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Evaluation of Two *Lupinus* Species Native from Central Mexico in Relation with Solubilization of Nitrogen, Phosphorus and Potassium in an Andosol

[1]Angel Alderete-Chavez, [2]Vicente Espinosa Hernández, [2]Nancy De la Cruz-Landero,
[2]Enrique Ojeda Trejo and [2]Hortencia Brito Vega
[1]Autonomous University of Carmen, Street 56 No. 4 Carmen, Campeche C.P. 24180, Mexico
[2]Department of Soil Science, Postgraduate College of Agricultural Sciences,
Km 36.5 Carr Mex-Texcoco, Montecillo, Edo de México C.P. 56230, México

Abstract: In Mexico there are few studies about lupine native species. In the oriental slope of the Sierra Nevada Mexico five species of *Lupinus* growing in soil andosol were identified and seeds of the plants were collected. The Lupinus species play an important ecological role by providing favorable conditions for the restauration of soils in forest areas after fire, in agriculture acidification of soil and solubilization of nutrients. Data about the performance of lupine native species and the characterization of its behavior during the growing cycle and the extraction of Nitrogen (N), Phosphorus (P) and Potassium (K) is not available. The present research was realized to explore the capacity of two species *Lupinus leptophyllus* and *Lupinus montanus*. An exploratory study under greenhouse conditions was realized to obtain the tendencies in the concentration of C, N, P and K available in the soil through time. For the two species there were an increase in the percentage of nitrogen and phosphorus at 120 days and for potassium at 80 days.

Key words: *Lupinus* andosol, nitrogen, phosphorus, potassium

INTRODUCTION

The *Lupinus* species are widely distributed at global level (Sugiyama, 2003; Walker *et al*., 2003; Diekmann and Falkengren-Grerup, 2002; Tozer and Bradstock, 2002). In Mexico almost 210 species have been found at altitudes varying from 0 to 4000 m as, The major concentration is in the central Mexico (Neo-volcanic plateau), with 123 species in the Valley of Mexico and at least two varieties have been reported in the Tlaloc mountain (Calderón and Rzedowski, 2005). However in two recent studies for *Lupinus* in this area, seven species are reported by Alderete-Chavez *et al.* (2008) and Ehsan *et al*. (2007). The two *Lupinus* species collected for this study are distributed widely in the oriental part of Tláloc mountain found in an altitudinal range varying from 2932 to 3640 m.a.s.l.

The legume family, to which the lupines pertain, performs an important ecological role providing favorable conditions for the development of soil organisms, improving physical and chemical properties of soil (Bahmanyar and Ranjbar, 2008; Falkengren-Grerup and Schöttelndreir, 2004) The white lupine is one of the most studied species (*L. albus* L.), it is adapted to acid soils and is growing satisfactorily in soils deficient in P which it leaves available for other plants (Dinkelaker *et al*., 1989). *L. montanus* and a few other species of the same genus are used in South America and Guatemala to increase soil fertility and for soil improvement in forest plantations due to their nitrogen fixation capacity (Andrist-Rangel *et al*., 2007). Indurate volcanic soils more commonly known as tepetates are common in the mountain (Polile *et al*., 2008); these soils are formed by consolidated deposits of volcanic ashes and have been incorporated into agriculture long before the arrival of the Spaniards in Mexico. The main problem of this soils is their relatively low level of fertility, mainly nitrogen and phosphorus (Oenema *et al*., 2004). *Lupinus* is capable of mobilizing essential nutrients to inorganic forms (Shenoy and Kalegudi, 2005; Darrah, 1993).

The differences in the absorption of nitrogen, phosphorus and potassium in soils with lupine are also related to their capacity to modify the pH in the rizosphere by means of proton liberalization which acidifies the soil (Vanlauwe and Giller, 2006; Zoysa *et al*., 1998). Closely related with the acidification is the transformations of nutrients among organic and inorganic, given that inorganic forms providing nourishment for microorganisms and plants (Gahoonia and Nielsen, 2004). The existence of alterations of carbon metabolism within

Corresponding Author: Angel Alderete-Chavez, DES Ciencias Naturales and Exactas, Universidad Autonoma del Carmen, Street 56 No. 4 Ciudad del Carmen, Campeche, C.P. 24180, Mexico Tel: 019383811018/1800

proteoid roots explains also the amount of acid exuded by plants subjected to phosphorus deficiency (Zhou *et al.*, 2008).

This investigation explores the capacity of the two species collected in the sierra Nevada, Mexico *Lupinus leptophyllus* and *Lupinus montanus* and their potential to solubilize nitrogen, phosphorus and potassium in soils derived from volcanic ash.

MATERIALS AND METHODS

The two species growingly more abundantly in the Sierra Nevada (*L. montanus* and *L. leptophyllus*) were used to evaluate their effect on Carbon and fertility of the soil under greenhouse conditions.

Soil for this study was collected in the agriculture fields were *Lupinus* was growing. The *Lupinus* were sown in 24 PVC tubes (12 with *L. montanus* and 12 with *L. leptophyllus*) PVC tubes of six inches in diameter and 40 cm height creating an adequately sized container holding 8 kg of soil. Soil samples of 200 g were taken from the pots with a clean drill and with a slight inclination towards the rhizosphere of the plants. At sowing and after 80, 120 and 160 days. The samples were dried and sifted through a wire mesh 2 mm and in the laboratory the following properties were determinate: bulk density by the test tube method, soil texture by Boyoucos, pH using a potentiometer in a soil-water ratio of 1:2, Total Nitrogen by Micro-Kjeldahl, Phosphorus by Bray I and potassium by flame photometry (Table 1). The arithmetic mean was calculated for the two lupinus and graphicated in bars to analyse the tendencies in the content of C and N, P, K in time.

RESULTS AND DISCUSSION

The two species of *Lupinus* evaluated in this study, presented potential to liberate essential nutrients from the soil to available forms, this situation can improve the growth of plants around the *Lupinus*, the evaluations were carried out among the months of April to July, when the plants were in the middle of development.

Total soil N: Table 1 shows an initial low content N (%) 0.13% (similar to that reported in this area by Velázquez-Rodriguez *et al.* (2001). The behavior of the % in N is similar for both plants a very low content until the 80 days with a high increase at 120 days amount 57 and 56%, respectively and at the end of the experiment after 160 days, the N (%) in soil diminished to the initial content. This situation could indicate that *Lupinus* increase its capacity of fixation of atmospheric nitrogen

Table 1: Physical and chemical characteristics of soils originating from volcanic ash

Soil characteristics	Values
Sand	34.00
Silt	37.00
Clay	29.00
pH 1:2	6.34
Apparent density (g cm^{-3})	1.12
Total carbon (%)	3.32
Total nitrogen (%)	0.13
Phosphorus (mg kg^{-1})	14.70
Potassium (cmol kg^{-1})	1.46

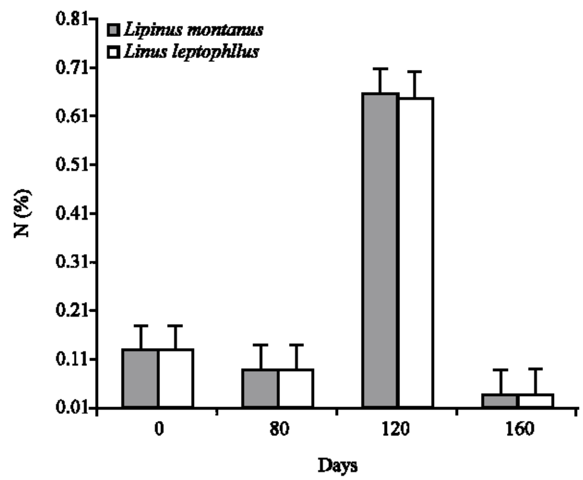

Fig. 1: Available nitrogen in soil by the effects of two species (*L. montanus and L. leptophyllus*)

80 days after planting to 120 days or more. These differences in the absorption on nitrogen could be related to the capacity of the plant to modify pH from the rhizosphere by means of proton liberation which acidifies the soil as similarly reported by Zoysa *et al.* (1998). Moreover as a legume *Lupinus*, have the capacity to fix atmospheric nitrogen into soil. This process depends on a series of factors which includes soil temperature, humidity, aeration and low pH which favors denitrification (Li *et al.*, 2005; Qualls, 2000). As signaled by Fontaine *et al.* (2003) in poor soils this mechanism is more active as the plant grows and the necessities of N are lower, the mechanism of Fixation decreases as is showed in Fig. 1. The increase and reduction of the N (%) to the initial condition during the growing period means that the Lupine not only utilize fixed nitrogen by themselves, but also they are using the available nitrogen in the soil.

Total soil P and K: Table 1 shows the initial concentration of P in the soil as 14.7 mg kg^{-1} (similar to that found for volcanic soils in the same area Velázquez-Rodriguez *et al.*, 2001). In agreement with Timothy *et al.* (2008), the behavior of the amount of P is similar for both plants with small variations and a reduction in its amount after

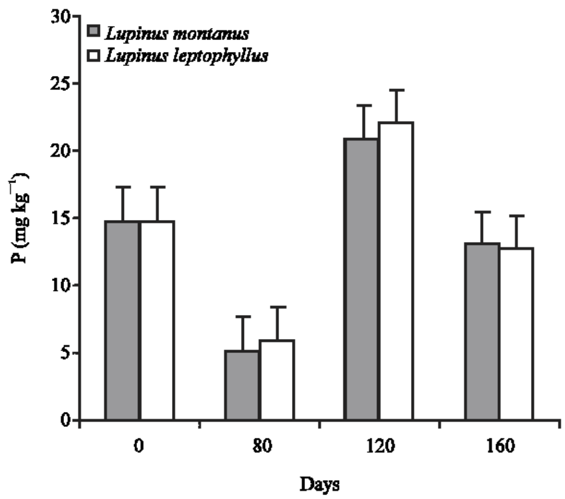

Fig. 2: Available phosphorus in soil by the effects of two species (*L. montanus* and *L. leptophyllus*)

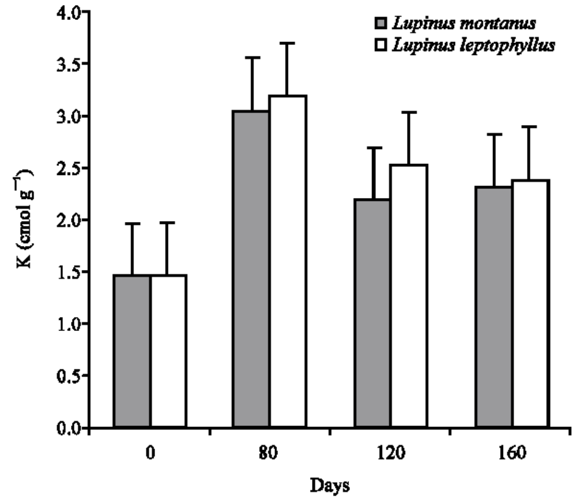

Fig. 3: Available potassium in soil by the effects of two species (*L. montanus* and *L. leptophyllus*)

80 days in almost 9 ppm and with a high increase at 120 days amount to 15.8 ppm and 16.1 at the end of the experiment after. At the endo of the experiment the amount of P was reduced, but the quantity of P remains almost equal that the initial condition (Fig. 2).

The mechanisms of liberation of Phosphorus by *Lupinus* is similar to the results of Adamczyk *et al*. (2008), Yadav and Tarafdar (2004) found that the differences in the absorption of phosphorus could be related to two main mechanisms a) the plant's capacity to modify the pH of the rhizosphere by means of proton liberation which causes soil acidification. b) The hydrolysis of organic phosphorus is mediated by the activity of the ectoenzyme acid phosphatase released by bacteria and fungi and secreted by the roots particularly in tip or apex zones (Yadav and Tarafdar, 2004).

The activity of the acid phosphatase has been proven in the rhizosphere of plants cultivated in soils with low levels of Phosphorus. The results obtained in this research coincide with those with *L. consentinni*, *L. angustifolius* and particularly with *L. albus*, which has allowed researchers to fully understand the solubilization and mobilization capacity of phosphorus from non-usable sources for other crops (Derry *et al*., 2005).

In the Table 1, is appraised, that potassium has an initial value of 1.46 cmol kg^{-1} in the limits of critical value for numerous crops (0.15-0.30 cmol kg^{-1}) (Schneider, 2005; Tait and Morris, 2000). In this research both species of *Lupinus* increased the amount of potassium (Porres *et al*., 2008; Moritsuka and Masumoto, 2006), inclusive 120 and 160 days after planting, in more than 50% of the initial content in the soil. *L. leptophyllus* was the species which maintained a higher level of potassium in the soil with 3.19, 2.53 and 2.39 cmol kg^{-1} for the evaluated dates. This represents a high increase to the soil reservoir of nutrients (Fig. 3).

CONCLUSION

The two species of *Lupinus* evaluated in this study, are able to increase the levels of N, P and K in the soil during the period of growth of the Lupine with higher increase at 120 days after planting *L. leptophyllus* is lightly more efficient than *L. montanus*. The results of this study, reflect a tendency of the species evaluated to improve the mineral nutrients in the soil during the period of growth of Lupine. However, only in the case of K the amount of this nutrient was higher that the initial amount at the end of the growing period. It is advisable, to continue carrying out this type of studies for a better understanding of the temporal availability of nutrients in the different seasonal phenology periods of *Lupinus*.

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