

EFFECT OF REDUCING CHEMICAL FERTILIZER AND USING ORGANOMINERAL FERTILIZATION ON NUTRITIONAL BEHAVIOR AND VEGETATIVE GROWTH OF OLIVE TREES

EFEITO DA REDUÇÃO DA ADUBAÇÃO QUÍMICA COM FERTILIZAÇÃO ORGANOMINERAL NO COMPORTAMENTO NUTRICIONAL E CRESCIMENTO VEGETATIVO DE OLIVEIRAS

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ABSTRACT: This research was conducted with the aim of evaluating the nutritional behavior and vegetative growth of two olive tree varieties with the reduction of chemical fertilization and the application of organomineral fertilizer. Three-year-old trees of varieties 'Barnea' and 'Grappolo 541' were used and cultivated on Quartzarenic Neosol in the field. The split-plot scheme was used, with a 4 x 2 factorial design, with the factors of four fertilizations and two varieties and the subplot of evaluation years. The four fertilizations consisted of 100%, 75%, 50% and 0% of the chemical fertilizer recommended for olive trees. Treatments were arranged in a randomized complete block design, with three blocks and three plants per plot. The organomineral fertilizer was used on all of the plants. Leaf samples and vegetative growth were evaluated in July 2012 and June 2013. The nutritional behavior of olive tree varieties 'Barnea' and 'Grappolo 541' was unchanged with a 50% reduction of chemical fertilizer and the application of organomineral fertilizer. The variety 'Barnea', with habit of rapid growth, had lower foliar nutrient concentrations. A 64.5% reduction of the chemical fertilizer with the application of the organomineral fertilizer had no effect on the vegetative growth of the olive tree variety 'Grappolo 541'.

KEYWORDS: *Olea europaea*. Chemical nutrition. 'Barnea'. 'Grappolo 541'.

INTRODUCTION

The olive tree (*Olea europaea* L.) is one of the most widespread fruit tree species in regions with a Mediterranean climate (PROIETTI et al., 2015). However, there are areas in Brazil that have favorable climatic conditions for its production, such as the South and Southeast of the country, which has attracted some farmers (MARTINS et al., 2012; CARVALHO et al., 2014).

Although the olive tree is considered a rustic species, it needs to be submitted to adequate levels of nutrients in its early stage of growth, because the nutrients perform essential functions in vegetative growth and reproductive development (CARVALHO et al., 2013). The issuance of inflorescences is important to tree development and fruit quality, as well as the quality of the oil (FERNÁNDEZ-ESCOBAR et al., 2006; CHOULIARAS et al., 2009; BOUSSADIA et al., 2010).

Thus, due to the knowledge of the effect of nutrients on the development and productivity of olive groves, the excessive application of chemical fertilizers has occurred. This is often done without

considering the phenological variability of plants and features related to the area of cultivation, resulting in increased production costs and environmental risks (BOUSSADIA et al., 2010).

To ensure the sustainability of agricultural systems, some farmers, encouraged by researchers, are using fertilizers with less environmental impact and lower cost. These fertilizers come from organic materials available in the environment and do not compromise the quality of production. In the case of the olive tree, whose cultivated area is expanding in Brazil, it is important to adopt practices to facilitate crop management.

Therefore, the organomineral fertilizers presented good results in agriculture, improving the efficiency of the plant uptake and reducing the use of chemical fertilizers and production costs (FERNANDES et al., 2007). Organomineral fertilizers contain sources of both organic and chemical fertilizers, which helps reduce nutrient losses by increasing the proliferation of microorganisms and the use of fertilizer in the soil, which represents a significant reduction in costs to farmers.

Actual results in some studies showed the benefits of organomineral fertilization in agriculture, such as in the production of coffee crop (FERNANDES et al., 2007), the growth of rootstock 'Rangpur' lime (CARNEIRO et al., 2011), flower production (FARIAS et al., 2013) and sugarcane rations (SANTOS et al., 2014). However, the effect of fertilizer is linked to the fertilizer formulation and the species, or even the variety, that is being fertilized.

Thus, this study was done to evaluate the nutritional behavior and the vegetative growth of two olive trees varieties with the reduction of chemical fertilization and the application of organomineral fertilizer.

MATERIALS AND METHODS

The research was conducted in Diamantina, Minas Gerais, Brazil, located at 18° 14' 56" S and 43° 36' 0" W, at an altitude of 1,384 m. The climate is classified as humid temperate, with dry winters and rain in summers. The area has an annual average temperature of 18 °C and approximately 1,400 mm of rainfall (VIEIRA et al., 2010). Low temperatures occur from May to August, and there is more rainfall from November to January. During the experimental period, the variations of temperature and precipitation in the region were recorded (Figure 1). The experimental area was classified as Quartzarenic Neosol, with 83% sand, 10% clay and 7% silt.

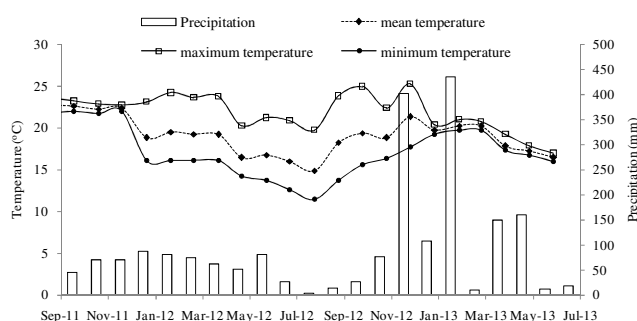


Figure 1. Mean, maximum and minimum temperatures (°C) and monthly precipitation (mm) during the evaluation period in Diamantina, Minas Gerais, Brazil.

The planting of olive trees was conducted in June 2010, with a 5 m spacing between rows and 3 m between plants. The nursery olive trees were obtained from the Experimental Farm of EPAMIG in Maria da Fé, MG, Brazil, and they were two years old at the time of planting.

The experiment started in October 2011, and the fertilization was based on the soil chemical characteristics at eight months after planting (Table 1).

Table 1. Soil chemical characteristics at eight months after planting at a depth of 0-20 cm, UFVJM, Campus JK, Diamantina, Minas Gerais, Brazil.

Depth (cm)	pH	P	K	Ca	Mg	Al ⁺³	H + Al
	H ₂ O	----- mg dm ⁻³ -----		----- cmol _c dm ⁻³ -----			
0-20	6,2	12,59	30,7	1,36	0,44	0,01	1,5
Depth (cm)	SB	t	T	V	m	M.O	
	----- cmol _c dm ⁻³ -----		----- % -----		----- dag kg ⁻¹ -----		
0-20	1,88	1,89	3,38	56	1	1,2	

SB – sum of bases; t – cation exchange capacity; T – cation exchange capacity at pH 7.0; V – base saturation; m – aluminum saturation index; and OM – organic matter.

The olive varieties used were 'Barnea' and 'Grappolo 541'. 'Barnea' is characterized as a vigorous and erect plant, while 'Grappolo 541' has

medium vigor and a well-developed canopy circumference.

The experiment was conducted in a split plot design, in a 4 x 2 factorial design. There were

four fertilization levels, 100%, 75%, 50% and 0% of the chemical fertilizer recommended for olive trees (MESQUITA et al., 2006), with organomineral fertilizer used in all fertilizations, and two varieties of olive tree, 'Grappolo 541' and 'Barnea', in each subplot. The evaluation periods were July 2012 (eight months after the application of organomineral fertilizer) and June 2013 (eight months after the application of organomineral fertilizer in the second year of assessment). Treatments were arranged in a randomized complete block design, with three replications and three plants per plot.

The organomineral fertilizer used in the experiment was developed by the company Ceres Tecnologia Agrícola (Lavras, Minas Gerais, Brazil) and was composed of organic natural sources (laying hen manure and coffee husk), inorganic sources (magnesium silicate, calcium sulfate and partially soluble phosphorus source) and calcified seaweed (*Lithothamnium sp.*). The chemical analysis of this product was 1.55% N, 4.08% P₂O₅, 3.24% K₂O, 11.03% Ca, 2.25% Mg, 0.006% B, 0.029% Cu, 0.024% Mn, 0.018% Zn, 0.22% Fe, 1.03% SiO₂, and 2.64% S-SO₄.

The fertilization was based on a soil analysis and the recommendation for olive trees proposed by Mesquita et al. (2006), taking into account that during the first and second years of the experiment, the plants had already been in the field for one year and two years. Thus, the first-year fertilizer recommendation, which corresponded to 100% of the chemical fertilizer, was 320 g of ammonium sulfate and 50 g of potassium chloride. In the second year, the fertilizer recommendation was 380 g of ammonium sulfate and 66 g chloride potassium. The fertilizer was applied in three installments, in the months of November, December and January (the months of higher rainfall).

The monitoring of pests and diseases was done periodically throughout the crop cycle. Pests and diseases were controlled using products with low environmental impact, such as copper fungicide that was registered for use in fruit species.

Weeds in the crop area were controlled with a brush cutter, and mulch was placed on the spaces between the rows.

For the determination of the levels of nutrients in the leaves, samples of mature, fully expanded leaves at the middle of the plant and the median part of the branch from all parts of the plant were collected in July 2012 and June 2013. Samples were composited for approximately 30 to 40 leaves with petioles.

The material was immediately washed and dried in an oven with forced air circulation at 65 °C

for 72 hours until a constant weight. After this period, the leaves were ground in a Wiley-type mill and subjected to a chemical analysis to determine the levels of nutrients. The chemical analysis was performed according to the methodology proposed by Malavolta et al. (1997).

The increment in height (with a graduated ruler placed vertically next to the plant), increment in stem diameter (at 20 cm height from ground with a caliper), and surface production were evaluated by measuring the diameter cup in two perpendicular positions, corresponding to its largest (D1) and smallest widths (D2). The formula for calculating surface fruiting is $SF = \Pi DH$, where D is the average of two diameters (D1 and D2) and H is the height of the canopy (RÍO; CABALLERO, 2006).

The data increments in the height and stem diameter were calculated by the difference in height found at the time evaluated from the previous time to July 2012 and June 2013. The objective of this evaluation was to characterize the differences between varieties and their capacity development in the area of cultivation due to the application of different fertilizers.

The data were subjected to analysis of variance and regression to compare the treatments. The choice of models was based on the ability to explain the biological phenomenon in question, the coefficient of determination and significance of the regression coefficients using the t-test at 5% probability of error.

RESULTS AND DISCUSSION

The levels of N in the leaves of the variety 'Barnea' did not differ after fertilization, with values of 16.9 g kg⁻¹ in July 2012 and 24.0 g kg⁻¹ in June 2013 (Figure 2A). In the variety 'Grappolo 541', there was a 44.3% increase in the levels of N in the leaves eight months after fertilization (July 2012) in the plants that received 100% of chemical fertilizer compared to those without chemical fertilization. However, in June 2013, eight months after the second application, there were no differences in the concentrations of N in leaves in relation to fertilization, with an average value of 27.2 g kg⁻¹ (Figure 2B).

Previous studies suggested that nitrogen fertilization, as well as other nutrient fertilization, should only be performed when the previous season's leaf analysis indicates that the nutrient was deficient (FERNÁNDEZ-ESCOBAR et al., 2009, 2012). Thus, the results obtained in this study indicated that, with the application of organomineral fertilization, the chemical N fertilization was

reduced in the two varieties. In addition, the foliar N increased in all treatments in the second year after

fertilization (Figures 2A and 2B).

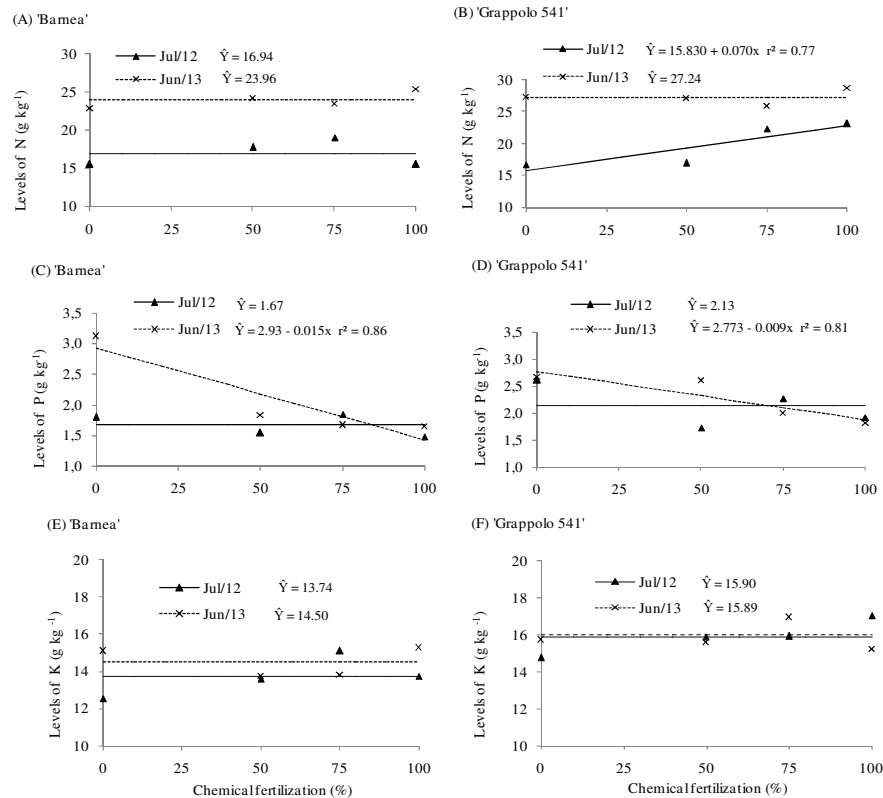


Figure 2. Foliar levels of N (A and B), P (C and D) and K (E and F) in olive tree varieties 'Barnea' and 'Grappolo 541' depending on the chemical fertilization in July 2012 and June 2013, UFVJM, Diamantina, MG, Brazil.

Differences in the level of P in the leaves were observed in 'Barnea' in relation to fertilization only in the second year (June 2013), with a linear decrease from 51.2% in plants that received the 100% level of the chemical fertilizer. The highest P levels were observed in plants that received no chemical fertilizer, while in July 2012, the P levels did not differ among chemical fertilizations, with average values of 1.3 g kg^{-1} and 1.7 g kg^{-1} , respectively (Figure 2C). In the leaves of variety 'Grappolo 541', the levels of P were approximately 2.1 g kg^{-1} in July 2012. However, in June 2013, the P levels decreased linearly from 2.8 g kg^{-1} to 1.9 g kg^{-1} with increasing chemical fertilization (Figure 2D).

The reduction in foliar P could be because nutrient was only applied during planting, as was the organomineral fertilizer, and as the plant grows, the nutrients are used for the growth and flowering process (RODRIGUES et al., 2012; EREL et al., 2013).

The levels of K in the leaves of the two varieties did not differ in relation to fertilization in all periods, showing that even with the reduction of

chemical fertilizer, the level of this nutrient remained unchanged (Figures 2E and 2F).

The results observed with respect to P and K showed that the organomineral fertilizer supplied these nutrients without the application of a chemical fertilizer. The foliar concentrations of nutrients were close to olive trees cultivated in Minas Gerais, Brazil, under a conventional fertilization system, with P from 1.2 g kg^{-1} to 5.2 g kg^{-1} and K from 15.0 g kg^{-1} to 23.8 g kg^{-1} (MESQUITA et al., 2012).

Thus, foliar analysis is the primary tool to assess the nutritional status of the plant, taking into account the relationship between nutrient concentrations and growth or productivity. Fernández-Escobar et al. (2009) found that, based on the annual application of N, P and K, along with spraying micronutrients, the traditional fertilization of olive groves practiced in the main cultivated regions increased the cost of fertilization without increased vegetative growth and production when compared with a fertilization program based on leaf analysis.

There were no differences in the foliar levels of Ca, Mg and S for the two varieties of olive

tree among the fertilizers applied in both years (Figure 3). However, the Ca and Mg increased after the application of the organomineral fertilizer in the two varieties evaluated. In 'Barnea', which has rapid growth, Ca increased by 44.2% and Mg increased by 100.0% (Figures 3A and 3C). Increases of 60.0% in Ca and 80.0% in Mg (Figure 3B and 3D) occurred in 'Grappolo 541'. These increases occurred eight months after the application of the

organomineral fertilizer in the second year (June 2013) compared to the previous season of the application of treatments.

This may have occurred because the organomineral fertilizer was composed of calcified seaweed of the genus *Lithothamnium*, which had the ability to adjust the pH of the soil, which improved the uptake of fertilizers and provided soluble Ca and Mg (MELO; FURTINI NETO, 2003).

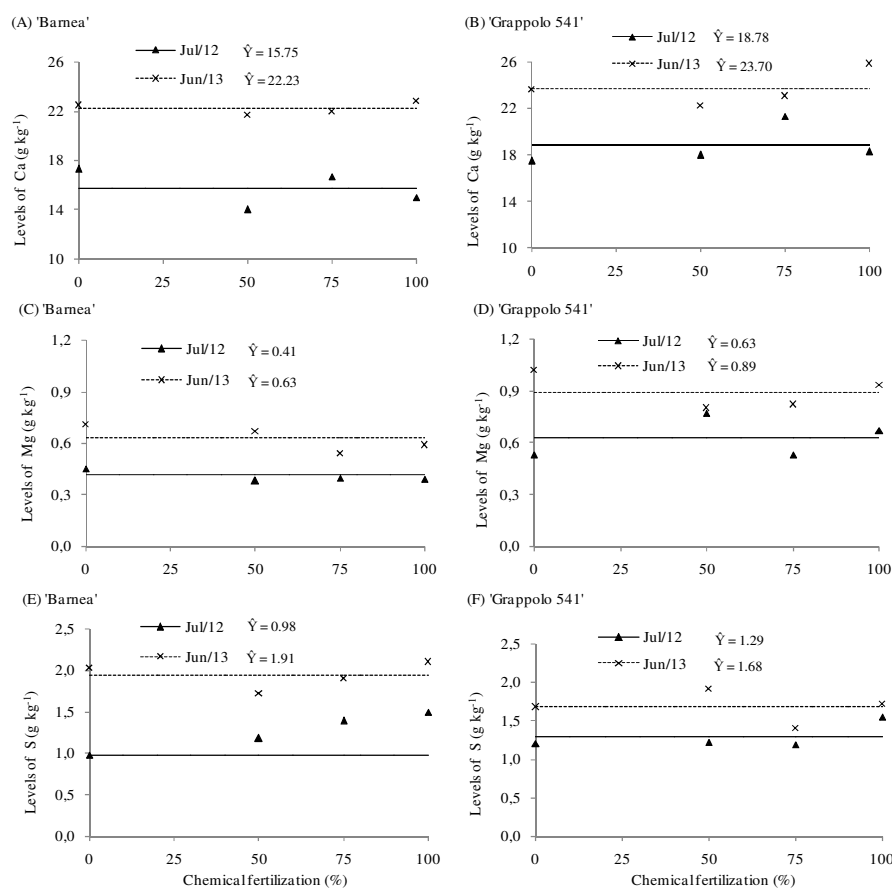


Figure 3. Foliar levels of Ca (A and B), Mg (C and D) and S (E and F) in olive tree varieties 'Barnea' and 'Grappolo 541' depending on the chemical fertilization in July 2012 and June 2013, UFVJM, Diamantina, MG, Brazil.

The micronutrients Fe and B decreased in both varieties after fertilization, and the lowest values were observed in the last assessment in June 2013 (Figure 4). However, there were no differences between plants supplied with different fertilizations for B. The difference between seasons may be related to the start of production of the plants, since B is essential for the formation of flower buds and fruit development in olive trees (CARVALHO et al., 2013).

There was an increase in the foliar concentrations of copper after fertilization in the

variety 'Barnea', with values of 15.7 mg kg⁻¹ before fertilization and in July 2012. Values increased linearly according to the increase in chemical fertilization, with a 260.0% increase in the plants that received 100% chemical fertilization and organomineral fertilizer (Figure 4C). The variety 'Grappolo 541' had a similar behavior, and copper levels were approximately 11.6 mg kg⁻¹ before fertilization and in July 2012. The values reached 51.7 mg kg⁻¹ in plants with 100% chemical fertilization, which corresponded to an increase of 231.0% (Figure 4D).

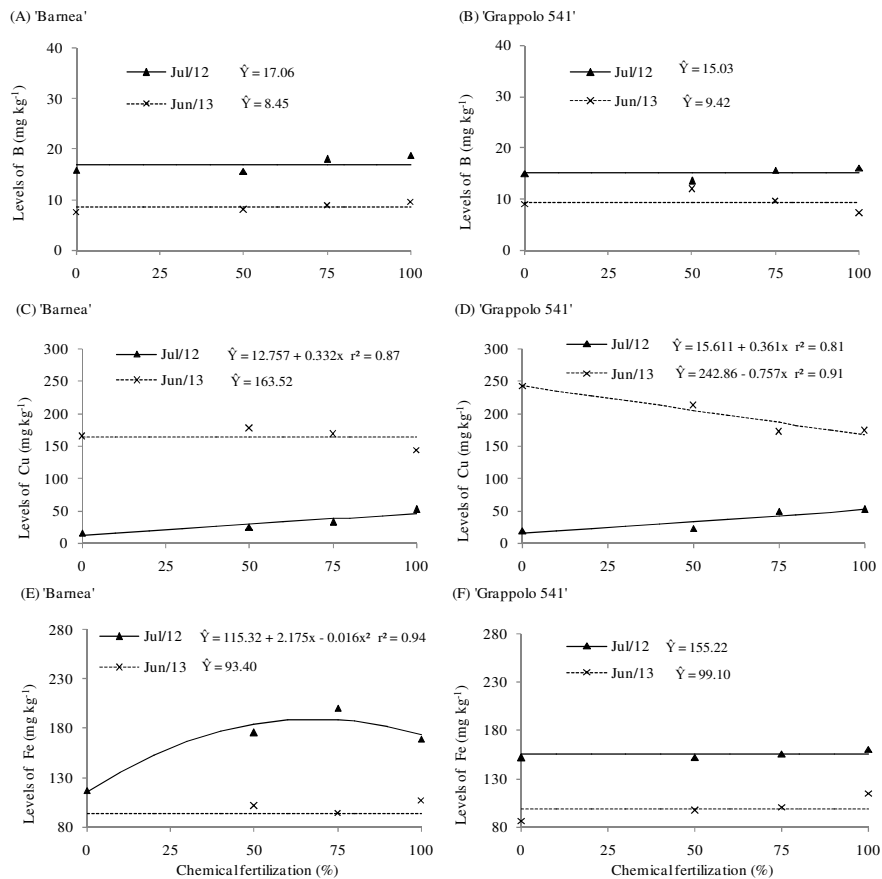


Figure 4. Foliar levels of B (A and B), Cu (C and D) and Fe (E and F) in olive tree varieties 'Barnea' and 'Grappolo 541' depending on the chemical fertilization in July 2012 and June 2013, UFVJM, Diamantina, MG, Brazil.

Eight months after the second application (June 2013), the leaf levels of copper increased in both varieties, compared to the assessments at previous times. This result was likely due to a foliar spray with fungicide based on copper that was applied one month before the foliar sampling, which may have contributed to the elevation of the levels in plants of all treatments.

The Mn levels in the variety 'Barnea' after fertilization did not differ between plants in different treatments, with values of 18.4 mg kg⁻¹ in July 2012 and 14.7 mg kg⁻¹ in June 2013 (Figure 5A). The 'Grappolo 541' had a similar behavior, except in July 2013, when there was a linear increase of Mn foliar levels in accordance with the increase of chemical fertilizer. 'Grappolo 541' plants treated with 100% of the chemical fertilizer had 40.1 mg kg⁻¹ of Mn (Figure 5B).

The foliar concentrations of Zn in 'Barnea' linearly reduced with increasing chemical fertilization. Plants fertilized with 100% of the chemical fertilizer had levels of 12.3 mg kg⁻¹ in July

2012 and 14.1 mg kg⁻¹ in June 2013, corresponding to decreases of 22.7% and 58.8%, respectively (Figure 5C). In the leaves of variety 'Grappolo 541', the Zn levels did not differ among the fertilizations in June 2013; all had values of 29.0 mg kg⁻¹. There was a quadratic response in July 2012, with the highest value (24.4 mg kg⁻¹) measured for the plants receiving an estimated 45% chemical fertilization (Figure 5D).

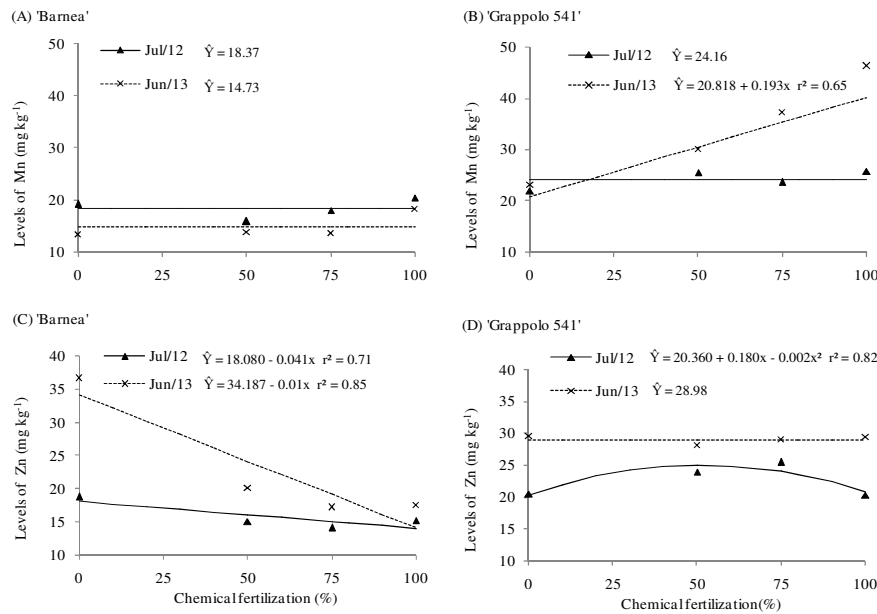


Figure 5. Foliar levels of Mn (A and B) and Zn (C and D) in olive tree varieties 'Barnea' and 'Grappolo 541' depending on the chemical fertilization in July 2012 and June 2013, UFVJM, Diamantina, MG, Brazil.

The lower levels of Mn and Zn after fertilization may be related to the use by plants, because the olive trees that received larger amounts of chemical fertilizer showed higher vegetative growth (Figure 6). Moreover, these micronutrients are involved in the reproductive process (CARVALHO et al., 2013).

Taking into account the appropriate levels of foliar nutrients in the dry matter of olive trees in the main countries that grow them (FERNÁNDEZ-ESCOBAR, 2008), it was found that a 50% reduction of chemical fertilization promoted levels of macronutrients and micronutrients, with the exception of Mg and B, that were considered adequate in all periods in the two varieties of olive tree. This may have occurred as a result of the benefits of the organomineral fertilizer in terms of providing nutrients (FERNANDES et al., 2007).

It should be mentioned that there are no standards for the appropriate levels of nutrients in olive trees in Brazil, due to its recent cultivation. It is known that nutrient levels vary depending on plant phenology and that soil and climate factors influence their composition (FERNÁNDEZ-ESCOBAR et al., 2009; MESQUITA et al., 2012). Thus, the patterns observed in other countries may not be consistent with the Brazilian reality, making it necessary to establish standards for olive trees grown in Brazilian conditions.

In Minas Gerais, Brazil, a state that has seen an increase in olive cultivation, foliar nutrient levels in different varieties of olive trees in different stages of growth were established over years of analysis

(MESQUITA et al., 2012). Comparing these data with the results observed in this study for all treatments applied, it was found that the foliar nutrients, P, K, Ca, S, B, Cu, Mn and Zn, were within the levels obtained for olive trees cultivated in a conventional system. N and Mg were also within these levels at the last evaluation, i.e., the levels increased after the second year with the use of the organomineral fertilizer without differences due to the reduction of the chemical fertilizer.

Despite the reduction of chemical fertilizer, nutrient levels were not reduced in plants, highlighting that the organomineral fertilizer improved the efficiency of utilization by plants. This was possibly because the organomineral fertilizer contained sources of organic fertilizers, such as chicken manure and coffee husk, in addition to chemicals sources, such as magnesium silicate, calcium sulfate and partially soluble phosphorus, and calcified seaweed (*Lithothamnium sp.*). These sources provided nutrients and improved the plant utilization by reducing nutrient losses.

The vegetative growth of the olive trees increased by 425.0% in increment in height only in the variety 'Barnea', with 100% application of chemical fertilizer compared to plants that received no fertilizer in July 2012 (Figure 6A). However, in June 2013, the variety 'Barnea' showed the greatest height with 68.9% of the recommended chemical fertilization and 'Grappolo 541' with 64.6% fertilization (Figures 6A and 6B).

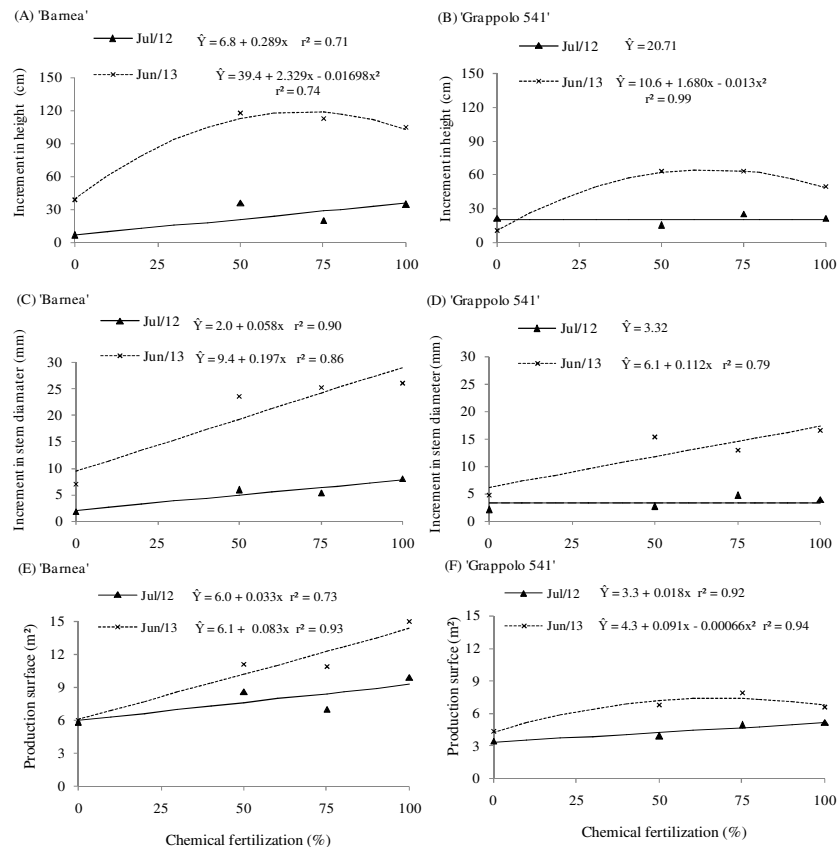


Figure 6. Increment in height (A and B), increment in stem diameter (C and D) and production surface (E and F) in olive tree varieties 'Barnea' and 'Grappolo 541' depending on the chemical fertilization in July 2012 and June 2013, UFVJM, Diamantina, MG, Brazil.

In the variety 'Barnea', the stem diameter increased by 285.4% and 209.7% with the application of 100% chemical fertilizer in July 2012 and June 2013, respectively, compared to plants without chemical fertilization (Figure 6C). In 'Grappolo 541', there was an increase of 182.2% in June 2013, with 100% chemical fertilization compared to plants fertilized only with the organomineral fertilizer (Figure 6D).

The greater vegetative growth of the trees depending on the fertilization of plants is mainly related to N, which is important for the metabolism of plant growth and can be stored in organs when it is not used (Bustan et al. 2013). N is also important to the growth habit of varieties, which justifies the foliar N after fertilization in the variety 'Grappolo 541' in July 2012 (Figure 2A). Thus, comparing the vegetative behavior, it is possible to relate the highest concentration of N in 'Grappolo 541', which received 100% of the recommended chemical fertilizer, to the slower growth of these plants.

'Barnea' had a linear increase in the production surface as a function of chemical fertilizer with growth of 55.3% in July 2012 and 137.0% in June 2013, compared to plants without chemical fertilization (Figure 6E). In 'Grappolo

541', the increase was 53.8% in July 2012 and 48.53% in June 2013, at an estimated 45.5% of chemical fertilization compared to those fertilized with only the organomineral fertilizer (Figure 6F).

The difference in the vegetative growth of 'Grappolo 541' in relation to fertilization may be related to the growth habit and nutrient utilization. Higher nutrient levels observed in this variety may be related to this habit of slower growth, a behavior already reported for the variety 'Nabali' compared with the olive tree varieties 'Grossa d' España', 'Nabali Mohassan' and 'Manzanillo' (FREIHAT; MASA'DEH, 2006).

In addition to the nutritional factors, the vegetative growth of the olive tree is very influenced by environmental factors because, according to Orlandi et al. (2013), a short photoperiod completely limits the development of the crown of the olive tree, while a long photoperiod promotes the acceleration of this development. The high temperatures combined with high rainfall temperatures, as those recorded in this study during the summer (Figure 1), also favored the vegetative growth.

It is necessary to consider that the plants were established in a newly prepared area and, after

the application of the organomineral fertilizer, the soil chemical properties improved. Perennial species fertilizations should be thoughtful, observing the use of nutrients by the varieties during vegetative and reproductive growth, and aiming to promote the development and productivity of the trees. The excessive application of chemical fertilizer without consideration of the phenological variability of plants and features related to the area of cultivation leads to increased production costs and environmental risks (Boussadia et al. 2010).

CONCLUSIONS

The nutritional behavior of olive tree varieties 'Barnea' and 'Grappolo 541' was unchanged with a 50% reduction of chemical fertilizer combined with the application of an organomineral fertilizer. The variety 'Barnea', with the habit of rapid growth, had lower foliar nutrient concentrations. Reduction of the chemical fertilizer to 64.5%, with the application of the organomineral fertilizer, had no effect on vegetative growth of the olive tree variety 'Grappolo 541'.

RESUMO: A pesquisa foi realizada com o objetivo de avaliar o comportamento nutricional e o crescimento vegetativo de duas variedades de oliveira, com a redução da adubação química, pela aplicação do fertilizante organomineral. Foram utilizadas duas variedades de oliveira, 'Barnea' e 'Grappolo 541', de três anos de idade, implantadas no campo, em solo classificado como Neossolo Quartzarênico. Utilizou-se o esquema de parcela subdividida, na parcela o fatorial 4 x 2, sendo quatro adubações e duas variedades e, na subparcela, os anos de avaliação. As adubações constituíram-se 100%, 75%, 50% e 0% da adubação química recomendada para a oliveira, distribuídas em blocos casualizados, com três blocos e três plantas por parcela. Em todas as plantas foi feita a aplicação do fertilizante organomineral. As amostras foliares e a avaliação do crescimento vegetativo foram realizadas em julho de 2012 e julho de 2013. O comportamento nutricional das variedades de oliveira 'Barnea' e 'Grappolo 541' não foi alterado com a redução de 50% da adubação química e a aplicação de fertilizante organomineral. 'Barnea', com hábito de crescimento rápido, apresenta menores teores foliares de nutrientes. A redução da adubação química em 64,5%, com a aplicação de fertilizante organomineral, não interferiu no crescimento vegetativo da 'Grappolo 541'.

PALAVRAS-CHAVE: *Olea europaea*. nutrição mineral. 'Barnea'. 'Grappolo 541'.

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