Article

Tuning Potassium Fertilization to Improve pH and Acidity in Glera Grapevine (*Vitis vinifera* L.) under a Warming Climate

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Abstract: Potassium concentration in grape berries can affect acidity and pH in must and wines. Under the current warming scenario, where preserving equilibrated value for these grape parameters is increasingly challenging, K fertilization could represent a tool to manage grape composition. In this study, the effect of potassium fertilization was investigated over 4 years (2013–2016) in field-grown grapevines (*Vitis vinifera* cv. Glera). Four different potassium rates (0, 15, 30, 60 kg K₂O ha^{−1} year^{−1}) were tested and agronomic responses, grape quality as well as K concentration in the berry were recorded over the four years. At harvest, yield parameters and total soluble solids were unaffected by potassium fertilization. On the contrary, the titratable acidity of the musts was increased by the higher rate of potassium (K60), and both tartaric and malic acids showed higher values when the K rate was higher. K fertilization did not affect the pH, as all the treatments displayed comparable pH values and in an optimal range for winemaking. Overall, in our experimental conditions, medium potassium inputs showed better results on Glera grape quality compared to low K rates, by promoting higher titratable acidity levels without altering the pH in musts.

Keywords: fertilization; potassium; grape acidity; grape pH; climate change

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1. Introduction

The beneficial effect of adding mineral elements to soils through fertilization has been well known for several years, and nowadays professional viticulture requires regular mineral supplementation to ensure yield and quality. Among the mineral nutrients, potassium is the most abundant cation and plays an important role in cultivated grapevines, being involved in the sugar transport to the fruits [1] and in the modulation of the acidity level in must and wine [2]. Several studies reported that high K concentrations tend to decrease the acidity level in grape berries at harvest [3]. Potassium accumulates primarily in the berry tissues during ripening. Its accumulation is a function of K availability in the soil, uptake by roots [4], extent of remobilization from the mature leaves [5] and from storage sinks within the vine woody structures [6].

The total K content in grape berries at harvest depends on different factors, such as the rootstock [7,8], the fertilization management [9,10] and also the climate conditions [11]. In the berry, K is involved in the neutralization of negative charges and can reduce the amount of free tartaric acid, forming potassium bitartrate and eventually affecting the final pH of the grape juice. The potassium content increases throughout berry development [12], while both tartaric and malic acid reach their maximum content before the start of ripening and then decrease until harvest. The ripening of the berry leads to an increase in volume, which dilutes the tartaric acid and jointly reduces its concentration. The malic acid decreases at a faster rate, due both to dilution and respiration processes. A positive correlation between potassium and malate has been shown during grape ripening [13] due to a probable effect of potassium on the tonoplast permeability of the vacuoles, the cellular organs that contain most of the malate. A similar positive relation between potassium

and malate was observed also in peach [14]. As no relationship between malate content and the activities of enzymes involved in the metabolism of malic acid was observed, Moing et al. [15] suggested that malate accumulation in the fruit could have been determined not by changes in its metabolism, but by the conditions of its transport into the vacuoles of the mesocarp cells.

The current climate change context, with increasing temperatures and decrease in precipitation patterns, is imposing new challenges to vine growers. A significant earlier occurrence of grapevine developmental stages due to increasing temperatures has been reported in several wine regions [2,16,17], thereby placing ripening during a warmer period of the year. This results in increased sugar levels and lower acid concentrations for grapes, leading to unbalanced wines with higher alcohol content and deprived of freshness and aromatic complexity [18–20]. High temperature affects the organic acid content of berries inducing a faster consumption of malic acid as a respiratory substrate [21]. Moreover, warmer temperatures favor the accumulation of K during grape ripening, leading to an increase in the electrical neutralization of organic acids and increasing pH values in musts [7,22].

Limited rainfall may amplify the negative effect of temperatures, contributing to increased K concentration in grapes. In fact, it has been reported that under drought stress, some key K transporters (namely shaker channels VvK1.1, VvK1.2 and VvK3.1) are up-regulated, increasing K loading into berries [23,24]. Considering the detrimental effect of excessive K accumulation on musts, K content can represent a key element to be monitored in order to ensure grape quality under a changing environment. This is especially true for white grapes destined to the production of sparkling wines, for which titratable acidity and the malic acid content at harvest are of utmost importance [25].

The cv. Glera is a white grape variety cultivated in the northeast of Italy for the production of the renowned Prosecco sparkling wine [26]. The temperature increase experienced in the last decades in the Prosecco production area has resulted in a harvest date shifted 14 days earlier compared to the average before the 1990s [27]. One of the most negative impacts of this temperature increase is the extreme difficulty in preserving the grape acidity during ripening, with an average titratable acid content reported to be 2 g/L lower nowadays compared to the period before the 2000s [28]. Given the considerable “Glera” economic importance due to the worldwide distribution of “Prosecco” wine, research efforts have been recently made to assess the impact of environmental stresses associated with climate change on this variety and identify solutions able to preserve the Prosecco wine’s quality and identity [29].

In this study, a field trial was established in 2013 to investigate the effects of different potassium fertilization rates on Glera vines grown under field conditions. Yield and grape composition were determined in a 4-year study. The main goal of this work was to increase the knowledge on potassium nutrition management in the vineyard and provide new information to develop fertilization strategies able to counteract the adverse effects of climate change on Glera grape quality.

2. Materials and Methods

2.1. Vineyard and Treatments

The study was carried out for four years (2013–2016) in a 6-year-old commercial vineyard located in the Prosecco DOC area, in Northeastern Italy (lat. 45°7′55″ N; long. 11°26′47″ E). The study site is situated in an alluvial plain area, formed on the ancient fine deposits of the rivers Adige and Brenta. The total surface of the vineyard is 1.46 ha, and the surface where the treatments were applied was 380 m² (Figure 1).

Figure 1. Localization of the vineyard in the study area: the red line indicates the perimeter of the vineyard (a). Map of the experimental plots where treatments were applied (b).

The vineyard was planted in 2007 with Glera variety grafted onto Kober 5BB rootstock and trained to a double Guyot system, with 8 buds per cane and with a vine spacing of $2.65 \text{ m} \times 1.0 \text{ m}$. During the vegetative season, the growing shoots were positioned vertically using a trellis system based on two pairs of horizontal galvanized steel catch wires located at 100 and 140 cm above ground. Shoots were mechanically trimmed twice in the season, between flowering and veraison, at 180 cm above the ground (leaving around 13 nodes per shoot). As typical of commercial practice in this area, herbicide was applied in the under-row while the inter-row was covered by natural grass. No irrigation was applied during the experiment. All cultural practices in this experiment were similar to those applied in commercial vineyards in the local area.

Since the beginning of the trial, four fertilization treatments corresponding to four levels of mineral K were imposed each year (0, 15, 30, 60 kg $\text{K}_2\text{O}/\text{ha}$). The amounts of K were selected to be equal or below the conventional K fertilization practice in the Prosecco DOC production area, where amounts between 40 and 80 kg $\text{K}_2\text{O}/\text{ha}$ are applied annually, depending on the soil characteristics and climate conditions [30,31].

Each treatment was imposed to 6 plots (replicates) consisting of 6 contiguous vines, with sampling and measurements being carried out on the 4 middle plants. Plots were arranged in a completely randomized block design. Mineral K was supplied once before flowering, as potassium sulphate (K_2SO_4 , 50% K_2O). The fertilizer was applied manually on an approximately 60 cm wide line in the under-row. In all the treatments, nitrogen and phosphorous fertilization was performed two times, before budding and before flowering, with 70 kg N/ha and 30 kg P/ha as ammonium nitrate (40% N) and ammonium phosphate (12% N and 23% P), respectively, according to the vine management in the area.

2.2. Climate and Soil

For each year of the study, weather records for air temperature and rainfall were recorded by a nearby weather station. Data readings were collected every 60 min and stored in a datalogger (Watch Dog 1400; Spectrum Technologies, Bridgend, UK) for further analysis.

Soil physical and chemical composition were determined at the beginning of the study. Three soil samples of about 1 kg were collected at 3 random sites selected within the experimental plot designated for treatment application. Soil samples were collected using a hand drilling equipment. Before sampling, the grass cover was removed and 3 cores that extended to a depth up to 40 cm were acquired at each site and merged to obtain a composite soil sample of 1 kg. Samples were sieved moist (2 mm) and stored at ambient temperature. Physical and chemical analyses were performed by an external laboratory,

which applied standard methods, as indicated by Italian Law Decree for soil analysis n. 121/1992 [32].

2.3. Vegetative Growth, Yield and Grape Composition

Agronomic traits and grape composition were analyzed on 24 vines for each treatment (6 repetitions of 4 vines). The grape harvest was performed on the same day for all the fertilized treatments (K15, K30, K60) and for the control (K0). Harvest dates for treatments and control in the four vintages were: 12 September 2013, 4 September 2014, 9 September 2015, 12 September 2016. Grapes were harvested at technological maturity, defined as total soluble solids (TSS) ≥ 15 °Brix and titratable acidity (TA) ≤ 10 g/L of tartaric acid. Yield per vine and average cluster weight were recorded for each vine using a hanging scale (CH, Kern, Germany). Cluster weight was calculated by dividing fruit yield per vine by the number of clusters harvested. Berry weight was measured on a subsample of 30 berries randomly collected from all measuring vines in each plot using a precision scale (PJ3600 DeltaRange; Mettler Instruments AG, Greifensee, Zurich, Switzerland). Winter pruning wood from the same vines was weighed, as an indicator of vine vigor. Fruit composition at harvest was measured on a sample of 1 kg of grapes randomly collected from all vines of each replicate. Soluble solids were measured by refractometer (Atago PR32; Norfolk, VA, USA) at 20 °C; pH and titratable acidity (expressed as g/L of tartaric acid) were determined using an automatic titrator (Crison Micro TT 2022; Crison Instruments, Barcelona, Spain) by titration with 0.1 n NaOH. Malic and tartaric acid content (g/L) were determined using RP-HPLC method (Agilent 1220 Infinity LC; Agilent Technologies, Santa Clara, CA, USA). Samples were diluted 50 times and then filtered through 0.2 mm nylon filters and 20 µL and then directly injected onto GRACE Alltima HP C18 5 micron 150 mm $\times$ 4.6 mm. Separations were carried out under isocratic conditions at 36 °C using a 6×10^{-3} mol/L H_3PO_4 solution mobile phase at a 0.6 mL/min flow rate. Organic acids were detected at 210 nm as described by Kordiš-Krapež et al. [33]. K concentration was analyzed on the must obtained from 30 berries randomly collected from all the vines of each replicate. After removing the skins and seeds, the musts were diluted 10 times and analyzed by atomic absorption spectroscopy (Perkin-Elmer, model 2380, Norwalk, CT, USA).

2.4. Statistical Analysis

All statistical analyses were carried out within the RSTUDIO environment version 1.2.1335 for R (version 3.6.1; www.R-project.org (accessed on 26 October 2021)). Two-way ANOVA was used to assess the effects and interactions of treatments and year with yield components and grape compounds. One-Way ANOVA was performed within each year to analyze the effect of fertilization treatments. When a significant effect was found, the Fisher's test (emmeans package, v. 1.15.15; [34]) was applied to determine significant differences between treatments. Any difference was accepted with p -value < 0.05 . The correlation analysis was performed using ggscatter function built in "ggpubr" package. Graphics were made using ggpubr package (v. 0.1.2; [35]).

3. Results

3.1. Climate and Soil

The studied area has a typical Mediterranean climate, with warm summers and cool winters. Annual rainfall is approximately 900 mm, falling mainly in spring and autumn. For each year of the study, the annual and seasonal (March–September) weather records for mean air temperature and rainfall are reported (Table 1). Monthly rainfall during the vegetative season in the four years of study is reported in Figure 2.

Table 1. Annual and seasonal mean temperatures and rainfall in the four study-years. Seasonal values are from 1st March to 30th September.

Meteorological Data	Year			
	2013	2014	2015	2016
T annual (°C)	13.5	14.7	14.1	13.8
T seasonal (°C)	18.2	18.4	19.2	18.6
Σ Rainfall annual (mm)	1122	1026	639	898
Σ Rainfall seasonal (mm)	671	598	372	441

Figure 2. Monthly rainfall during the growing season in the four study-years.

The soil in the experimental site is relatively deep (>1 m) and is classified as an Oxyaquic Haplustepts coarse—loamy, mixed, mesic (USDA, 1988) [36]. The soil physical and chemical characteristics determined at the beginning of the trial, before treatment application, are reported in Table 2.

Table 2. Soil properties in the experimental vineyard at the beginning of the trial. Data are the average of 3 replicates (soil samples) ± standard errors.

Soil Characteristics	Values (Soil Depth 0–40 cm)
Sand %	53.5 ± 5.3
Silt %	30.2 ± 2.9
Clay %	16.3 ± 3.7
pH	8.27 ± 0.28
Organic matter g/kg d.w.	15.6 ± 2.9
Total N g/kg	0.70 ± 0.07
P mg/kg	43.2 ± 5.2
exchangeable K mg/kg	162 ± 15
Ca carbonate %	15.0 ± 1.2

3.2. Effect of K Fertilization on Vegetative Growth and Yield Components

Total yield and number of clusters per vine were unaffected by potassium treatments (Table 3). Despite climate conditions showing some differences in the average rainfall and temperature between seasons, cluster weights were consistent over the four study years, and the averaged values indicated that this yield component was not affected by potassium fertilization either.

Table 3. Yield components and pruning weight of Glera vines in response to different potassium fertilization. Means followed by different letters differ significantly by Fisher's least significant difference test (* = $p \leq 0.05$; ns: non-significant).

Variable	Treatment	2013	2014	2015	2016	Average 2013–2016
Pruning weight (kg/vine)	K15	2.39	2.53	1.7	2.35	2.24
	K30	2.50	2.20	2.21	2.20	2.28
	K60	2.67	2.52	2.00	2.28	2.37
	K0	2.37	2.52	1.94	2.06	2.22
	F test sign	ns	ns	ns	ns	ns
	Treatment $\times$ year					ns
Yield (kg/vine)	K15	9.0	5.8	5.8	6.8	6.9
	K30	8.1	6.5	5.2	7.4	6.8
	K60	8.4	6.7	4.5	7.3	6.7
	K0	8.5	6.3	5.4	8.0	7.1
	F test sign	ns	ns	ns	ns	ns
	Treatment $\times$ year					ns
Clusters per vine	K15	36	21	20	33	28
	K30	29	24	16	32	25
	K60	28	21	16	36	25
	K0	32	21	19	39	28
	F test sign	ns	ns	ns	ns	ns
	Treatment $\times$ year					ns
Cluster weight (g)	K15	247	c	282	b	257
	K30	284	ab	278	b	280
	K60	303	a	320	a	278
	K0	263	bc	299	ab	263
	F test sign	*	*	*	b	ns
	Treatment $\times$ year					ns
Berry weight (g)	K15	1.76				
	K30	1.96				
	K60	1.88				
	K0	2.04				
	F test sign	ns				
	Treatment $\times$ year	ns				

Pruning weight was measured as an indicator of vine vigor and was fairly similar in all treatments over the four years. It must be pointed out that trimming operations performed between flowering and veraison may have dampened differences in the growth of main shoots. However, we could have expected also differences related to the bud fertility or to the number and growth of lateral shoots. As we did not observe changes in the pruning weight between treatments, we can suppose that none of these parameters was significantly influenced by the K fertilization.

Berry weight was recorded only in the first year of study; however, potassium supply did not show a significant effect on this parameter.

3.3. Grape Composition

Total soluble solid content (TSS) in the study period was never significantly affected by the K fertilization treatments (Table 4). The 4-year values for the total content of titratable acids (TA) in the grape must range between 7.4 and 7.9 g/L, with K60 treatment showing values significantly higher than K0 and K15, but not different from K30 treatment. As shown in Figure 3, the decline of TA displayed an almost linear trend in all the vintages. In 2015 and 2016, significant differences were found only one week before harvest, with K30 and K60 displaying higher acidity values than K0 and K15.

Table 4. Fruit composition of Glera vines in response to different K supply treatments. Means followed by different letters differ significantly by Fisher's least significant difference test (*, **, *** = $p \leq 0.05, 0.01, 0.001$, respectively; ns: non-significant).

Variable	Treatment	2013		2014		2015		2016		Average 2013–2016		
TSS (°Brix)	K15	15.3		14.8		18.0		17.7		16.5		
	K30	15.5		15.1		18.1		17.7		16.6		
	K60	15.0		14.6		18.1		17.3		16.3		
	K0	15.8		15.0		18.1		17.8		16.7		
	F test sign	ns		ns		ns		ns		ns		
Titratable acidity (g/L)	Treatment × year	ns										
	K15	7.9		9.6		5.4		6.6		7.4		b
	K30	7.8		10.0		5.8		6.9		7.6		ab
	K60	8.3		10.1		6.1		7.0		7.9		a
	K0	7.7		9.5		5.8		6.4		7.4		b
pH	F test sign	ns		ns		ns		ns		**		
	Treatment × year	ns										
	K15	3.18		3.13		ab	3.39		3.23		3.23	
	K30	3.18		3.10		b	3.38		3.23		3.22	
	K60	3.16		3.14		a	3.36		3.24		3.23	
Malic acid (g/L)	K0	3.19		3.11		ab	3.37		3.22		3.22	
	F test sign	ns		*		ns		ns		ns		
	Treatment × year	ns										
	K15	4.6	ab	5.7	b	2.8	b	3.2	b	4.1	b	
	K30	4.4	b	6.4	a	2.8	b	3.5	ab	4.3	ab	
Tartaric acid (g/L)	K60	5.1	a	6.5	a	3.3	a	3.7	a	4.7	a	
	K0	4.3	b	6.0	ab	2.9	ab	3.1	b	4.1	b	
	F test sign	*		*		*		*		***		
	Treatment × year	ns										
	K15	6.0	c	6.2	a	4.5		7.3	b	6.0	b	
Potassium (mg/L)	K30	6.4	ab	6.5	a	4.6		7.2	b	6.2	ab	
	K60	6.6	a	6.2	a	4.8		7.8	a	6.4	a	
	K0	6.1	bc	5.8	b	4.7		6.9	b	5.9	b	
	F test sign	*		*		ns		*		***		
	Treatment × year	ns										
TSS (°Brix)	K15	1144		1215		1184		ab		1196		ab
	K30	1165		1301		1320		bc		1270		a
	K60	1152		1265		1391		a		1192		a
	K0	1075		1197		1152		c		1178		b
	F test sign	ns		ns		*		ns		**		
Treatment × year	ns											

The pH was not affected by potassium applications, with mean values almost equal for all treatments.

On the 4-year average, K60 showed a significantly higher malic acid content than K15 and K0, whereas K30 was not significantly different from the treatments receiving lower or zero K rates.

Comparing the values of tartaric acid, similarly to what observed for malic acid, in the 4-year average K60 showed significantly higher contents than K15 and K0, while K30 showed intermediate values, not significantly different from all the other treatments.

Finally, analyzing the results for single years, the K content in the berries did not show a clear relation with the amount of K supplied with the fertilization. Considering the 4-year average, the only significant difference was recorded between the treatments receiving the highest K rate (K30 and K60) and the control K0, while K15 showed intermediate values.

Figure 3. Trends for titratable acidity, during the ripening period, in response to different potassium supply. Data are means $\pm$ SE. Significant differences are indicated by * = $p < 0.05$, as attested by Fisher's test.

To further analyze the relation between K content and the pH in the berry, a regression was calculated using the data collected in the four years of study (Figure 4). Weak correlations between K content and pH were found only in 2013 ($R = 0.49$, $p = 0.014$) and in 2016 ($R = 0.54$, $p = 0.0066$) vintages, but on the averaged data, no significant relations were found between these two parameters ($R = 0.19$, $p = 0.063$).

Figure 4. The relation between grape juice pH and K concentration for Glara vines over 4 study seasons. Within each year, a data point represents the means of 6 replicate vines for every treatment. The dotted line represents the mean regression line for all vintages.

4. Discussion

This study has investigated the effect of potassium fertilization on yield and grape composition of Glera cv., a white grape variety used to produce the renowned Prosecco sparkling wine. Given the oenological destination of this variety, maintaining grape acidity under warmer conditions has become a major challenge for Glera cultivation. In this context, potassium fertilization may be of great interest given the impact this technique may have on the acidity and pH values of musts.

This trial was carried out in a sub-area of the DOC Prosecco where soils were characterized by good potassium availability (see Table 2). We tested three different K rates: 15, 30 and 60 kg/ha, the latter being comparable to the conventional K rate used in this specific area. Considering the negative effects caused by excessive K accumulation on musts, our goal was to assess if reduced K fertilization may influence and improve grape yield and quality, with specific attention for the acidity and pH parameters.

Our results indicate that K had more effects on grape composition than on yield components. Previous studies investigating the impacts of potassium fertilization on grapevine production showed discordant results. Amiri et al. [37] reported that a potassium fertilization with 300 g per vine increased yield and cluster number in the grapevine cv. Bidaneh Qermez compared with a non-fertilized control. On the contrary, Ruhl et al. [38] analyzed the effect of potassium supply on the yield of “Riesling”, “Chardonnay” and “Cabernet Sauvignon” under controlled conditions and reported that increased K fertilization (60 kg K/ha) did not affect the fruit yield. In another greenhouse trial, potted Cabernet Sauvignon receiving 25 g K per vine were compared to control vines fed with 0 g K (no K added) and authors found that total yield, cluster number per vine, cluster and berry weight were unaffected by K supply [9]. A significant reduction in the yield of Concord grape variety was observed in another study, where extremely high levels of potassium fertilizer (225 to 900 kg/ha) were supplied using KCl as a source. In this case, the probable cause of yield loss was the Cl accumulation in soils due to the prolonged use of KCl [39]. In our experiment, moderate or low amounts of potassium were applied, similarly to what was performed by [9,38], and this may explain why the fertilization impact on yield components was smaller than that observed in other studies. It must also be outlined that data obtained from different studies are not subject to easy comparison, due to differences in the experimental conditions and in the plant material used for the study.

The relationship between the K concentration in grape berries and wine quality is well documented; however, there is still some controversy over the effects of K fertilization on sugar and acid contents in grapes [40]. K supply plays a key role in the sugar/acid ratio of wine, which is crucial to ensure a balanced taste. Zatloukalová et al. [41] reported no significant variation in the sugar content of cv. Riesling italic after five foliar applications of a 5% solution of K_2SO_4 in comparison to an untreated control. In a similar experiment [42], the sugar content of cv. Zweigelt treated with potassium applied foliarly was lower than the untreated control. In the greenhouse trial mentioned above [9], the sugar content of potted Cabernet Sauvignon vines receiving 25 g K per plant did not show differences in comparison to the control vines. Conversely, other studies argue that K fertilization causes a significant increase in the sugar/acid ratio. Martin et al. [43] found that increasing the amount of K fertilization caused an increase in the sugar/acid ratio due to a reduction in acidity. The authors postulated that higher potassium levels (120 g K_2O per vine, corresponding to 266 kg K_2O /ha) caused an excessive migration of K cations into the fruit, leading to the production of potassium bitartrate from tartaric acid. In our study, in four years of experiments, the TSS was always unaffected by K fertilization. We can speculate that in our experimental conditions, probably other agronomic practices, such as canopy management and crop control, might have exerted a major impact on sugar accumulation, minimizing the effect of the K fertilization. It is known, in fact, that a well-exposed foliar surface and a balanced ratio between photosynthetically active leaves and kilograms of grapes are major drivers for sugar accumulation in grape berries for Glera variety [27].

Analyzing the effect of K on the acidity and pH, Poni et al. [9] found similar acidity and pH values in vines receiving 25 g K per plant and control vines with no K fertilization. On the contrary, Gawel et al. [44] observed that excessive K levels in grape berries decreased the free acid fraction and increased the overall pH, with detrimental effects on the wine quality. In our experiment, the 4-year average values for titratable acidity, malic and tartaric acids resulted higher in the treatment that received the highest rate of K (K60), while the lowest rates (K30, K15) were similar to the no-fertilized control. These results indicate that for the Glera variety, a reduced K supply did not positively affect the acidity. On the contrary, medium K rates (60 kg/ha) showed the best results on this grape parameter.

With regards to the malic acid amount, a direct effect of K availability on the synthesis of this acid has been suggested. This might be explained by the fact that, in the berry, a K supply not completely balanced by anion uptake could determine an extra malic acid synthesis [45,46]. Failla et al. [47] found a positive relation between malic acid and K level during veraison, particularly if K in the berry juice was above the threshold of 0.8–1.0 g/L, as in our study. Moreover, a direct or indirect effect of K on the rate of malic acid metabolization during ripening was proposed, which, according to Hale et al. [13], could be due to an effect of K on the tonoplast permeability. This would result in less malate available in the cytosol for use in metabolism. In support of this hypothesis, an inverse relationship between potassium and tonoplast permeability in ripening fruits was observed in other crops [48].

As observed for malic acid, tartaric acid was also higher in the treatment that received the highest rate of K (K60), followed by K30. The explanation could be linked to the pathway of synthesis of this acid. In fact, it has been reported that high amount of potassium may promote the biosynthesis of ascorbic acid [49,50], increasing the availability of one of the precursors for the tartaric acid biosynthesis [51].

Regarding the must pH, all K treatments showed pH values comparable to those of the non-fertilized control, despite showing higher berry K content. It is commonly accepted that a high potassium concentration in grape berries leads to high pH values [7]. In this study, only a weak correlation between pH and potassium content was found. This can be related to the fact that the K rates supplied in this study induced moderate potassium accumulation in grape musts, preventing pH from increasing. Moreover, it has been reported that there are varietal differences in the relationship between juice pH and K concentration [3]; therefore, Glera response to K supply might be smaller than that observed in for other cultivars. Overall, the data in our study showed that the K fertilization did not affect the pH, as all treatments displayed comparable values in the range between 3.10–3.39, which is considered optimal for wine making.

5. Conclusions

Potassium fertilization is required to restore the annual removals to the vines, but excessive K supply can cause fruit pH to increase and reduce titratable acidity in musts. This effect might be even emphasized under warmer and drier climate conditions. In this study, we analyzed the effect of potassium fertilization on the grapevine cv. Glera, comparing low and medium rates of K supply (15–30–60 K₂O/ha). Results from 4 years of study indicate that potassium fertilization does not have an influence on grape yield in Glera vines grown in field conditions. Concerning the grape composition, our data shows that low K supply (15–30 kg/ha) did not affect any grape quality parameter, while values for titratable acidity, malic and tartaric acids resulted improved in the treatment that received the highest rate of K (60 kg K₂O/ha). In contrast to what has been reported from other studies, in our trial the K fertilization did not affect the pH, as all the fertilization treatments displayed comparable pH values and in an optimal range for winemaking. Based on these results, we can suggest that in growing conditions similar to those of our study, medium potassium inputs (60 K₂O/ha) can positively affect the composition of the grapes by promoting higher titratable acidity levels without altering the pH in wines.

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