Vitis 12, 277—285 (1974)

Tamil Nadu Agricultural University, Coimbatore, India

Correlation between yield, quality, and petiole nutrients in grapes

by

C. R. Muthukrisiinan and C. Srinivasan

Korrelation zwischen Ertrag, Mostqualität und Nährstoffgehalt in den Blattstielen von Reben

Zusammenfassung. — Die Korrelationskoeffizienten zwischen dem Gehalt der Blattstiele an N, P, K, Ca und ihren Mengenverhältnissen einerseits und den Ertrags- und Qualitätseigenschaften der Rebe andererseits wurden ermittelt. Signifikant negative Korrelationen wurden beobachtet zwischen Nitrat-N und P, P und Ca sowie P und Mg der Blattstiele. Die Akkumulation des Ca erfolgte synergistisch mit der des Mg. Der Ertrag war negativ korreliert mit Nitrat-N und den Verhältnissen N/P, Ca + Mg/K sowie mit dem Gesamt-Kationengehalt (N + P). P, N/K und das Kationen/Anionen-Verhältnis waren positiv korreliert mit dem Ertrag der Reben. K, Mg und N/K beeinflußten das Mostgewicht positiv. Der Ca-Gehalt im Blattstiel zeigte eine negative Beziehung zur Säure. Außerdem ergab sich für die Verhältnisse Ca/Mg und Kationen/Anionen eine signifikant positive Bindung an das Verhältnis Mostgewicht/Säure. Der Gesamtgehalt an Kationen zeigte eine enge positive Korrelation zum Kationen/Anionen-Verhältnis, während der Gesamtgehalt der Anionen mit diesem Verhältnis negativ korreliert war.

Introduction

In an earlier work on foliar analysis, emphasis was placed on nutrient balance and critical nutrient levels. While the logic behind this concept is reasonable, data is lacking on yield and quality, with reference to the specific levels of each element within the plant. In grapes, petiolar tissues serve as a sensitive indicator of nutrient status (Ulrich 1942, Chapman 1964). Many workers have tentatively fixed the petiole nutrient optima for a specific quantity of grape yield (Beattie and Forshey 1954, Shaulis and Kimball 1956, Abdalla and Sefick 1956, Bryant *et al.* 1958), and these studies were generally limited to the common three nutrient elements. Further, precise statistical relationship has yet to be established between the petiole nutrients and their ratios with yield and quality attributes of grapes. In the present study, we tried to establish correlation coefficients between tissue nutrients and their ratios with yield and quality attributes.

Materials and Methods

Representative samples from thirty overhead arbour-trained vineyards of five-year-old bearing vines of Anab-e-Shahi (*Vitis vinifera* L.), a popular cultivar of the Indian Peninsular, were selected as variants for the study. The soils in which the vines were growing had a high N and K content with moderate P. The vines were fertilized with 1.5 to 2.8 kg N, 0.7 to 1.4 kg P and 1.5 to 2.5 kg K as ammonium sulphate, super phosphate and potassium chloride respectively. Twenty recently matured, healthy petioles opposite the inflorescence were sampled from each vine at flowering to reckon the nutrient status of the vine.

The petioles so sampled were oven dried at 70 °C, powdered and utilised for the nutrient determinations. As everyone knows, nitrate N has been found to be the functional form of N rather than total N in grapes (Dintscheff *et al.* 1964, Havelka

1964) hence it was taken as the N indicator in the petiolar tissues. Nitrate N was determined by micro Kjeldahl method (Humphries 1956). 500 mg of dry powdered petioles were digested with triacid containing nitric acid, sulphuric acid, and perchloric acid (9 : 2 : 1) and utilized for determining P, K, Mg and Ca. Phosphorus was determined colorimetrically by the vanadomolybdate method (Koenig and Johnson 1942). Potassium was determined flame photometrically from the triacid extract. Calcium and magnesium were estimated by titration (Sankaram 1966). All estimations were done in triplicate and the mean values were expressed as percent on dry weight basis. The ratios of nutrients were computed for each vine.

The total yield of grapes was recorded for each vine. Brix was measured using a Zeiss hand refractometer and expressed as a percentage at 20 °C. To determine the titratable acidity, water extractives of the berries were titrated against decinormal KOH and expressed as a percentage of anhydrous tartaric acid. The Brix/acid ratio was also computed.

Linear correlation coefficients and multiple regression coefficients were worked out between the petiole nutrient contents and their ratios with yield and quality attributes of grapes.

Results

The correlation coefficients were established between a) petiole nutrients, b) petiole nutrients and yield, c) petiole nutrients ratios and yield, d) petiole nutrients and quality attributes, e) petiole nutrients ratios and quality attributes, f) yield and quality attributes, and g) total anion nutrients, cation nutrients and their ratio with yield and quality.

a) Petiole nutrients

The existence of inter relationships in the accumulation of N, P, K, Ca and Mg in the vines was examined (Table 1). An unambiguous negative correlation could be noted between nitrate N and P. Based on these relationships, it is reasonable to infer the prevalence of antagonism in the relative accumulation of these two nutrients. A similar negative association could also be established between P and Ca as well as with Mg. The accumulation of Ca is synergistic to Mg as evidenced by a high positive correlation coefficient. The correlations between N and K, N and Ca, N and Mg, P and K, K and Ca, as well as K and Mg were virtually not significant.

b) Petiole nutrients and yield

A linear correlation of yield as dependent variable and N, P, K, Ca and Mg as independent variables, when computed, revealed that nitrate N had a pronounced

Table 1

Correlation coefficients between yield and petiole nutrients in grapes
Korrelationskoeffizienten zwischen dem Ertrag und dem Nährstoffgehalt des Blattstieles bei Reben

Variants	N	P	K	Ca	Mg
Yield	—0.946**	0.711**	0.224	—0.361*	—0.278
N		—0.686**	—0.244	0.303	0.200
P			—0.106	—0.511**	—0.388*
K				—0.008	—0.032
Ca					0.900**

negative correlation with yield (—0.946) while P showed a significant positive correlation coefficient. There was no significant correlation between K, Ca and Mg with yield (Table 1).

A multiple regression equation indicated the existance of a very close link between yield and petiole nutrients, by registering the R^2 value as high as 0.9078.

$$Y = 132.8137 + 75.3897^{**}\ x_1 + 12.2315^{NS}\ x_2 + 0.6101^{NS}\ x_3 + 2.3928^{NS}\ x_4 + 31.4710^{NS}\ x_5$$

where x_1 x_2 x_3 x_4 and x_5 are N, P, K, Ca and Mg respectively. Y is the predicted yield.

The R^2 value is significant at 0.1 percent level of probability (Table 2). It could be further observed that nitrate N contributed to the R^2 to a greater extent than the other nutrient variables.

Table 2

Analysis of variance
Varianzanalyse

	D.F.	S.S.	M.S.	'F'
Due to regression	5	9858.11	1971.62	
Residual	24	1001.30	41.72	47.26**
Total	29	10859.41		

The evaluation of the intensity of direct and indirect effects of nutrients on yield (Table 3) again showed that nitrate N contributed to the yield to a much greater degree, more particularly, the direct effect of nitrate N was found to be much higher compared to its indirect effect. Other nutrients contributed to the yield, mainly indirectly. But, on the whole, the direct effect of nutrients is more predominant than their indirect effects, mainly due to the major contribution of nitrate N to the R^2 value.

Table 3

Direct and indirect effects of independent variables (petiole nutrients) to R^2 (0.9078)
Direkte und indirekte Wirkungen der unabhängigen Variablen (Nährstoffe im Blattstiel) auf R^2 (0.9078)

	x_1	x_2	x_3	x_4	x_5	x_5
Direct	0.7420	0.0119	0.0005	0.0046	0.0153	0.7743
Indirect	0.0731	0.0658	0.0046	—0.0291	0.0191	0.1335
Net effect	0.8151	0.0777	0.0051	—0.0245	0.0344	0.9078

Table 4

Correlation coefficients between yield and petiole nutrient ratios
Korrelationskoeffizienten zwischen dem Ertrag und den Nährstoffverhältnissen im Blattstiel

Variants	N/P	N/K	K/P	K/Ca	K/Mg	K/Ca + Mg	Ca + Mg	Ca + Mg/K
Yield	—0.635**	0.527**	0.317	0.300	0.303	0.061	0.306	—0.481**

c) Petiole nutrient ratios and yield

The nitrate N/K ratio also showed such positive association with yield to a moderate level of probability. On the contrary, nitrate N/P and $\frac{Ca + Mg}{K}$ have also influenced the yield but this was of a negative nature. As such, it could be inferred that it is not the individual nutrient which control the yield potential of grapes, but the definite proportion of them (Table 4).

Table 5

Correlation coefficients between yield and quality attributes in grapes
Korrelationskoeffizienten zwischen Ertrag und Qualitätseigenschaften bei Reben

Variants	Brix	Acidity	Brix/Acid ratio
Yield	0.065	0.431*	0.138
Brix		0.006	0.381
Acidity			—0.845**

d) Petiole nutrients and quality attributes

There was no significant influence of nitrate N and P on any of the quality attributes, but K showed a positive association with Brix only. In the case of secondary nutrients, a moderate degree of positive correlations could be established between Ca and Brix, whereas with acidity Ca showed a negative relationship. Magnesium did not exhibit any link with quality attributes (Table 6). The ratio between Brix and acidity is generally reckoned as the measure of quality in grapes. Multiple regression between petiole nutrients and quality was also not significant, registering the R^2 as 0.1366. The equation was:

$Y = 23.74 + 0.399NS\ x_1 - 5.954NS\ x_2 + 2.685NS\ x_3 + 6.396NS\ x_4 + 55.59NS\ x_5$,

where Y = Brix/acid ratio or quality.

e) Petiole nutrient ratios and quality attributes

Though nitrate N independently did not have any bearing on quality attributes, the N/K ratio was found to be positively related to Brix. Similarly, Ca/Mg ratio exhibited a significant positive r value with Brix/acid ratio. Other petiole nutrient ratios did not show any measurable correlation coefficients (Table 6) with quality attributes.

f) Yield and quality attributes of grapes

The yield of grapes proportionately influenced the titratable acidity and as such, a significant positive correlation coefficient was noted. Further, the yield did not show a significant association with the Brix as well as Brix/acid ratio. Brix was positively correlated to the Brix/acid ratio, whereas a fairly high negative r value (—0.845) could be seen between the acidity and the Brix/acid ratio (Table 5).

g) Total anion nutrients, cation nutrients and their ratio with yield and quality of grapes

The total anion nutrients percent (Nitrate-N + P) was found to show a significant negative correlation coefficient with the yield, while no relationship could be established between the total cation nutrients percent (K + Ca + Mg) and the yield. A highly significant positive correlation (r = 0.920) was observed between the

Table 6

Correlation coefficients between quality attributes of grapes, and the petiole nutrients and their ratios
Korrelationskoeffizienten zwischen Qualitätseigenschaften von Reben und den Nährstoffen sowie Nährstoffverhältnissen im Blattstiel

Variants	N	P	K	Ca	Mg	N/P	N/K	K/P	K/Ca	K/Mg	Ca/Mg	Ca + Mg/K
Brix	0.163	0.017	0.413*	0.418*	0.197	0.066	0.373*	0.283	0.180	0.333	0.109	0.071
Acidity	0.222	0.027	—0.250	—0.510**	—0.040	—0.194	—0.055	—0.145	0.020	0.071	0.078	0.034
Brix/acid ratio	0.014	—0.149	0.251	0.108	0.186	0.144	0.239	0.340	0.141	0.133	0.579**	0.069

Table 7

Analysis of variance for regression between quality (Brix/acid ratio) and petiole nutrients
Varianzanalyse für die Regression zwischen der Mostqualität (Verhältnis Brix/Säure) und dem Nährstoffgehalt im Blattstiel

Source	D.F.	S.S.	M.S.	'F'
Due to Regression	5	231.9462	46.3892	< 1NS
Residual	24	1465.4538	61.06	
Total	29	1697.4000		

Table 8

Correlation coefficients between total anion nutrients, cation nutrients and their ratio with yield and quality
Korrelationskoeffizienten zwischen Gesamt-Anionen, Gesamtkationen sowie ihrem Verhältnis und Ertrag sowie Mostqualität

Variants	Total anion nutrients	Total cation nutrients	Cation/anion ratio
Yield	—0.532**	0.076	0.920**
Quality (Brix/acid ratio)	—0.058	0.281	0.673**
Total anion nutrients (N + P)		—0.355	—0.605**
Total cation nutrients (K + Ca + Mg)			0.954**

cation/anion nutrients ratio and the yield. In the case of quality, a significant positive association existed between the cation/anion ratio and the Brix/acid ratio. Further, the total cation nutrients exhibited a very strong positive correlation coefficient ($r = 0.934$) with the cation/anion ratio, but the total anion nutrients were negatively correlated with the ratio (Table 8).

Discussion

Thus the results indicated how far the petiole nutrients are related to yield and quality attributes. Nitrate N (here called as N) was found to play a definite role among the inorganic nutrient factors governing the yield. A highly significant negative correlation was obtained between yield and tissue N by El-Shourbagy and Ismail (1961). It suggests that yield correspondingly decreases if tissue nitrate N in the grape vine increases beyond the adequacy level. Vergnes (1961) also observed a depression in the productivity of grapevine when soil application of N was enhanced. Recently, Satyanarayana (1972) reported that in Anab-e-Shahi grapes the N level in leaves is a major controlling factor in determining the yield and an excess of N hampers the fruit production and lowers the yield. But this study provided a definite correlation coefficient for those observations. On the contrary, petiole P content obviously exhibited a positive association with yield which also confirms the observations of Serpukhovitina (1965) who reported an increased yield of grapes with enhanced P fertilisation. Such a promotive effect of P on yield was perceived in grapes, due to the soil application of P, by Arutiunian (1964) and Nanaya (1966).

Unlike N and P, K did not show any bearing on yield. This is contradictory to the results of LARSEN *et al.* (1955) who obtained a positive relationship between petiole K and yield. They achieved this relationship by K fertilization in K deficient soil, but the failure of tissue K to show any relationship with yield in this study may be due to the high K content of Indian soils. Similarly, Ca and Mg also did not independently affect the yield. Accordingly, BRYANT *et al.* (1959) found no correlation between Mg and yield. On the contrary N/K and Ca + Mg/K ratios have been found to express a bearing on yield. Recently LAVY (1968), based on his data collected over 18 years, also concluded that N/K ratio is more important than NPK ratios in predicting the optimal yield in grapes.

Furthermore, a significant positive correlation between yield and acidity provided ample proof of the fact that as the yield of grapes increases, the quality of the berries becomes poor, due to the consequent increase in titratable acidity.

Examination of relative net accumulation of petiole nutrients showed that N accumulation is antagonistic to P. A similar antagonism between these two major nutrients have been widely reported from many parts of the world (SMITH 1962). Further, the antagonistic effect of N is exemplified by the negative correlation between N/P ratio and yield. The antagonistic effect of excess N on yield was not nullified by P, though r value is less between N/P ratio and yield than N with yield. Further, this study confirms the synergism in the tissue accumulation of Ca and Mg reported by SMITH (1962).

Numerous data are available on the effect of K on Brix (ARNON 1966). The Brix content in pineapple (SANFORD 1968) and papaya (AWADA and LONG 1971) has been increased by increment in K fertilization. In grapes, COOK (1968) found that K fertilization increased the sugar content. Our work confirms these reports by establishing a significant positive correlation between K and Brix. Moreover, it is generally recognized that the sugar of the ripe grapes is manufactured in the leaves (WINKLER 1965). As Ca and K are involved in the active translocation of the sugars from leaf to fruit, a positive correlation was evident between petiole K and Ca with Brix of fruits. HUMBERT (1968) also stated that unlike N and P, K showed a linear relationship to the rate of translocation of sugars from leaf to fruit. K is required more for improvement in quality than for maximum yield. Further, the N/K ratio plays a significant role in influencing both yield and quality factor (Brix). It is interesting to observe that K exhibited no significant relationship with yield and N did not show any association with quality attributes, but their ratio (N/K) was found to have a positive correlation coefficient with yield as well as Brix. HILL *et al.* (1950) showed that a proper foliage N/K ratio is necessary to get significantly higher quality apple fruits. ARNON (1966) also pointed out that the N and K interaction is a criterion to assess the yield and quality in many fruit plants. Cation nutrients, both independently (K, Ca and Mg) as well as collectively (K + Ca + Mg), did not show a significant association with changes in yield and quality (Brix/acid ratio) in grapes, but their ratio with total anion nutrients exerted a striking influence on the yield as well as on the quality. The results thus support the concept of SHEAR *et al.* (1946) that the net accumulation of individual plant nutrients in the tissues alone does not govern the yield and quality, but the intensity and balance between these nutrients are rather important.

In addition, this study provides certain evidence to confirm that the recently matured petiole is the sensitive indicator of nutrient status in grapes and the tissue nutrients are correlative to yield and quality. Further, a more precise study on the effect of graded doses of these nutrients on the petiole nutrient concentrations in

relation with yield and quality of grapes will give the critical tissue concentrations for optimum yield and better quality.

Summary

The correlation coefficients between the N, P, K, Ca and Mg content of petioles and their ratios with yield and quality attributes were established in grapes. Significant negative correlations were observed between nitrate N and P, P and Ca as well as P with Mg in the petioles. Accumulation of Ca was synergistic with that of Mg. Yield was negatively correlated to nitrate N, N/P, Ca + Mg/K and total cation nutrients (N + P). P, N/K and cation/anion ratio were positively related to the yield of grapes. With regard to quality attributes, K, Mg and N/K influenced the Brix in a positive manner. The Ca content in the petiole showed a negative relationship with acidity. Further, Ca/Mg and cation/anion ratios exhibited a significant positive association with the Brix/acid ratio. The total cation nutrients exhibited a strong positive correlation with the cation/anion ratio, but the total anion nutrients was negatively correlated with the ratio.

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Eingegangen am 5. 12. 1972

Prof. Dr. C. R. Muthukrishnan
Ass. Prof. C. Srinivasan
Department of Horticulture
Tamil Nadu Agricult. Univ.
Coimbatore
641003 India