Nutrient Reference Levels for Fertigation Scheduling in Olive Groves of an Arid Region of Argentina (San Juan)

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Abstract

The diagnosis of tree nutritional status in fruit trees by leaf-nutrient analysis allows for fertilization scheduling by fertigation. In olive, a specific equilibrium in leaf nutrient concentration occurs that depends on the dominant edaphic and climatic conditions as well as the time of year. Therefore, the objective of this study was to determine leaf-nutrient reference values in olive in an arid region of central-western Argentina at two different times of the year. Leaf samples were taken during the winter rest period (July) and summer (January; a month after pit hardening) over three consecutive years in 100 commercial olive orchards from several cultivars in the Tulum Valley of San Juan, Argentina. These periods have been proposed previously in other regions. Leaf nutrient contents were analyzed and the obtained values were compared with those reported elsewhere. Confidence intervals (95%) of nitrogen (N), phosphorus (P) and potassium (K) in the winter were 1.73-1.83, 0.14-0.16 and 0.92-0.98%; respectively, while summer values were 1.56-1.70% (N), 0.16-0.18% (P), and 1.14-1.26% (K). The N concentrations were somewhat lower than those reported for the mediterranean basin with P and K values in contrast being similar or greater. Values of the remaining nutrients (Ca, Mg, Mn, Na, Cu, Zn, B and Fe) were generally similar to those reported for the Mediterranean. However, boron levels were somewhat high in the winter (25.38 ppm), and magnesium (0.13%) and manganese (33.04 ppm) were low in the summer. Given that the winter period showed narrower confidence intervals than the summer period for N, P, and K, winter sampling could be considered for annual fertilizer scheduling in intensive olive orchards in arid central-western Argentina. However, sampling during the early summer period may provide critical information just prior to oil accumulation.

INTRODUCTION

To efficiently fertilize olive orchards, an understanding of plant nutrient use is necessary to obtain maximum fruit and oil yields. Centeno and Campo (2011) recently reported preliminary findings that some increase in yield can be obtained by applying additional doses of nitrogen (N), phosphorus (P), and potassium (K) even when leaf nutrient concentrations are considered adequate. In contrast, Erel et al. (2013) have suggested that fruit load increases up to a foliar N concentration of 1.7%, and subsequently decreases as more N is applied. In this same study, fruit load increased up to a foliar P concentration of 0.2%, while K had little effect. In a long-term study, Fernández-Escobar et al. (2009) found that yield did not respond to nitrogen application even after 13 years, although foliar N concentration did not decrease below 1.2% in unfertilized plots. High levels of fertilization; particularly N, can also decrease olive oil quality (Fernández-Escobar et al., 2006).

Due to the apparent variation in response to fertilization that may be associated with regional climate, soil, and management practices, determining foliar nutrient concentrations in olive orchards in new growing regions should be a priority (Michelakis, 2002). Thus, the objective of this baseline study conducted in an arid region of central-western Argentina (San Juan), whose climate differs markedly from that of the mediterranean basin, was to determine nutrient reference values over three years. Such information should allow for more efficient fertilizer use and optimum yields.

MATERIALS AND METHODS

A total of 100 plots were selected from 15 different commercial farms located in the various production zones of Tulum Valley in San Juan, Argentina. The trees were 8-11 years old with 408 trees/ha being the most common planting density. All of the plots evaluated had pressurized irrigation systems using micro-irrigation (drip or sprinkler) and the equipment to fertilize using fertigation if deemed necessary by the grower. The plots averaged 10 ha in area and were mono-varietal. The olive oil cultivars included and number of plots for each cultivar were: 'Arbequina' (34), 'Frantoio' (19), 'Picual' (15), 'Hojiblanca' (4), 'Barnea' (4), 'I-77' (4), 'Empeltre' (3), 'Koroneiki' (2), and 'Leccino' (1). Additionally, there were two table olive cultivars, 'Manzanilla fina' (10) and 'Changlot Real' (4).

The soils of the plots included textures from sandy loam to clay loam, were slightly basic pH (7.6-8.0), and had moderate to high salinity (1.7-12.0 dS m^{-1}). Organic material content was typically low (3.3-15.8 g/kg of soil). N content was also fairly low (254-1007 mg/kg of soil), while P was intermediate (20-151 mg/kg) and K content was high (238-1121 mg/kg). Most of the soils are classified as Entisols with little or no horizon development.

The fertilization doses on a per plant basis in the 100 plots varied from no fertilization to 0.75 kg N, 0.09 P_2O_5, and 0.36 K_2O. Over three years (2006-2008), leaf samples were taken in July and January to determine the nutrient concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), zinc (Zn), copper (Cu), iron (Fe), sodium (Na), and boron (B). The July sampling represented the winter rest period, while the January sampling was similar to the early summer sampling period often used in the Northern Hemisphere. The leaf sampling consisted of removing a total of approximately 100 leaves per plot using the protocol of Bouat (1960). In brief, the first completely expanded leaf of shoots oriented at all four azimuth directions was taken from shoots of several trees at breast height (1.6 m).

All leaf samples were analyzed at the INTA San Juan Experimental Station. The total N content was determined using the Kjeldhal method (Bremmer and Mulvaney, 1982); total P and B were determined by colorimetry (Watanabe and Olsen, 1965; Matt et al., 1975); and values of Ca, Mg, Na, K, Fe, Mn, Zn and Cu were obtained by atomic absorption spectrophotometry (Analyst 200, Perkin Elmer). The concentrations of the most abundant nutrients (N, P, K, Ca, Mg, Na) were expressed as a percentage (%) on a dry weight basis, while the micronutrients were expressed as ppm. To obtain a reference value for each nutrient in the winter rest period and in early summer, the average value of the plots from each of the 15 different commercial farms was used (n=15) and a 95% confidence interval was calculated.

RESULTS AND DISCUSSION

In Table 1, leaf nutrient concentrations (%) are shown for the winter (July) and early summer (January) sampling periods based on the minimum and maximum values of the confidence intervals. The confidence interval for N was 1.73-1.83% for the winter sampling and 1.56-1.70% for the summer. These N concentrations are very similar to the optimal value proposed by Erel et al. (2013) for maximizing fruit load in a controlled study with 'Barnea'. In contrast, Fernández-Escobar et al. (2009) indicated that yield response to N did not occur above a leaf nutrient concentration of 1.4%, although this may have been related to the orchards being non-irrigated.

The P concentrations (0.16-0.18%) were slightly lower than optimum values (approx. 0.2%) found by Erel et al. (2013). This implies that applying some P via fertigation could be beneficial in high density olive orchards in our region. Currently, P fertilization is not common in the majority of orchards in arid Argentina. The observed K concentrations (1.14-1.26%) in our study are normal to high for irrigated orchards, and should be adequate for obtaining high fruit and oil yields.

A comparison of the nutrient concentrations (N, P, K) obtained for the winter sampling in our study with reference values reported previously for the same time period by other authors (Bouat, 1960; Nijensohn et al., 1996; Failla et al., 1997; Marcelo et al., 2008) is shown in Table 2. Nitrogen concentration in San Juan was somewhat lower than that of the other studies, while P was medium to high and K was higher than other studies. It is likely that these differences are explained by differences in the soil nutrient content with N being low in our arid, poorly-developed soils and K being high.

Few studies have assessed the concentrations of other nutrients during the winter period. With the exception of boron, our values are similar to those of Failla et al. (1997). The boron concentration was 25 ppm in San Juan (Table 1) compared to 10 ppm in Failla et al. (1997). Values greater than 20 ppm are considered normal in some fruit trees with deciduous leaves such as pear (*Pyrus communis* L.) (Sanchez, 1999) and in evergreen citrus species including *Citrus sinensis* L. (Shuang Han et al., 2008, 2009).

The early summer sampling period values are compared with reference values of other studies obtained at pit hardening (Freeman et al., 1994; Failla et al., 1997; Nieto et al., 2006) in Table 3. Nitrogen concentration was lower than that of Freeman et al. (1994) in California and Failla et al. (1997) in Italy, but similar to Nieto et al. (2006) in Spain. In contrast, P (0.17%) and K (1.20%) concentrations in our study were only lower than Freeman et al. (1994) and Failla et al. (1997); respectively, for the summer period. In the case of magnesium and manganese, the leaf concentration values were fairly low under our conditions possibly due to the high soil K (238-1121 mg/kg) and the basic pH (7.6-8.0) of the soils.

A previous study in our region reported that the period prior to flowering was optimal for leaf sampling because of the low variation in nutrient concentrations between years (Bueno et al., 2011). However, our results indicate that the winter and summer periods are also useful moments for leaf sampling. The winter period showed narrower confidence intervals than the summer period for N, P, and K, and also provides more time to the grower to get samples processed and to schedule the annual fertilization program. On the other hand, sampling during the summer period (just after pit hardening) may provide critical information just prior to oil accumulation.

CONCLUSION

The leaf nutrient concentrations in Table 1 are proposed as reference values for the early summer and winter sampling periods in the arid region of central-western Argentina (San Juan). The proposed values were obtained from 15 different commercial farms, which represent local management practices. Further research is required to evaluate how leaf nutrient levels are affected by fertilization programs, cultivar and productivity level.

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Tables

Table 1. Confidence intervals (95%) of leaf nutrient concentrations (%, ppm) for the winter (July) and summer (January) sampling periods in adult olive trees in the Tulum Valley in San Juan, Argentina. Each value represents the average value of the plots from each of the 15 different commercial farms (n=15).

Element	Winter	Summer	Element	Winter	Summer
N (%)	1.73-1.83	1.56-1.70	Mn (ppm)	34.79-41.35	30.69-35.39
P (%)	0.14-0.16	0.16-0.18	Cu (ppm)	14.64-21.84	10.28-15.72
K (%)	0.92-0.98	1.14-1.26	Zn (ppm)	17.61-20.21	15.89-17.63
Ca (%)	1.76-2.20	1.39-1.53	Fe (ppm)	78.82-93.80	79.49-91.09
Mg (%)	0.14-0.16	0.12-0.14	B (ppm)	24.51-25.67	32.74-36.50
Na (%)	0.063-0.079	0.068-0.092			

Table 2. Reference values of nitrogen (N), phosphorus (P), and potassium (K) during the winter from various studies. Mean values are presented.

Study	Leaf concentration (%)		
	N	P	K
Bouat (1960)	2.10	0.15	0.83
Nijensohn et al. (1996)	1.90	0.11	0.88
Failla et al. (1997)	1.93	0.13	0.78
Marcelo et al. (2008)	1.97	0.16	0.83
Bueno et al. (this study)	1.78	0.15	0.95

Table 3. Reference values of macronutrients and micronutrients during the early summer from various studies. Mean values are presented. NA=not available.

Study	Leaf concentration (%)					Leaf concentration (ppm)				
	N	P	K	Ca	Mg	Mn	Cu	Zn	Fe	B
Nieto et al. (2006)	1.63	0.10	0.85	1.45	0.15	51	14	14	NA	33
Freeman et al. (1994)	1.75	0.20	0.80	1.00	0.10	20	4	NA	NA	19-150
Failla et al. (1997)	1.93	0.14	1.32	1.78	0.16	36	10	18	87	17
Bueno et al. (this study)	1.63	0.17	1.20	1.46	0.13	33	13	16	85	39