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Response of mint (*Mentha spicata* L.) crops to chemical and organic fertilization

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Respuesta del cultivo de la menta (*Mentha spicata* L.) a la fertilización química y orgánica

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ABSTRACT

With the purpose to define the appropriate doses in the production of mint cultivation, this research was conducted in three locations (Gibraltar, Arboleda and Aguacatal) of the municipality of Jardín, Antioquia. The soils of these localities are andisols, with medium contents of organic matter, low in interchangeable bases, low in phosphorus and boron, with characteristics of low fertility. For this research, *Mentha spicata* L. (mint) was seeded at a distance of 0.3x0.3 m, in an experimental design of randomized complete blocks with four repetitions, with five increasing doses of compound fertilizer (10-30-10) (0, 60, 120, 180, and 240 kg ha^{-1}), in combination of five increasing doses of organic fertilizer (0, 1.8, 3.6, 5.4, and 7 t ha^{-1}), and one control with a biological fertilizer. In five foliage harvests, the highest dry matter (DM) yields were achieved with the application of 180 and 120 kg ha^{-1} of 10-30-10, with yields of 156 and 158 g of DM per square meter, respectively.

Keywords:
Andisols soils
Aromatic herbs
Chemical fertilization
Organic fertilization

RESUMEN

Con el propósito de definir las dosis apropiadas en la producción del cultivo de menta, se realizó la presente investigación en tres veredas (Gibraltar, Arboleda y Aguacatal) del municipio de Jardín, Antioquia. Los suelos de estas localidades son andisoles, con contenidos medios de materia orgánica, bajos en bases intercambiables, bajos en fósforo y boro, con características de baja fertilidad. Para esta investigación se sembró *Mentha spicata* L. (menta) a una distancia de 0,3x0,3 m, en un diseño experimental de bloques completos al azar con cuatro repeticiones, con cinco dosis crecientes de fertilizante compuesto (10-30-10) (0, 60, 120, 180 y 240 kg ha^{-1}), en combinación con cinco dosis crecientes de fertilizante orgánico (0, 1.8, 3.6, 5.4 y 7 t ha^{-1}), y un testigo con fertilizante biológico. En cinco cosechas de follaje, los mayores rendimientos de materia seca (MS) se lograron con la aplicación de 180 y 120 kg ha^{-1} de 10-30-10, con producciones de 156 y 158 g de MS por metro cuadrado, respectivamente.

Palabras clave:
Suelos andisoles
Aromáticas
Abonamiento químico
Abonamiento orgánico

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The Lamiaceae family is composed mainly of plants such as mints (*Mentha* spp.), Basils (*Ocimum* spp.), Rosemary (*Rosmarinus officinalis*), and thyme (*Thymus* spp.), among many others of known medicinal and culinary value (Castro et al. 2019; Velasquez et al. 2019).

Mentha spicata, popularly known as spearmint or garden mint, is a species of the genus *Mentha*, an aromatic herb widely used in gastronomy and perfumery for its intense and fresh aroma (Gallegos-Zurita 2016). Aromatic plants contain appreciable amounts of phytochemicals (phenols, their derivatives, among others), which are found in the whole plant or parts of it (Vicente-Herrero et al. 2013; Gastaldi et al. 2018; Morales et al. 2018).

Mint (spearmint and peppermint) has been grown primarily for the oil produced from its leaves. It is a perennial plant that does not produce seed, it is sown in rows, from stolons and roots of previous crops and/or rhizomes (Vacca-Molina et al. 2015). The oil is stored in leaf glands. The plant is trimmed and dried, then the dried material goes through a distillation process to recover the oil (Castro et al. 2013; Salehi et al. 2018).

Mentha spicata is among the aromatic species used in oral health, the interest in it and patenting are increasing due to its aroma and its effects as an antibiotic and sometimes as a pesticide (Ferreira et al. 2018). In addition, in recent years there has been an improvement in the processes normally used in the extraction of chemotypes, with the purpose of increasing the effectiveness of its active ingredient (Tofiño-Rivera et al. 2017).

Mint cultivation lacks technological information regarding fertilization, there are few reports in the literature on its behavior in different conditions such as cultivars, fertilization levels, climate, water availability, etc. For optimal nutritional management, it is necessary to know the nutritional requirements of the crop, which is expressed in kilograms of nutrients per ton of product, in this case as fresh product. These data are key in estimating nutrient demand, an essential parameter to assess the appropriate fertilization dose for crops (Juárez-Rosete et al. 2019). Since in this crop the aerial part is harvested and commercialized, successive harvests of shoots are carried out. This makes it a crop with a high capacity to extract nutrients from the soil (Juárez-Rosete et al. 2019).

Mint, like many other crops, extracts good amounts of nutrients, so to obtain approximately 6.7 t ha^{-1} of biomass, the crop requires at least 335 kg ha^{-1} of K_2O. To avoid a depletion of reserves of this nutrient in the soil, it is necessary to periodically supply this nutrient in the periods of greater development, growth of roots and stems (Brown et al. 2003).

During the growth period, phosphorus is an essential element in root development, for this reason an adequate supply is necessary after each harvest, so that it is a stimulus in each production cycle. It has been determined that each harvest extracts between 50 and 100 kg ha^{-1} of P_2O_5 (Arango et al. 2012).

Works carried out by Brown et al. (2003) determined that mint needs applications of N between 250 and 300 kg ha^{-1}, between 55 to 110 kg ha^{-1} of P_2O_5, and approximately 375 kg ha^{-1} of K_2O to obtain good yields. Therefore, if high yields are to be obtained with good biomass development, a sufficient supply of nutrients is necessary to avoid reducing the natural fertility of the soil (Brown et al. 2003).

Among the factors necessary for sustainable production in the cultivation of mint, there is the proper management of nutrition to obtain a high yield both in biomass and a high production and quality in the content and concentration of the oils. Normally in leaf production crops, slow-release nitrogen doses are applied periodically in each production cycle, but sufficient for good foliar development. It is estimated that 1 ha of mint produces between 95 to 125 kg of oil (Brown et al. 2003).

There is little information on the response of the crop to the application of NPK and organic matter. For this reason, El Centro de Investigación La Selva - Agrosavia had as aimed used different doses of fertilizer were used chemical (10-30-10), in combination with organic matter in the foliage production of the *Mentha spicata* variety.

MATERIALS AND METHODS

Localization

The experiment was carried out in three localities of the municipality of Jardín (Antioquia) with a moderate cold climate, located in the upper part of Gibraltar

(5°33'0.23'' N, 0.75°51'0.23'' O) at 1,963 m; in the lower part of Gibraltar (5°34'59.3'' N, 0.75°50'57.4'' O) at 1,800 m; and in La Arboleda, Aguacatales sector (5°34'0.78'' N, 0.75°51'25.2'' O) at 1,961 m. For the experiment, andisol soils with undulating topography, medium contents of organic matter, low in phosphorus, calcium, magnesium, and potassium were used. Regarding the minor elements, in general, they presented medium content, high in iron and low in boron (Table 1). For the present study, the variety of *Mentha spicata* was used according to the genetic description made by López-Hernández and Cortés (2022).

Statistical design

Increasing doses of compound fertilizer (10-30-10) (0, 60, 120, 180, and 240 kg ha^{-1}) were evaluated in combination with increasing doses of organic matter (0, 1.8, 3.6, 5.4, and 7 t ha^{-1}). Each plot consisted of 2 m long by 1.2 m wide; to harvest the four central plants, a randomized complete block design was used with four repetitions in a factorial arrangement where factor A were the harvests and factor B the levels of chemical fertilizer (10-30-10) in combination with the different levels of organic matter. The variation between the different treatments were analyzed using an ANOVA at each evaluation time. Multiple comparisons were made with a Tukey test with a probability of 5%.

Nutrient concentration

The dried samples were pulverized in a Thomas Scientific stainless-steel mill (Wiley Mini Mill 3383-L10), with 40 sieve (0.425 mm mesh size). The nutritional composition was determined in three composite samples, each one made up of stem and leaf tissues. The dry samples were sent to the Agrosavia-Tibaitatá soil and plant tissue chemistry laboratory (Mosquera, Cundinamarca, Colombia). There, the contents of total N (Kjedhdhal) and the extractable fractions of P (Bray II); Ca, Mg and K (1 N ammonium acetate, pH=7.0); Fe, Mn, Zn, Cu (modified Olsen), and B (monobasic calcium phosphate) were established. The protocols are described in Westermann (1990).

RESULTS AND DISCUSSION

According to Table 1, the soils have a pH between strong and moderately acidic. They have low phosphorus contents. With respect to exchangeable bases, they have low levels of calcium in two localities and low in magnesium and potassium in all localities. In terms of minor elements, they are low in all localities, except for iron. In general terms, they are soils of low to medium fertility.

Table 1. Chemical characteristics of the soils studied.

Locality	pH	MO (%)	P	CICE	Ca	Mg	K	Fe	Cu	Mn	Zn	B
			(mg kg^{-1})		(cmol kg^{-1})			(mg kg^{-1})				
1	5.58	9.32	31	5.73	5.02	0.43	0.14	72.6	3.10	2.59	2.33	0.08
2	5.76	9.86	6.88	2.19	1.53	0.33	0.19	362	3.33	8.80	3.87	0.10
3	5.34	10.55	3.80	2.04	1.02	0.32	0.15	75.6	2.08	2.44	2.87	0.11

1:Gibraltar-upper part; 2:la arboleda-aguacatal path; 3:Gibraltar lower part-La Bonaza path.

When performing a combined statistical analysis of the five crops, Table 2 shows that the dry matter production per meter and per hectare was affected by the amounts of chemical and organic fertilizer applied. Significant differences were observed between localities, being localities 1 and 2 statistically equal and different from locality three with productions of 1,055 and 1,146 kg of dm ha^{-1}, respectively. Work carried out by (Pedraza and Henao 2008) in Cundinamarca found high environmental variability (climatic and edaphic factors), it differs greatly in the nutritional requirements of the crop.

Table 2. Production of dry matter of the variety of mint (*Mentha spicata*) under different levels of 10-30-10. Three locations. Jardín.

Location	dm (m^{-1}*)	dm (ha^{-1}*)
1	146.63^{a}	1055.75^{a}
2	159.28^{a}	1146.83^{a}
3	121.18^{b}	872.47^{b}

*Averages followed by the same letter do not differ statistically at the 5% level, according to Tukey's test (P<0.05).

Franco et al. (2023) evaluated in mint, the effect of the application of chemical synthesis compounds and organic matter, and determined that the crop is highly extractive in nitrogen; in addition, found that the chemical composition of the soil had a direct relationship with the dry matter contents in the plants obtained at harvest, which was similar to that reported in the present research, where significant differences were obtained with increasing doses of complete fertilizer (10-30-10), in combination with applications of organic matter.

According to Table 3, the simple factor of crops, presented differences between the crops carried out, the highest production of dry matter of mint per square meter and per hectare was observed in the first harvest, 158 and 1,141 kg ha^{-1} after the first harvest showed a significant decrease in yields until harvests four and five.

Table 3. Production of dry matter of mint (*Mentha spicata*) under different levels of 10-30-10. Five harvests. Factor A.

Harvest	dm (m^{-1}*)	dm (ha^{-1}*)
1	158.55^{a}	1141.58^{b}
2	148.99^{ab}	1072.75^{b}
3	138.56^{bc}	997.61^{a}
4	140.85^{abc}	1014.14^{b}
5	124.86^{c}	899.01^{b}

*Averages followed by the same letter do not differ statistically at the 5% level, according to Tukey's test (P<0.05).

Table 4 shows the different combinations of chemical and organic fertilizer, this factor presented statistical differences between the different doses applied, being the one with the highest yield of dry matter when it was fertilized with 50% chemical fertilizer and 50% organic fertilizer (158 and 1,138 kg ha^{-1} of dm). This treatment was statistically equal to the application of only chemical (1,090 kg ha^{-1}) and to the combination of 75% chemical fertilizer and 25% organic fertilizer (1,124 kg ha^{-1} of dm). It should be noted that Henao-Rojas et al. (2022) reported that combined chemical and organic fertilization doses improve secondary metabolites and increase the yields of oils and volatile compounds, which is similar to those found in this study where the combined doses increased yields and improved the quality of the mint.

Table 4. Production of dry matter of mint (*Mentha spicata*) under different levels of 10-30-10. Five harvests. Factor B.

Chemical (%)	Organic (%)	dm (m^{-1}*)	dm (ha^{-1}*)
100	0	151.45^{ab}	1090.45^{ab}
75	25	156.24^{ab}	1124.95^{ab}
50	50	158.11^{a}	1138.37^{a}
20	75	145.12^{b}	1044.85^{ab}
0	100	136.40^{b}	982.07^{b}
0	Biologic	106.86^{c}	769.40^{c}

*Averages followed by the same letter do not differ statistically at the 5% level, according to Tukey's test (P<0.05).

In general terms, the order of nutrient extraction per ton of dry matter was N>K>Ca>Mg>P>S>Fe>Mn>Zn>B>Cu, which implies careful nutrient management to balance a high biomass growth and high production (Jiménez-alonso et al. 2012). Cano-Gallego et al. (2022) found significant differences with increases in soil fertilization (10-30-10), observing the highest expression of dry matter when between 120 and 180 kg ha^{-1} are applied; within the study carried out, it was found that dry matter increases with the increase in edaphic fertilization (10-30-10), the same as reported in this research.

According to Table 5, it is observed that as the amount of chemical fertilizer decreases, the concentration of nutrients in the tissues decreases. Work carried out by Avelar et al. (2015) in the Mentha aquatica variety, found this same situation when organic fertilizer increased. The element that presented the highest concentration in the leaves and stems was nitrogen. N is one of the nutrients responsible for vegetative growth; however, it does not follow an infinite linear trend, but the crops reach a saturation point of the element (Alejo-Santiago et al. 2015); in second order there are potassium and calcium, this agrees with that reported by Castro et al. (2005) in dandelion (*Taraxacum officinalis* Weber). However, works carried out by Giraldo and Henao (2019), in absorption curves carried out in the greenhouse, found that the element that was most extracted was Ca, followed by K and N (58.87, 36.97 and 26.92 kg ha^{-1} per production cycle, respectively).

Work carried out by Ozcan (2004) in a local market in Turkey, in leaves and flowers of *M. spicata*, found that the tissues contained among major elements such as KYP, percentages of 2.47 and 0.22%, respectively. Among secondary elements they had concentrations of 1.13% Ca, 0.5% Mg and 0.31% S, and between elements less concentrations of 97.6, 18.7, 47.6, 8.48 mg kg^{-1} of Mn, Zn, B and Cu, respectively.

Table 5. Nutrient concentration in tissues (leaves and stems) of the mint plant in Antioquia.

Dose	N	P	K	Ca	Mg	S	Fe	Cu	Mn	Zn	B
	(g 100 g^{-1})						(mg kg^{-1})				
1	3.9	0.5	2.5	1.0	0.5	0.3	84.8	10.7	182	45.3	43.2
2	3.8	0.4	2.5	1.0	0.4	0.3	80.2	8.48	129	33.8	41.0
3	3.8	0.4	3.1	0.9	0.4	0.3	88.0	10.7	187	26.7	46.0
4	3.6	0.4	2.2	0.8	0.4	0.4	89.2	15.4	140	27.4	44.3
5	3.5	0.6	3.5	0.9	0.4	0.4	87.7	14.4	92.8	25.8	50.5
6	2.6	0.4	3.1	0.7	0.3	0.3	67.5	22.4	59.7	26.0	46.0
Average	3.5	0.4	2.8	1.0	0.4	0.3	82.9	13.7	131.7	30.8	45.2

In investigations carried out by Hart et al. (2003) during 3 years in six different locations, they found that the accumulation of biomass and concentration of nutrients in *M. piperita* fluctuated between 3.85 to 4.41% for nitrogen; 0.40 to 0.63% for phosphorus; 3.65 to 4.77% for potassium; 0.36 to 0.48% for sulfur; 0.88 to 1.52% for calcium; 0.28 to 0.45% for magnesium; and for the minor elements between 20.24 to 27.8; 1.25 to 19.4; 77.5 to 119.9; and 28.0 to 45 mg kg^{-1} for B, Cu, Zn and Mn, respectively.

The minor elements are notable for the concentration of boron that exceeds zinc and copper. For phosphorus, the concentration was similar among all the applied doses, its content was between 0.38 to 0.56%. A similar situation occurred with magnesium (0.32 to 0.37%). The lowest concentration was presented for sulfur (0.34 to 0.37). Work carried out by Torres et al. (2013) on the species *Satureja macrostema* (Benth) Briq. found that the increase and yield of volatile compounds can be favored, which is closely related to the increase in biomass in plants treated with chemical fertilization. Franco et al. (2022) reported that the most relevant nutrients in the cultivation of Mentha, in their order were N, K, Ca and Mg, being similar to what was found in this study. It should be noted that the excess of Zn presented antagonism with B, showing a differential when making foliar and/or edaphic applications with this element.

In five harvests, it was determined that the removal of nutrients requires the application of at least 35 kg of N for each ton of dry matter of production; thus, 28 kg of K are required for each ton of extracted dry matter, Ca and Mg follow in their order (8.9 and 4.2%, respectively). In these soils derived from volcanic ash with low phosphorus content, a positive response to the application of this element can be expected, this is confirmed by the low concentration for the treatments of only organic and/or biological matter. To obtain good crops and maintain soil fertility, it is necessary to apply the following elements for each ton of dry matter (N 40, P 10, K 35, Ca 45, and 35 of Mg kg). According to Brown et al. (2003), to obtain high yields the mint crop requires between 250 and 300 kg ha^{-1} of N, between 55 and 110 kg ha^{-1} P_2O_5, and about 375 kg ha^{-1} of K_2O.

CONCLUSIONS

In this research, it was found that the combination of chemical and organic fertilization in equal proportions increases crop yields. Likewise, the increase in chemical fertilization is proportional to the increase in dry matter in the mint crop, where the order of total nutrient removal per ton of dry matter was N>K>Ca>Mg>P>S>Fe>Mn>Zn>B>Cu.

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