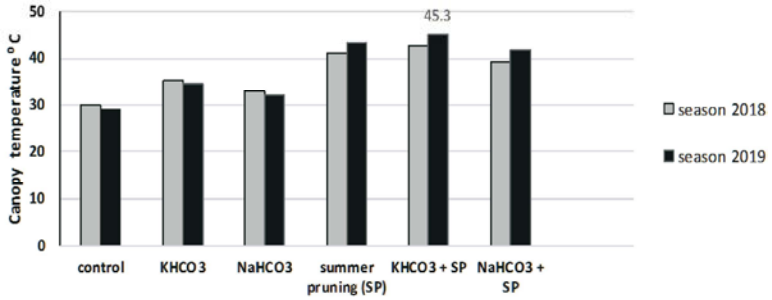

Fig. 1: Effect of summer pruning treatments and foliar spraying with potassium and sodium bicarbonate on canopy temperature°C of Black Monukka cultivar in the two seasons 2018-2019

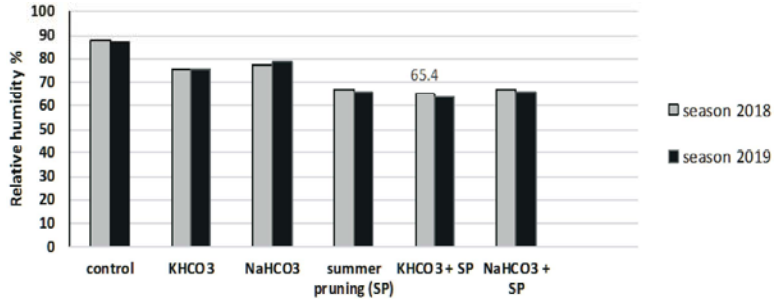

Fig. 2: Effect of summer pruning treatments and foliar spraying with potassium and sodium bicarbonate on Relative humidity % of Black Monukka cultivar in the two seasons 2018-2019

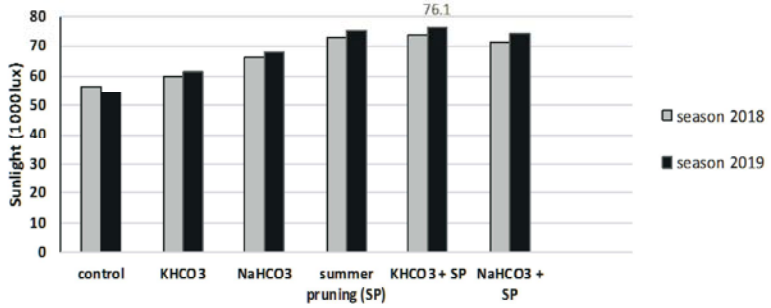

Fig. 3: Effect of summer pruning treatments and foliar spraying with potassium and sodium bicarbonate on Sunlight intensity (1000 lux) of Black Monukka cultivar in the two seasons 2018-2019

In addition, these results agree with Hunter [22] who mentioned that the crop practices of shoot thinning and leaf removal favored increases in grape production and quality. In addition, Silvestroni *et al.* [20] stated that shoot thinning increases yield and decreases vegetative growth, leading to higher yield to leaf area ratios.

Similarly, data of grapevine clusters showed that cluster weight was increased with the combined treatment of Potassium bicarbonate and summer pruning, while the increment was only slight in the unpruned treatments followed by the control, in both seasons. Koblet *et al.* [23] found that leaf removal maybe increased photosynthetically and physiologically efficient leaf area, which results in translocation of more carbohydrates to clusters, hence yield was increased. However, few studies reported an increase in the number and weight of clusters, where the Potassium fertilizations was applied [24].

Chemical Characteristics of Berries: The following determinations were carried out:

Total Soluble Solids (TSS %), Titratable Acidity % and TSS / Acid Ratio: There are significant differences among treatments in TSS %, titratable acidity and TSS /acid ratio as shown in Table (1). Spraying with Potassium bicarbonate alone or combined with summer pruning treatments were significantly accompanied with improving quality of the berries in terms of increasing TSS % and

Table 1: The influence of summer pruning and foliar spraying with potassium and sodium bicarbonate on yield and its attributes of Black Monukka cultivar during the two successive seasons 2018 and 2019

	Yield/vine (Kg)		Cluster weight (kg)		No. of infected berries.		Severity of infection %		The net yield /vine (Kg)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	8.2	8.0	512.2	500.8	33.4	36.4	16.7	18.2	6.8	6.5
$KHCO_3$	9.6	9.8	600.1	612.6	16.8	17.9	7.6	7.8	8.8	9.0
NaHCO3	9.1	9.2	559.6	575.0	19.7	20.0	8.2	8.4	8.4	8.4
Summer pruning (SP)	10.2	10.6	637.4	663.1	24.9	24.8	10.3	11.7	9.1	9.4
$KHCO_3$ + Summer pruning	11.7	12.0	731.2	750.5	8.1	6.2	4.1	3.1	11.2	11.6
NaHCO3 + Summer pruning	11.1	11.2	693.9	700.3	12.4	10.1	5.2	4.6	10.5	10.7
New L.S.D at 5%	0.4	0.5	11.0	12.1	2.1	2.2	0.5	0.5	0.2	0.3

total sugars and reducing total acidity % in relative to the other treatments and the control in both seasons. This may be ascribed to the Potassium nutrition, which stimulates the photosynthetic activity and favors the translocation of sugars to the fruit. Similar results were obtained by Fregoni and Vercesi [25] who stated that Potassium caused significant reductions in the total acidity compared with the treatments with no fertilizer application. Loss of acidity is caused by excessive migration of K^+ cations to the clusters, which produces potassium bitartrate from tartaric acid.

Moreover, the rates sugar accumulation were slower in fruits from vines with shaded leaves in the pruned vines [26]. However, leaf removal showed lower values of acidity which could be explained by the high berry temperature that may have induced a higher rate of malic acid respiration [27]. In addition, severely infected clusters have higher total acidity than healthy ones [28].

Total Anthocyanin in Berry Skin (mg/100g): It is clear that total content of anthocyanin in berry skin positively affected by the application of potassium bicarbonates alone or combined with summer pruning treatments (Table 2). The beneficial effect may be due to Potassium ability to modify the grape color by intervening directly in the synthesis of specific anthocyanins and/or other phenols that can influence color by copigmentation [29]. A previous study on shoot thinning found that shoot thinned vines exhibited berry anthocyanin concentrations as compared to un-thinned vines [30].

Leaf removal and shoot thinning affected the accumulation of anthocyanin in berry skin, due to the clusters exposition to more sunlight as shaded microclimate reduces color, which are usually interpreted as delayed maturity. Morrison and Noble [26] ensured that anthocyanin and total soluble phenols were lower in fruits that developed in shade. However, severely infected clusters have a lower content of total anthocyanin [27].

Morphological Measurements

Leaf Area (cm^2): Leaf area development is an important characteristic affecting yield and fruit quality of grapevines. Table (2) shows the effect of different treatments on the average leaf area of Black Monukka cv. It is obvious from the recorded data that there are significant differences among treatments. The highest values were obtained from the combined treatment of Potassium bicarbonate and summer pruning followed by sodium bicarbonate and summer pruning then the single treatments potassium and Sodium bicarbonate respectively then the control. These results are similar to those of Urbano [31] who mentioned that Potassium treatments enhanced the nitrogen content in petioles at veraison; this fact shows that potassium supplies improve the assimilation of nitrogen, which in turn is an important key in balancing the vegetative and reproductive growth of the vine canopy. There are also reports about the effectiveness of potassium bicarbonate ($KHCO_3$) on the reduction of foliar damage produced by the fungi, declared previously by Vinale *et al.* [32].

Pruning vines affect the Powdery mildew progression negatively through, enhancing the light penetration and reducing the relative humidity inside the canopy. Similarly, Naor and Gal [33] reported that shoot thinning increased leaf area per shoot. However, it was found that the leaves left on the vines after defoliation increase photosynthetic activity to recover the reduction on total leaf area activity and to supply the photoassimilates demand of sinks [34, 35].

Shoot Length (cm): It is evident from the obtained data in Table (2) that there is a significant stimulation on shoot length by using a combination of Potassium bicarbonate and summer pruning. Results are linear to those obtained from Maser *et al.* [36] who stated that K helps plant body to produce starches, enhance shoot length. In addition, the unapplied treatments by Potassium had a negative

Table 2: The influence of summer pruning and foliar spraying with potassium and sodium bicarbonate on chemical characteristics of berries and morphological measurements of Black Monukka cultivar during the two successive seasons 2018 and 2019

	TSS %		Total acidity %		TSS/acid Ratio		Anthocyanin (mg/100g)		Leaf area (cm^2)		Shoot length (cm)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	17.4	17.0	0.55	0.59	31.6	28.8	27.2	27.0	166.3	165.8	126.3	128.5
$KHCO_3$	20.6	21.1	0.41	0.39	50.2	54.1	40.0	41.6	170.2	173.5	130.2	135.7
NaHCO3	18.0	17.5	0.53	0.54	33.9	32.2	28.5	27.9	168.0	171.2	129.6	131.3
Summer pruning	18.5	17.9	0.52	0.55	35.5	32.5	34.0	33.5	172.1	178.8	140.0	140.8
$KHCO_3$ + Summer pruning	21.2	22.0	0.39	0.34	54.3	64.7	42.1	43.0	180.5	183.6	157.9	158.3
NaHCO3 + Summer pruning	19.8	19.3	0.48	0.49	41.2	39.3	38.6	38.2	177.3	180.2	155.1	154.5
New L.S.D at 5%	0.5	0.6	0.05	0.04	1.2	1.3	1.0	0.9	1.8	2.0	2.4	3.0

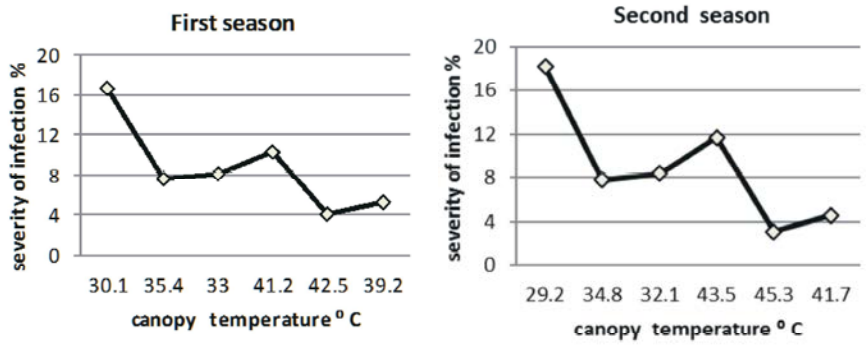

Fig. 4: The severity of infection % by powdery mildew disease as affected by canopy temperature (°C) in Black Monukka grapevine in the two growing seasons 2018-2019

effect on the shoot length produced the shortest shoot while the shoot length was enhanced by increasing K rates [37].

In an agreement with the present results were those mentioned by Bernizzoni *et al*. [38] who found that although the shoot-thinned vines had initially lower photosynthesis (carbon assimilation) than un-thinned vines due to the removal of photosynthetic source (leaf), they had regained photosynthetic capacity to levels similar to the un-thinned vines within 17 days of treatment. This occurred as a result of a substantial increase in both main leaf size and amount of lateral leaves as a result of shoot thinning.

Powdery Mildew Disease Assessment:

The Severity of Infection: Severity of infection percent as affected by different treatments at the end of the growing season is shown in Table (1). It is obvious that the lower values of infection were obtained by the combined treatment of Potassium bicarbonate and summer pruning in both seasons. These results are in linear with those obtained by Di Lorenzo *et al.* [6] who stated that summer pruning helps to improve the microclimate in the canopy, promotes good ripening of the grapes and creates less suitable conditions for the development of pathogens.

It is obvious that the severity started to slow down as the canopy temperature started to rise above 35°C and the relative humidity decreased to 65% (Figure 1, 2) in the fifth treatment. These results are due to the defoliation and shoot thinning which create an unfavorable microclimate for the powdery mildew progression limiting its spread [39].

The apparent infection rate was a function of temperature and moisture. Ignouet *et al*. [40] found that solar radiation and air temperature were main factors affecting grape cluster temperature. Data in Figure (4) clarified the importance of the microclimatic factors in determining the severity of disease obtained from each treatment.

CONCLUSION

We can conclude that potassium bicarbonate accompanied by summer pruning (shoot thinning and leaf removal), was an effective treatment in increasing cluster weight, as well as enhancing the chemical characteristics of berries, TSS %, TSS/acidity ratio whereas it decreased acidity % in berry juice. Vegetative growth parameters were also improved through increasing the surface area of leaves, more than the other treatments and the control. However, potassium bicarbonate provides the possibility

for partial replacement for harmful minerals besides its possibility to be used up until one week before harvest as it has an eradicant ability, unlike sulfur, which has a restriction of 30 days. In addition, the statistical analysis of microclimatic data showed that canopy temperature, relative humidity and solar radiation within the vine canopy were main factors affecting grape quality. Therefore, canopy structure should be designed to avoid dense canopies, as they create shade and higher humidity. By maximizing exposure of the foliage to sunlight and reducing humidity levels through greater air movement, along with spraying the vines by Potassium carbonate as preventive and curative schemes, creates an environment less favorable for powdery mildew disease and other diseases. The success of this system is attributed to good light penetration and relatively high temperatures in the canopy.

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