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Effect of phosphoric fertilization on mycorrhizal colonization in corn in the colombian caribbean

Abstract

Plants require essential nutritional elements for their growth and development, including phosphorus, but this in the soil is usually deficient and slow in mobility, so biological practices must be used to make the uptake of this element by plants more efficient, for which, mycorrhizal symbiosis could greatly contribute to the uptake of phosphorus. The symbiosis becomes more effective when the soil contains low levels of phosphorus in the soil, however, these low contents do not favor the development of the corn crop. In response to this, this research was proposed, which was developed in semi-controlled conditions at the University of Córdoba, warm climate, in which different doses of phosphorus were evaluated (0, 5, 10, 20, 30, 40, 50 kg/ha) and the degree of colonization and vegetative development of the corn crop was evaluated in a soil with low nutritional supply and especially phosphorus (5 mg/kg). Corn of the ICA V 109 variety was used, in a complete randomized design, seven treatments with three repetitions were evaluated. The variables height, stem diameter, leaf area, wet and dry biomass and degree of colonization (mycorrhization) were evaluated. It was found that phosphorus is a limiting element in the growth of the corn plant and also influences the degree of mycorrhizal colonization. It was concluded that phosphorus fertilization has an inverse effect on mycorrhizal colonization in corn cultivation in edaphoclimatic conditions of Montería-Colombia. However, the amount of phosphorus available in the soil is directly proportional to the growth of this cultivar.

Keywords: Mycorrhizal symbiosis, mycorrhization in corn, phosphorus, corn, acid soils

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Eliecer M. Cabrales-Herrera,[1] Germán F. Estrella-Cantero,[2] Jesús Ayala-Cárcamo[3]

[1]Professor of the soil area, University of Córdoba, Colombia
[2]Advisor and technical consultant in tropical crop management, Colombia
[3]UNIBAN researcher, Colombia

Correspondence: Eliecer M. Cabrales Herrera, Ing. Agrón. PhD. Professor of the soil area, University of Córdoba, Colombia, Tel 3126659668, Email ecabrales@correo.unicordoba.edu.co

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Introduction

Phosphorus is one of the most limiting elements in agricultural production and is found in the soil in organic and inorganic forms grouped according to its labile and available representation.[1] The few quantities of elements available to plants in soils with low fertility or due to adverse chemical characteristics such as extremely acidic or alkaline pH leads to the insolubilization of essential nutrients, among which is phosphorus. In these scenarios, complementary contributions of fertilizers are made to improve crops, without the certainty that all the added fertilizers will be taken up by the plants, that is, many of them will be lost through washing, leaching,[2] these losses may be subject to environmental conditions and intrinsic properties of the soil. Plants take their nutrients through mechanisms such as diffusion, root intersection and mass flow; they are available in the rhizosphere where they are solubilized by substances secreted by the plants themselves and the action of microorganisms that inhabit that area.[3] But through evolution, species have developed interspecific relationships that facilitate the survival of those involved, among these mutualism and in plants has not been the exception, where there is a symbiosis with the fungi that form arbuscular mycorrhizas, whose interaction facilitates and It makes the absorption of nutrients efficient, especially those that are less dynamic such as phosphorus, copper and zinc. Likewise, this symbiosis offers protection to plants against biotic and abiotic factors.[4] Mycorrhizal-forming fungi receive photosynthates from plants, the carbon investment is greater compared to the supply of phosphorus in the plant-fungus reciprocity, which alludes to the storage of organic carbon in the soil,[5] being participate in this symbiosis the cereals and example them the corn.

In Colombia, nearly 1.4 million tons of corn are produced, bat is not enough to satisfy the needs of the cereal industry, so the grain must be imported from countries such as the United States and Brazil, principally.[6] Corn is one of the crops that offers food security to the world and in the case of Colombia the vast majority of the planted area is in the hands of small producers, in areas no larger than five hectares with a deficit in technology transfers. Based on the above, this research aimed to evaluate the dynamics of mycorrhizal colonization of the corn crop under different doses of phosphorus in acidic soils of Montería-Colombia, and to find the colonization curve in this crop. Likewise, physiological components of the culture were measured.

Methodology

Location: The research was carried out at the facilities of the University of Córdoba - Colombia, whose geographical coordinates are 8° 47' 31" N and 75°51' 36"W, in reference to the Greenwich meridian, 15 meters above sea level, relative humidity of 85%, average annual precipitation of 1200 mm, annual sunshine of 2108 hours. According to Holdridge, the area belongs to the warm-moderate climatic zone, the transition between Humid Forest and Tropical Dry Forest.[7]

Soil sampling: A clay soil was taken from the municipality of Monteria, geographical coordinates are 8°37'43"N and 75°47'18"W, soil from the second horizon was used with the purpose of reducing the contribution of phosphorus by organic matter and with a subsample of approximately 1 kg was made to a physical-chemical soil analysis.

Preparation of the substrate and sowing: Substrate was prepared in a 2:1 ratio of clay and sand to improve the permeability of the substrate. Planting was done with corn of the ICA V 109 variety, depositing three (3) seeds per site.

Experimental design: The experimental unit corresponds to corn plants variety ICA V 109, arranged in a complete randomized design, represented by a statistical model:

$$Y_{ij} = u + t_i + \varepsilon_{ij}$$

Where.

Yij is the response variable concerning phosphorus treatments i, repetition j.

u is the general average of the treatments.

t is the effect of treatments i (phosphorus dose).

ε is the experimental error due to treatment i, repetition j.

Description of treatments: Seven (7) treatments were worked with three (3) repetitions:

- **T1:** Without phosphorus application (Control)
- **T2:** Phosphorus was applied in doses of 5 kg/ha
- **T3:** Phosphorus was applied in doses of 10 kg/ha
- **T4:** Phosphorus was applied in doses of 20 kg/ha
- **T5:** Phosphorus was applied in doses of 30 kg/ha
- **T6:** Phosphorus was applied in doses of 40 kg/ha
- **T7:** Phosphorus was applied in doses of 50 kg/ha

Nitrogen fertilization was 120 kg/ha, Urea was used as a source, its application was made 15-25-35 days after emergence. KCl was used as a source of potassium at a dose of 80 kg/ha, this was applied in its entirety at the time of sowing. For phosphorus, DAP was used in the doses described in the treatments, this was applied in its entirety at the time of sowing. For nitrogen fertilization, the amount of N contained in the DAP dose applied in each treatment was taken into account.

Inoculation: At each planting site, 10 g of commercial mycorrhizae were applied at the time of planting. This mycorrhiza contains between 80 to 100 spores/g of substrate and has the following species: *Glomus fasciculatum, Scutellospora heterogama, Glomus mosseae, Glomus manihotis, Acaulospora rugosa* and *Entrophospora colombiana.*

Variables evaluated: Plant height, stem diameter, leaf area, wet and dry biomass and absolute growth rate were evaluated. To evaluate mycorrhization, the root staining technique of Phillips and Hayman[8] was implemented with some modifications.[9]

Information processing: The information was tabulated in Excel and processed with the statistical program SAS version 9.0, make analysis of variance and comparison of means were performed by Tukey with a confidence level of 95%.

Result and discussion

Soils. The soils are acidic in reaction, with very low organic matter content, and also have phosphorus deficiencies, but sulfur sufficiency. The soil bases are usually of medium quantity; however, magnesium is usually above the average content of agricultural soils, with an inverted calcium/magnesium ratio, indicating that calcium deficiencies could occur in plants. Minor elements are deficient (Table 1), which implies that the crops must be accompanied by applications of foliar fertilization rich in minor elements. The important thing about these results is that the soil is poor in phosphorus and that the organic source is very low, which indicates that the soil is ideal for such investigation.

Table 1 Results of the chemical analyzes of soils used in the investigation

pH	MO	S	P	Ca	Mg	Na	K	CICE	Cu	Fe	Zn	Mn	B
1:1	%	mg/kg		cmol(+)/kg					mg/kg				
5,7	0,34	12	3	4,8	7,5	0,33	0,1	12,7	1,7	5	0,8	27,4	0,31

Physiological variables

Plant height: The highest height of the mycorrhizal corn plant was achieved when doses of 50 kg/ha was applied of phosphorus (T7) and was 181 cm, while in the treatment that did not receive phosphorus fertilization (T0), the height was 68 cm (Figure 1). This difference in heights may be subject to the effect of phosphorus and mycorrhization: the lowest expression occurred in the treatment without application of phosphorus, the soil having a low content of organic matter, could not provide phosphorus, therefore, there was a deficiency of this element.

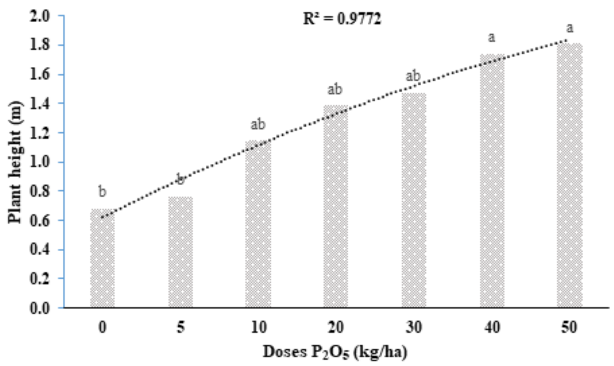

Figure 1 Influence of different doses of phosphorus on the height of the corn plant.

Likewise, it was found that the significant Tukey mean difference ($P<0.05$) showed that the treatments with phosphorus application above 40 kg/ha are statistically different from the rest, the expression of the plant height has a linear behavior that indicates that for each kilogram of phosphorus per unit area the plant height increases by 67 cm, 98% of this parameter depends on the phosphorus content, the remaining 2% may be subject to other factors such as genetic quality of the seed, climate, edaphic conditions, among others. The plant height behavior may be subject to the greater availability of phosphorus that the plant was able to absorb with the help of mycorrhizae, since this element is vital in the growth processes and in general in all the metabolic processes of the plants,[10] in such a way that according to the amounts of assimilable phosphorus in the soil, plants can express their growth.[11]

Dry biomass: The analysis of variance (table 2) shows significant differences ($P<0.001$) for the dry biomass variable, where it is evident that the treatments with phosphorus application above 20 kg/ha are statistically similar according to the comparison test Tukey means with a confidence percentage of 95%, with the treatment with a dose of 50 kg/ha being the one with the highest expression with 50.48 g of dry biomass, this variable can achieve results greater than 200 g in the same corn variety evaluated under similar mycorrhization and phosphorus fertilization conditions,[3] research carried out in clay soils suggests that dry biomass is affected when mycorrhizae and phosphorus fertilization are applied[26] as well Likewise, when there is an effect of mycorrhizae in corn at increasing doses of phosphorus, the correlation of crop growth is negative, thus affecting dry biomass contents,[13] while evaluations made in other Poaceae species the interaction of mycorrhizae with phosphorus fertilization increases dry biomass above 200 g, as is the case of pearl millet (*Pennisetum glaucum* L.).[14]

Table 2 Mean values of physiological parameters of the mycorrhizal and fertilized corn crop at different doses of phosphorus

	Criterion/Plant				
Phosphorus doses (kg/ha)	SD* (cm)	LA** (cm^2)	WB (g)	DB*** (g)	AGR (g/día)
0	1,04ab	122,42 b	75,50 a	16,34 cd	6,15a
5	0,97 b	128,87 b	70,55 a	15,56 d	3,89a
10	1,35ab	205,64ab	105,17a	24,60 bcd	7,57a
20	1,64ab	277,23ab	146,53a	37,00abcd	5,76a
30	1,36ab	300,60a	133,09a	37,66abc	9,88a
40	1,72a	313,84a	161,07a	42,29ab	5,20a
50	1,67ab	337,86a	163,23a	50,48a	4,89a

SD: Stem diameter, LA: Leaf area, WB: Wet biomass, DB: Dry biomass, AGR: Absolute growth rate. * Significance at 5%, ** Significance at 1%, *** Significance at 0.1%. Values with identical letters vertically are statistically equal, according to Tukey at 5%.

Leaf area: There was a highly significant difference (Table 2) ($P<0.01$), with this parameter showing an increase as the phosphorus content in the soil increased. This same trend has been reported in the cultivation of mycorrhizal corn with 15 % phosphorus fertilization.[15] Likewise, the leaf area of corn increases when mycorrhizae and phosphorus fertilization are applied, the difference with respect to the non-application of mycorrhizae can be up to 69.78 cm^2.[16] This same trend of phosphorus fertilization can present increases in leaf area greater by up to 57.62 cm2 compared to the non-application of phosphorus,[17] in contrast, the leaf area under the fertilizer application may not show differences in the absence of mycorrhiza application, the same factor that may be subject to the crop variety or mycorrhiza-forming fungus.[18]

Stem diameter: The phosphorus contents significantly influenced ($P<0.05$) the variable stem diameter (table 2), generally in the corn crop the interaction of phosphorus with mycorrhiza-forming fungi increases the thickness of the stem,[19] this as a consequence of the production of phytohormones from mycorrhizae.[20] In the same sense, there are statistical differences when evaluating the application of mycorrhizae and phosphorus in corn, but it is possible that the solubility of the applied phosphorus is capable of reducing the effectiveness of the action of mycorrhiza-forming fungi on the plants, reflecting greater stem diameter when soluble phosphorus is applied at a dose of 22.5 kg/ha.[21] The simple fact of applying phosphorus fertilization and mycorrhizae causes the diameter of the crop stem to increase up to 1.3 cm in relation to their application,[22] such is the effect it has on the diameter of the stem where it does not tend to decrease, even in the effects of drought in plants with mycorrhization and application of 100 kg/ha of phosphorus as a complement.[23]

Wet biomass and absolute growth rate (AGR): The variables of wet biomass and absolute growth rate are not statistically significant ($P>0.05$), similar results have been found in the cultivation of mycorrhizal corn where no statistical differences in fresh biomass are reported.[24] Mycorrhizae contribute to the absorption of water and nutrients in the corn plant, but a significant contribution was not found in this variable, perhaps because there was no water stress in the research period.[25] Likewise, wet biomass does not present significant statistical differences when mycorrhizae and phosphorus are applied, which is possibly due to the type of mycorrhiza-forming fungal species.[26] The absolute growth rate is considered the force with which the plant makes the demand for assimilates,[27] the treatments were not statistically different, the treatment with a dose of 30 kg/ha presented a higher absolute growth rate growth and the results found are lower than the results found by Cabrales and Barrera,[28] who report absolute growth rates higher than 10 g/day, however, absolute growth rates are also reported in corn cultivation higher than 0.86 g/day whose maximum peak of trends occurs 30 days after sowing,[29] the same trend of dry mass gain over time has been evident in other Poaceae like wheat.[30]

Mycorrhizal colonization: The percentage of mycorrhization shows highly significant statistical differences ($P<0.001$) and a decreasing trend was observed as the phosphorus doses increased (Figure 2), this represents a correlation of 97% dependence on the phosphorus content, similar data. have been reported in the corn crop where 95.5% of mycorrhization has been found.[31] Low phosphorus contents in plants encourage root exudation of strigolactones such as: orobanchol, solanacol and didehydro-orobanchol, this process being the basis of mycorrhizal symbiosis,[32] in soils with low phosphorus contents mycorrhization can be above 78.3%.[33] In sandy soils, Arroyo et al.[3] found that the native mycorrhizal population (spores) decreases as the phosphorus concentration increases in the corn crop, while mycorrhizal inoculations achieved a degree of symbiosis of 95% when a dose of 25 kg/ha of phosphorus was applied.

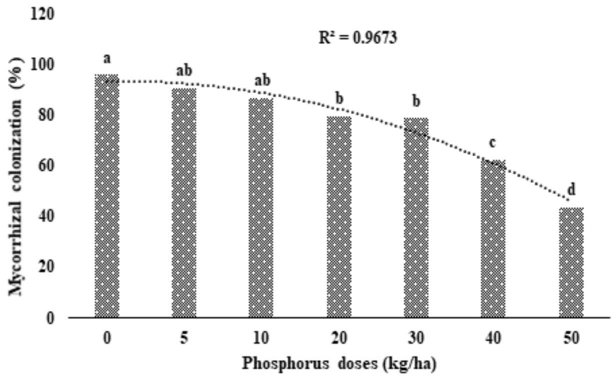

Figure 2 Influence of phosphorus doses on the percentage of mycorrhization of the corn crop.

Among the structures formed by the symbiont (Figure 3), it was found that 88.46% of vesicles were formed when phosphorus was applied in proportions of 10 kg/ha and the smallest amount of structures was evident with 45.85% when phosphorus was applied phosphorus at a dose of 50 kg/ha, the results found are possibly related to the fact that at lower doses of phosphorus the plants presented limitations in the formation of these fungal structures, which is why the reciprocity of the plant towards the symbiont was limited which induced the greatest formation of vesicles as a reserve source, the results found are higher by 67.96% and 39.55% in maximum and minimum values for this parameter reported by Gabardi et al.,[34] Likewise, Mário et al.,[35] reports that the percentage of vesicles in corn does not exceed 80%, Mora and Leblanc[36] found that in the same crop the percentage of vesicles without phosphorus application is 57.5 % and with phosphorus doses greater than 50 kg/ha, this parameter does not exceed 27% presence. Rendón et al.,[37] found a relation of 5.69% colonization by vesicles in corn, in the same way it states that the manifestation of vesicles depends on the climatic conditions and the species of mycorrhiza-forming fungus used.

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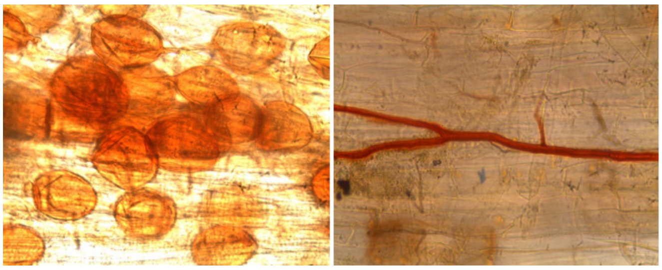

Figure 3 Structures found in mycorrhizal evaluation (vesicles and hyphae).

Conclusion

Phosphorus fertilization directly influences plant growth, which indicates that it is a limiting element for this crop.

Phosphorus fertilization has an inverse effect on mycorrhizal colonization in the corn crop in the climatic conditions of Montería – Córdoba, low content of available phosphorus induces an increase in the number of vesicles in the roots of the corn crop.

This study suggests that in future research the phosphorus adsorption isotherm curve evaluation technique be implemented, especially when soils with clay textures are used due to the nutrient adsorbent capacity they have.

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None.

Conflicts of interest

The authors declare that there is no conflicts of interest.

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