__Original Research Article__

Quality of 'Muscat Hamburg' Panner Grapes as influenced by Micronutrients foliar spray

Abstract

Micronutrient deficiencies play a significant role in impacting the yield and quality of grapes in vineyards. To address the deficiencies, a field study was conducted during summer, 2022 by using foliar micronutrients mixtures in three different concentrations (0.5%, 1.0%, and 1.5%), with application once or twice applied at two different stages to investigate the effects of foliar micronutrient application on the biochemical quality characteristics of the Muscat Hamburg grapevine cultivar. The results of the study showed that the application of micronutrients spray showed a beneficial impact on yield parameters, such as number of bunches per vine (ranging from 28 to 44), the yield per vine (varied from 5.56 to 6.55 kg $vine^{-1}$), with overall yield range between 20.7 to 24.2 t ha^{-1}. The biochemical properties of the berries, including sugars (reducing, non-reducing, and total sugars), juice pH and content, TSS (Total Soluble Solids), Titrable acidity, and berry firmness, were found to be high in grapevines sprayed at 1.0% twice. Results showed that total sugars ranged from 15.2% to 10.7%, with a juice pH of 3.47 to 3.94, juice content of 83.5 to 95.5% and TSS from 15.6 to 17.40 ºBrix. With regard to Titrable acidity and berry firmness results reflected from 0.92% to 1.14%, 9.4 to 12.9 N respectively. Findings from the study clearly showed that applying 1.0% micronutrients twice at fruit-set and berry stages increased yield and improved Paneer grape quality indices.

Keywords: Micronutrients; foliar spray; grape; fruit quality.

Introduction

Grape *(Vitis vinifera* L.) member of Vitaceae family, is one of the top-ranked fruit in the world due to its multifaceted uses and benefit. It has gained substantial importance due to its high nutritional content, flavor, varied uses, and higher profit to the farmers (Imran *et al*., 2017). It is one of the most important commercial fruit crop, from temperate to tropical regions, covering more land than any other fruit and accounting for more than half of global fruit production (Gowda *et al*., 2006). Micronutrients are necessary ingredients for plant growth and production (Hassan *et al.*, 2008; Palmer *et al.*, 2009) and each of these component is crucial for plant growth and development. Poor soil conditions bind these nutrients, reducing their availability and absorption. In inadequate conditions, the extrinsic administration of these chemicals via an integrated method can efficiently manage plant vitality. These supplements account for the decreased delivery of nutrients from the soil at various phases of development (Keller *et al*., 2005).

Nonetheless, employing a well-suited and harmonized approach to applying both essential macro and micronutrients has demonstrated its feasibility and lasting effectiveness in bolstering crop productivity. This approach has also proven effective in raising micronutrient levels and enhancing yield and biochemical quality parameters (Saha *et al*., 2023). Efficient micronutrient management, such as micronutrient soil and foliar delivery in a variety of soil-crop scenarios, could help alleviate micronutrient shortages in soils and crops, boosting agricultural output and crop quality (Shukla *et al*., 2020). To meet the requirement at critical stages, foliar application is gaining popularity because of several advantages, including its swift effects and the little amount of fertilizer required in the solution. Foliar fertilizers are more effective when there is a strong demand for nutrients, particularly whilst soil supply and root uptake are limited (Fernandez *et al*., 2013). With this insight, the current study is being conducted in order to investigate the impact of micronutrient foliar treatment on the yield and quality characteristics of grapes.

Materials and methods

Experimental vineyard

The field experiment was carried out during the summer of 2022 under irrigated conditions in a farmer's vineyard located at Mathipalayam village of Thondamuthur block, Coimbatore district, Tamil Nadu. The precise coordinates of the location are 10° 56'12.8" N latitude and 76° 50'44.0" E longitude. Field initial soil sample was collected at a depth of 0-15 cm and analysed for various physical and chemical attributes. Texture of the soil was silty clay (Piper, 1944), with neutral in soil reaction (7.74, Jackson, 2005). low electrical conductivity (0.28dS m^{-1}, Jackson, 2005) and high organic carbon content (1.23 g kg^{-1}, Wakley and Black, 1934). Available nitrogen (N) status was low (236 kg ha-1, Subbiah and Asija, 1956), while available potassium (K) (198 kg ha^{-1}, Stanford and English, 1949) and phosphorus (P) (21 kg ha^{-1}, Olsen *et al*., 1954) were at medium levels. In terms of available micronutrients, all micronutrients were present in sufficient quantities except for iron and boron, which exhibited a deficiency at 3.41 and 0.42 mg kg^{-1}respectively (Lindsay and Norwell, 1978).

This experiment was conducted using Randomized Block Design (RBD) with seven treatments, as varied concentrations i.e., micronutrients (Fe, Zn, Mn, Cu, and B), with concentrations of 0, 0.5%, 1.0%, and 1.5% applied once and twice. The foliar spraying of the micronutrient combinations was carried out during the fruit set and berry growth stages. The standard package of practices for nutrient management (200:160:600 NPK g/vine) and viticulture was followed in the vineyard, regardless of the treatment applied. Routine cultural practices were followed, berry was harvested, yield and quality parameters were determined

Yield parameters

The plants were grown until they reached full maturity, and the mature clusters were collected treatment wise. Various physical measurements were computed manually, encompassing metrics such as cluster count per vine, bunch weight (g), bunch length (cm), number of berries per cluster, berry diameter (mm), and berry weight (g) (Ali *et al*., 2021).

Biochemical Quality Analysis

A sample of berries was taken from each replicate's bunch and juice was extracted for estimating total soluble solids (TSS), pH, titratable acidity, berry firmness, reducing sugars, total sugars, and non-reducing sugars. The TSS of grape juice was determined with a hand-held refractometer and expressed in degrees Brix, while the pH was determined with a digital pH meter. Titratable acidity is determined by titrating the extracted sample of grape juice with an alkaline solution (such as 0.1N NaOH) with phenolphthalein as an indicator and expressed as a percentage of tartaric acid (Genanew *et al*., 2013). TSS/acid ratio was calculated by dividing TSS (^{o} brix) by acidity (%). Berry firmness is determined using a standard penetrometer and expressed in Newton (N) (Leng *et al*., 2022). The grape juice percentage was calculated, reducing, non-reducing, and total sugar content in the fruit was estimated using Fehling's solution, as reported by Ranganna (1997). The sugar-acid ratio was determined by dividing total sugar content by acidity.

Statistical analysis

The data collected from the experiment were statistically analysed utilizing AGRESS software version 7.01. A significance level of $P < 0.05$ was employed, and Critical Difference

(CD) values were computed for $P < 0.05$ whenever the "F" test yielded significant results (Gomez *et al*., 1984).

Results and Discussion

Yield parameters

The impact of applying various levels of micronutrients to crops via their leaves was investigated, and the results were documented in Table 1. The foliar treatment of micronutrients had a notable influence on the fruit yield such as the number of fruit bunches per plant, with a range between 28 to 44. Significantly higher bunch yield was recorded and the results were, 5.56 to 6.55 kg per plant, while the overall yield per hectare spanned from 20.7 to 24.2 t ha^{-1}. The higher yield per plant and per hectare was observed in 1.0% micronutrient spray twice, with a value of 6.55 kg per plant and 24.2 t ha^{-1} respectively. This was closely followed by the application of 0.5% micronutrient spray twice, which yielded 6.30 kg per plant and fruit yield of 23.9 t ha^{-1}. In contrast, the lowest yield of at 5.56 kg and 20.7 $tha^{-1}$was recorded in the control with water spray alone. Our findings align with earlier research, which demonstrated that applying Fe, Zn, and B through foliar methods led to substantial enhancements in vine productivity, bunch weight, and grapevine quality (Ali *et al*., 2021). In a recent study conducted by Saha *et al*. in 2023, it was found that simultaneous application of both Zn and B led to a noteworthy augmentation in crucial quality attributes of tomatoes. Furthermore, the influence of Fe was observed in direct aspects of fruit development, such as fruit set, retention percentage, bunch quantity, bunch length, berry count per bunch, berry diameter, bunch weight, compactness, berry weight, and overall vine yield (Nawaz *et al*., 2012; Singh *et al*., 2015).

Biochemical Quality Parameters

The quality attributes of grapes, such as juice content, pH, TSS, Titrable acidity, berry firmness, total sugars, reducing sugars, and non-reducing sugars, were notably affected by the application of micronutrient combination at varying doses. The juice content (%) ranged from 95.5% to 83.5%, with the highest juice content observed in the vines treated with 1.0% micronutrient spray twice (95.5%), followed by 1.5% micronutrient spray (93.0%). Conversely, the lowest juice content was recorded in the vines sprayed with water alone (83.5%). This difference in juice content can be attributed to the greater photosynthetic activity and biomass production in the vines, leading to an increased presence of metabolites. As the berries continue to grow and develop, significant amounts of water and other metabolites are transported into the berries. These results validate the conclusions drawn by previous studies (Ghosh and Basra, 2000; Kulkarni, 2004) in the context of sweet oranges. The pH of the juice varied from 3.94 to 3.47, with the highest pH recorded in the vines treated with 1.0% micronutrient spray twice (3.94), followed by the ones treated with 0.5% micronutrient spray twice (3.84). Whereas, the lowest pH was observed in the control (3.47).

Figure 1 shows the sugar contents (%) in the berries and demonstrates a direct relationship between the concentration of micronutrients and sugar content (%). The lowest amount of non-reducing sugars (3.22%) was evidenced in control with water spray alone without micronutrients, whereas the highest amount of non-reducing sugars (5.23%) was observed in grapevines treated with micronutrient foliar spray at 1.0% twice. Similar results were obtained for reducing sugars with the results varying from 9.74% to 7.31%.

The lowest amount of reducing sugars (7.31%) was noticed in control, while the application of micronutrients at various concentrations increased the concentration of reducing sugars in all the treatments, with statistically significant differences compared to the control. Furthermore, the total sugars in grapevines, ranged from 15.2% to 10.7%, showed a significant increase in concentration due to the application of micronutrients, compared to the control (10.7%). The grapevines treated with the micronutrients at 1.0% twice exhibited the highest level of total sugars (15.2%). The rise in sugar levels in grape berries was clearly associated with elevated chlorophyll contents and a higher rate of photosynthesis due to increased levels of Fe, B, and Zn (Perveen *et al.,* 2021). Similar observations have been documented in apple and grapevine studies (Spinelli *et al.,* 2009; Khan *et al.,* 2021; Ali *et al.,* 2021). Moreover, previous reports also documented that foliar sprays of micronutrients have led to increased sugar contents in strawberry, pomegranate, and grape crops (Manaf *et al.,* 2021; Wang *et al.,* 2021; Naqvee*et al.,* 2021).

The concentration of quality parameters such as total soluble solids (TSS), Titrable acidity, and berry firmness is a crucial factor for assessing fruit quality (Table 3). In this investigation, grapevines treated with a combination of micronutrients at 1.0% twice displayed the highest TSS content, measuring 17.4^{o} Brix. As the foliar dose of these micronutrients increased from the control to various concentrations, the TSS content also increased, ranging from 17.4 to 15.6^{o} Brix. In contrast, the lowest TSS was observed in control (15.6^{o} Brix). The gradual rise in TSS could be due to prime role of B and indicates a direct correlation between B and TSS, possibly attributed due to significant role in photosynthesis, flower and fruit set characteristics (Gune *et al*., 2015; Swathi *et al*., 2019). These findings align with previous studies on grapevines, where foliar treatment of B significantly elevated TSS levels in grape berries. Additionally, Zn, as an essential micronutrient, aids in activating enzymes (fructose1 and 6-bis phosphatase) which is crucial for biochemical reactions that contribute towards sugar synthesis and accumulation in fruits (Bybordi *et al*., 2010; Nikkah *et al*., 2013).

With regard to Titrable acidity of the juice, the results ranged from 0.92 to 1.14%. Similar to other biochemical parameters, in TA also micronutrient spray showed positive effect. Highest acidity (1.14%) was observed in grapevines that did not receive any supplemental micronutrients, while the application of micronutrients led to a significant reduction in acidity percentage. The lowest Titrable acidity (0.92%) was found in grapevines treated with a 1.0% micronutrient spray twice. These results are consistent with the earlier findings of Parthiban *et al*. (2021). Similarly, the studies conducted by Ali *et al*. (2021) on grape "Flame Seedless" and Mostafa *et al*. (2006) also reported that foliar application of boric acid progressively increased the total soluble solids (TSS) and reduced Titrable acidity in grapes, supporting the present observations.

The berry firmness exhibited significant variations among the treatments, ranging from 12.9 N to 9.40 N. Among all the treatments, 1.0% micronutrient spray twice resulted in the highest berry firmness (12.9 N), followed by the 0.5% micronutrient spray twice (10.5 N). Conversely, the lowest berry firmness was recorded in the water spray treatment (9.40 N). Fruits that had higher uptake of micronutrients demonstrated better firmness compared to the control, as these elements potentially contribute to strengthening pectin bonding and stabilizing the cell wall structure, involvement in metabolism and translocation as well. These findings are consistent with the observations made by Swathi *et al*. (2019). In addition, Mostafa *et al*. (1999) reported that a combination of boric acid and potassium sulphate increased fruit firmness in Anna apple. Similarly, research by Yadav *et al*. (2013) showed that foliar spraying of peach trees with 0.1% H_3BO_3 + 0.5% $ZnSO_4.7H_2O$ + 0.5% $FeSO_4.7H_2O$ led to an increase in fruit firmness in peach.

The sugar/acid ratio and TSS/acid ratio (Figure 2) indicate the organoleptic taste of the fruit which appeals to the consumers' acceptance and thus market preference. The sugar-acid ratio of the berries ranged from 16.6 to 9.42 wherein the highest was observed in the treatment sprayed with 1.0% micronutrient spray twice (16.6) followed by 0.5% spray twice

(14.5). Similarly, higher TSS/acid ratio (19.0) was calculated from the vines sprayed with 1.0% foliar-sprayed micronutrient blend followed by 1.0% micronutrient spray once (17.8). Balanced fertilization particularly micronutrients helps the plant to grow and produce potential growth steadily without any interruption provided the environment favours. In the present study also significant results were noticed for all the parameters, the results of sugar/acid ratio and TSS/acid ratio are in accordance with the findings of Pal *et al*., (2018) who recorded that foliar application of micronutrients improved the fruit quality in respect of a higher TSS/ acid ratio. Prabhu and Singaram (2001) also observed with higher TSS/acid ratio in the Muscat grape with foliar application of 0.5% $ZnSO_4$ and 0.2% borax.

Conclusion

The present study aimed to enhance the yield and quality of "Muscat Hamburg" table grapes through the foliar application of micronutrients (Fe, Zn, Mn, Cu, and B). Our discovery highlights that the combined utilization of micronutrients serves as an efficient approach for enhancing grape fruit yield, yield-related characteristics, and their constituents. Increasing doses of micronutrients led to an increased number of bunches per vine, yield per vine, and yield per hectare. Among all treatments, the most effective was the foliar spraying of 1.0% micronutrient spray twice, at the fruit set stage and at berry growth stages. Significantly higher fruit yield (24.2 t ha^{-1}) as well as improved quality attributes were recorded in foliar spraying of 1.0% micronutrient spray twice, at the fruit set stage and at berry growth stages. Similarly, the application of micronutrients had a positive impact on grape quality characteristics such as TSS, sugar content, and berry firmness (12.9 N) when compared to control without micronutrient spray (water alone). As the micronutrient spray increased, Titrable acidity in grapes decreased. Based on the findings, it was concluded that applying 1.0% micronutrient spray twice during fruit set and berry growth stages resulted in increased fruit yield (Paneer grape variety), along with enhanced quality parameters.

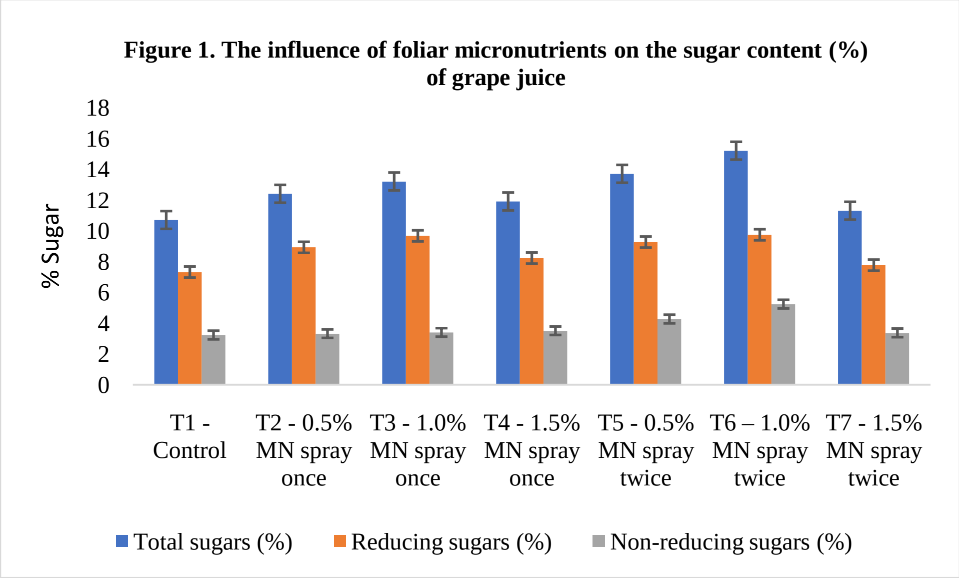
Figure 1. The influence of foliar micronutrients on the sugar content (%) of grape juice
% Sugar
18
16
14
12
10
8
6
4
2
0
T1 - Control
T2 - 0.5% MN spray once
T3 - 1.0% MN spray once
T4 - 1.5% MN spray once
T5 - 0.5% MN spray twice
T6 – 1.0% MN spray twice
T7 - 1.5% MN spray twice
Total sugars (%)
Reducing sugars (%)
Non-reducing sugars (%)

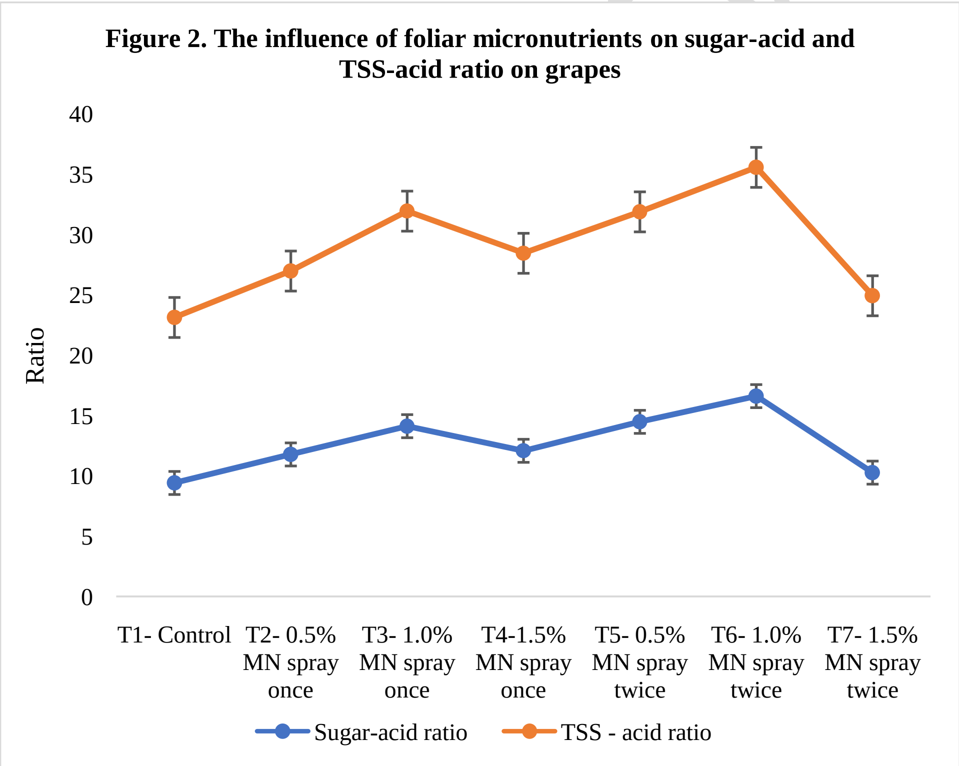
Figure 2. The influence of foliar micronutrients on sugar-acid and TSS-acid ratio on grapes
Ratio
40
35
30
25
20
15
10
5
0
T1- Control
T2- 0.5% MN spray once
T3- 1.0% MN spray once
T4-1.5% MN spray once
T5- 0.5% MN spray twice
T6- 1.0% MN spray twice
T7- 1.5% MN spray twice
Sugar-acid ratio
TSS - acid ratio

Table 1. Effect of foliar spraying of micronutrients on the yield of grapes

Treatments	Yield (kg vine^{-1})	Yield (t ha^{-1})
T_1 - Control	5.56^{b}	20.7^{d}
T_2 - 0.5% MN spray once	5.92^{a}	21.5^{d}
T_3 - 1.0% MN spray once	6.18^{a}	23.9^{ab}
T_4 - 1.5% MN spray once	5.29^{ab}	23.1^{bc}
T_5 - 0.5% MN spray twice	6.30^{a}	23.9^{ab}
T_6 – 1.0% MN spray twice	6.55^{a}	24.2^{a}
T_7 - 1.5% MN spray twice	5.30^{ab}	22.5^{c}
SEd	0.66	0.41
CD (*P*=0.05)	1.39	0.86

*MN – Micronutrients. Mean separation was conducted using the LSD test. Treatments with different lowercase letters indicate significant differences at the $P < 0.05$ level.

Table 2. Influence of foliar micronutrients on the pH and juice content (%) of grape juice.

Treatments	Juice pH	Juice content (%)
T_1 - Control	3.47^{c}	83.5^{d}
T_2 - 0.5% MN spray once	3.53^{bc}	85.0^{cd}
T_3 - 1.0% MN spray once	3.72^{abc}	89.2^{bc}
T_4 - 1.5% MN spray once	3.81^{ab}	93.0^{ab}
T_5 - 0.5% MN spray twice	3.84^{ab}	90.5^{ab}
T_6 – 1.0% MN spray twice	3.94^{a}	95.5^{a}
T_7 - 1.5% MN spray twice	3.83^{ab}	93.0^{ab}
SEd	0.15	2.60
CD (*P*=0.05)	0.31	5.46

*MN – Micronutrients. Mean separation was conducted using the LSD test. Treatments with different lowercase letters indicate significant differences at the $P < 0.05$ level.

Table 3. Impact of foliar nutrition of micronutrients on the TSS, Titrable acidity, and berry firmness

Treatments	TSS (^{o} brix)	Titrable acidity (%)	Berry firmness (N)
T_1 - Control	15.6^{d}	1.14^{d}	9.4^{e}
T_2 - 0.5% MN spray once	16.0^{cd}	1.06^{cd}	9.9^{d}
T_3 - 1.0% MN spray once	16.7^{b}	0.94^{ab}	10.8^{c}
T_4 - 1.5% MN spray once	16.1^{c}	0.99^{bc}	10.1^{d}
T_5 - 0.5% MN spray twice	16.5^{bc}	0.95^{ab}	11.5^{b}
T_6 – 1.0% MN spray twice	17.4^{a}	0.92^{a}	12.9^{a}
T_7 - 1.5% MN spray twice	16.1^{c}	1.10^{de}	10.3^{d}
SEd	0.24	0.04	0.24
CD (*P*=0.05)	0.50	0.07	0.51

*MN – Micronutrients. Mean separation was conducted using the LSD test. Treatments with different lowercase letters indicate significant differences at the $P < 0.05$ level.

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