



Revista Facultad Nacional de Agronomía Medellín

ISSN: 0304-2847

ISSN: 2248-7026

Facultad de Ciencias Agrarias - Universidad Nacional de Colombia

Cano-Gallego, Lucas Esteban; Tamayo-Molano, Álvaro de Jesús; Ortiz-Muñoz, Carolina; Henao-Rojas, Juan Camilo
Response of mint (*Mentha spicata* L.) crops to chemical and organic fertilization
Revista Facultad Nacional de Agronomía Medellín, vol. 76, no. 3, 2023, September-December, pp. 10465-10471
Facultad de Ciencias Agrarias - Universidad Nacional de Colombia

DOI: <https://doi.org/10.15446/rfnam.v76n3.102451>

Available in: <https://www.redalyc.org/articulo.oa?id=179976349011>

- ▶ [How to cite](#)
- ▶ [Complete issue](#)
- ▶ [More information about this article](#)
- ▶ [Journal's webpage in redalyc.org](#)

 redalyc.org

Scientific Information System Redalyc

Network of Scientific Journals from Latin America and the Caribbean, Spain and Portugal

Project academic non-profit, developed under the open access initiative

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

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

<https://doi.org/10.15446/rfnam.v76n3.102451>

Lucas Esteban Cano-Gallego^{1*}, Álvaro de Jesús Tamayo-Molano¹, Carolina Ortiz-Muñoz¹
and Juan Camilo Henao-Rojas¹

ABSTRACT

Keywords:

Andisols soils
Aromatic herbs
Chemical fertilization
Organic fertilization

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.

RESUMEN

Palabras clave:

Suelos andisoles
Aromáticas
Abonamiento químico
Abonamiento orgánico

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.

¹Corporación Colombiana de Investigación agropecuaria - Agrosavia. Centro de Investigación La Selva. Rionegro - Antioquia, Colombia. icanog@agrosavia.co , atamayo@agrosavia.co , cortizm@agrosavia.co , jhenao@agrosavia.co 

*Corresponding author

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 K₂O. 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 P₂O₅ (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 P₂O₅, and approximately 375 kg ha⁻¹ of K₂O 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.

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

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.

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 K, P, 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

favoured, 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 P₂O₅, and about 375 kg ha⁻¹ of K₂O.

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.

ACKNOWLEDGMENTS

The authors express their gratitude to the Colombian Agricultural Research Corporation - Agrosavia, for the support of this research which was developed in the project "Technification of the cultivation of *Mentha* spp., in the Southwest of Antioquia with small producers of the Integrated Rural Development program with a Territorial Approach DRIET of the Aurelio Foundation Llano Posada". To the Laureano Llano Foundation for financing the project, and to the farmers Javier Jaramillo, Adíela Jaramillo, Javier Arenas, Lady Arenas, and Leonel Osorio.

REFERENCES

- Alejo-Santiago G, Luna-Esquivel G, Sánchez-Hernández et al (2015) Determination of the nitrogen requirement for habanero pepper (*Capsicum chinense* Jacq.). Revista Chapingo Serie Horticultura 21(3): 215-227. <https://doi.org/10.5154/r.rchsh.2014.04.015>.
- Arango MC, Ruscitti MF, Ronco MG and Beltrano J (2012) Mycorrhizal fungi inoculation and phosphorus fertilizer on growth, essential oil production and nutrient uptake in peppermint (*Mentha piperita* L.). Revista Brasileira de Plantas Mediciniais 14(4): 692-699. <https://doi.org/10.1590/S1516-05722012000400018>
- Avelar Fabiana F, Matos Antonio T, Leite Junior et al (2015) Desempenho agrônomo de *Mentha aquatica* cultivada em sistemas alagados construídos sob diferentes taxas de aplicação orgânica. Engenharia. Agrícola 35(2):322-330. <https://doi.org/10.1590/1809-4430-Eng.Agric.v35n2p322-330/2015>
- Brown B, Hart JM, Wescott MP and Christensen NW (2003) The critical role of nutrient management in mint production. Better Crops 7(4): 9-11.
- Cano-Gallego LE, Minchalá-Buestan N, Loaiza-Ruiz RA et al (2022) Gas exchange and chlorophyll fluorescence in spearmint (*Mentha spicata* L.) leaves influenced by mineral nutrition. Revista Colombiana de Ciencias Hortícolas, 16(1). <https://doi.org/10.17584/rcch.2022v16i1.13685>
- Castro M, Ricaute CC and Quijano PA (2005) Determinación de metales en las estructuras del diente de león (*Taraxacum officinalis* Weber) hierbabuena (*Mentha piperita*) y manzanilla (*Matricaria chamomilla*) Bistua: Revista de la Facultad de Ciencias Básicas 3(1): 38-44. ISSN 0120-4211.
- Castro RD, Díaz GJ, Serna BR et al (2013) Cultivo y producción de plantas aromáticas y medicinales. 2ed Rionegro UCO. 98 p.
- Castro-Alayo E, Chávez-Quintana S, Auquiñivín-Silva E et al (2019) Aceites esenciales de plantas nativas del Perú: Efecto del lugar de cultivo en las características fisicoquímicas y actividad antioxidante. Scientia Agropecuaria 10(4): 479-487. <https://doi.org/10.17268/sci.agropecu.2019.04.04>
- Ferreira Melo W, Borges MP, César Ferreira LP et al (2018) Propriedades físico-químicas da hortelã (*Mentha piperita* L.) e seus benefícios à saúde. INTESA-Informativo Técnico do Semiárido (Pombal-PB) 12(2): 08-13. <https://www.gvaa.com.br/revista/index.php/INTESA/article/view/8519>
- Franco G, Estrada JAB, Paz RAO et al (2022) Guía para el establecimiento y manejo de la hierbabuena (*Mentha spicata* L.) en el Suroeste antioqueño. Corporación Colombiana de Investigación Agropecuaria (Agrosavia). ISBN-13 (15) 978-958-740-574-3.
- Franco G, Osorio Durango EJ, Sierra Henao KA et al (2023) Producción de menta (*Mentha spicata* L.) y su aprovechamiento agroindustrial. Corporación Colombiana de Investigación Agropecuaria (Agrosavia). ISBN-13 (15) 978-958-740-640-5.
- Gallegos-Zurita M (2016) Las plantas medicinales: principal alternativa para el cuidado de la salud, en la población rural de Babahoyo, Ecuador. Anales de la Facultad de Medicina. 77(4): 327-332. Recuperado en 03 de marzo de 2020. <https://doi.org/10.15381/anales.v77i4.12647>
- Gastaldi B, Marino G, Assef Y et al (2018) Nutraceutical properties of six native plants consumed as herbal infusion in Argentinian Patagonia. Plant Foods For Human Nutrition 73(3): 180-188. <https://doi.org/10.1007/s11130-018-0680-3>
- Giraldo GJ and Gutierrez CH (2019) Modelación de curvas de absorción de nutrientes edáficas para menta (*Mentha spicata* L.) y cebollín (*Allium schoenoprasum*) bajo condiciones del Oriente antioqueño. Repositorio.2019.UCO. <https://doi.org/10.47286/01211463.317>
- Hart J, Christensen N, Mellbye M and Gingrich G (2003) Nutrient and biomass accumulation of peppermint. Western nutrient management conference. Vol. 5. Salt Lake City, UT. pp. 63-70.
- Henao-Rojas JC, Osorio E, Isaza S et al (2022) Towards Bioprospection of commercial materials of *Mentha spicata* L. using a combined strategy of metabolomics and biological activity analyses. Molecules (27): 35-59. <https://doi.org/10.3390/molecules27113559>
- Jiménez-alonso A, Rodríguez-Mendiola M, López de Alba P et al (2012) Efecto de macronutrientes en la acumulación de (-) Mentol en el aceite esencial de menta (*Mentha piperita* L.) cultivado *in vitro* e invernadero. Gayana Botánica 69 (Número Especial): 101-108.
- Juárez-Rosete CR, Aguilar-Castillo JA, Aburto-González CA and Alejo-Santiago G (2019) Biomass production, nutritional requirement of nitrogen, phosphorus and potassium, and concentration of the nutrient solution in oregano. Revista Chapingo. Serie horticultura 25(1):17-28. <https://doi.org/10.5154/r.rchsh.2018.02.006>
- López-Hernández F and Cortés AJ (2022) Whole transcriptome sequencing unveils the genomic determinants of putative somaclonal variation in mint (*Mentha* L.). International Journal of Molecular Sciences (23): 52-91. <https://doi.org/10.3390/ijms23105291>

- Morales LJ, Peña FD, Torres RE et al (2018) Composición fitoquímica y actividad antibacteriana de los extractos clorofórmicos de las hojas de *Cassia uniflora* Mill. Revista Cubana de Plantas Medicinales 23(1). Disponible: <http://revplantasmedicinales.sld.cu/index.php/pla/article/view/533>
- Ozcan M (2004) Mineral contents of some plants used as condiments in Turkey. Food Chemistry (84): 437-440. [https://doi.org/10.1016/S0308-8146\(03\)00263-2](https://doi.org/10.1016/S0308-8146(03)00263-2)
- Pedraza R and Henao M (2008) Composición del tejido vegetal y su relación con variables de crecimiento y niveles de nutrientes en el suelo en cultivos comerciales de menta (*Mentha spicata* L.) Mineral composition of plant tissue in relation to growth variables. Agronomía Colombiana 6(2): 186-196. ISSN 0120-9965.
- Salehi B, Stojanović-Radić Z, Matejić J et al (2018) Plants of genus *Mentha*: From farm to food factory. Plants (Basel, Switzerland) 7(3): 70. <https://doi.org/10.3390/plants7030070>
- Tofiño-Rivera AP, Ortega-Cuadros M, Melo-Ríos A and Mier-Giraldo HJ (2017) Vigilancia tecnológica de plantas aromáticas: de la investigación a la consolidación de la agrocadena colombiana. Corpoica. Ciencia Tecnología Agropecuaria 8(2): 353-37. https://doi.org/10.21930/rcta.vol18_num2_art:636
- Torres-Martínez R, Bello-González M, Molina-Torres et al (2013) Efecto de la fertilización sobre el crecimiento y contenido de compuestos volátiles en *Satureja macrostema* (Benth) Briq. Revista Mexicana Ciencias Forestales 5(21): 122-134. <http://www.redalyc.org/articulo.oa?id=63439003008>
- Vacca-Molina M, Velásques JD, Bonomo ML and Avilés ZJ (2010) Menta (*Mentha arvensis* L.) micro and macropropagation. Revista Biociencias 3(3): 208-219. <http://doi.org/10.15741/revbio.03.03.07>
- Velasquez-Vasquez G, Pérez-Armendáriz B, Ortega-Martínez L and Nelly-Juarez Z (2019) Conocimiento etnobotánico sobre el uso de plantas medicinales en la Sierra Negra de Puebla, México. Bol Latinoam Caribe Plantas Medicinales aromáticas 18(3): 265-27. ISSN 0717 7917.
- Vicente-Herrero M, Terradillos-García M, Ramírez-Iñiguez M et al (2013) Especies, hierbas medicinales y plantas. Usos en medicina. Revisión de la bibliografía científica (Medline) Medicina Balear 28(2): 35-42. <https://dialnet.unirioja.es/servlet/articulo?codigo=4335203>
- Westermann RL (1990) Soil Testing and Plant Analysis. 3rd Edition, SSSA, Madison, pp. 534-587.

