Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 11 (6): 1044-1048, 2011
ISSN 1812-5654 / DOI: 10.3923/jas.2011.1044.1048

Evaluation of *Clitoria ternatea* L. in Relation with Fertility in Tropical Soils

A. Alderete-Chávez, J.J. Guerra-Santos, N. De la Cruz-Landero, R. Brito, E. Guevara,
R. Gelabert, E. Nuñez, E. Endañu and L.E. Amador-del Angel
Research Center of Environmental Sciences-Autonomous, University of Carmen Street 56 No. 4 Carmen,
Campeche, Mexico C.P. 24180, Mexico

Abstract: The present research was carried out to explore the ability of *Clitoria ternatea* to incorporate nutrients into soils. There are just few studies about native species in Mexico. *Clitoria* plays an important ecological role by providing favorable conditions for soil restoration in forest areas after forest fires occurrence. In agriculture, *Clitoria* species affect soil acidification and nutrient solubilization. Data about the performance of *Clitoria* species and the characterization of its behavior during the growing cycle and the extraction of some nutrients like Nitrogen (N), Phosphorus (P) and Potassium (K) is not available. An experiment using a completely randomized design with six replications was conducted under natural conditions in Carmen Island. Results showed that *C. ternatea* is able to increase the levels of N, P and K in the soil during the period of growth.

Key words: Carmen Island, seeds, growth, nutrients, *Clitoria ternatea*

INTRODUCTION

The sustainable management of soils with low natural fertility is a major challenge for small holder agriculture in tropical rain forest. Due to this it is important to use tropical species, one of them is *Clitoria ternatea*. An Asian pea (Butterfly pea), most likely originating from tropical Asia, *Clitoria ternatea* has been widely distributed to many tropical and subtropical countries, where it has become naturalized to South and Central America, China and India (Gomez and Kalamani, 2003).

This legume shows good growth in native tropical and subtropical grassland and scrubs, diverse type of soils, cultivated soils and in fallow land during the rainy season (Ibeawuchi, 2007).

Cliroria ternatea is a vigorous, strongly persistent herbaceous perennial legume (stems fine twining, sparsely pubescent, suberect at base, 0.5-3 m long). Leaves are pinnate with 5 or 7 leaflets; petioles are 1.5-3 cm long; stipules persistent, narrowly triangular, 1-6 mm long, subulate, prominently 3-nerved; rachis 1-7 cm long; stipels filiform, to 2 mm long; leaflets elliptic, ovate or nearly orbicular, 1.5-5 cm long, 0.3-3 cm wide, with apex acute or rounded, often notched, both surfaces sparsely appressed pubescent. Flowers axillary, single or paired; color ranges from white, mauve, light blue to dark blue; pedicles 4-9 mm long, twisted through 180° so that the standard is inverted. Bracteoles are persistent, broadly ovate or rounded, 4-12 mm long. Calyx is 1.7-2.2 cm long with a few fine hairs; tube campanulate, 0.8-1.2 cm long; lobes triangular or oblong, 0.7-1 cm long, acute or acuminate. Standard obovate, funnel-shaped, 2-5.5 cm long, 2-4 cm wide, notched or rounded at apex, blue with a pale yellow base, or entirely white, a few fine hairs at apex. Pods linear-oblong, flattened, 4-13 cm long and 0.8-1.2 cm broad, with margins thickened and style persistent, sparsely pubescent when mature, pale brown, dehiscent when dry. Seeds 8-11/pod, oblong, somewhat flattened, 4.5-7 mm long, 3-4 mm wide, *C. ternatea* is a vigorous, strongly persistent, herbaceous perennial legume (Morris, 2009).

The family that *Clitoria* belongs, performs an important ecological role providing favorable conditions to the development of soil organisms; as well as improving physical and chemical properties of soil (Aguiar *et al*., 2010; De Moura *et al*., 2010).

The potential of legumes to fix nitrogen and increase organic matter in the soils had not been fully exploited, especially using the land race legumes (Ibeawuchi, 2007; Alderete-Chavez *et al*., 2009; Brito-Vega *et al*., 2009; De la Cruz-Landero *et al*., 2010). In conventional cultivation the plants promote soil stability and modify its structure, low infiltration velocity, soil compactness due to agricultural machinery passage and higher water loss due to evaporation (Molumeli *et al*., 2008).

Corresponding Author: A. Alderete-Chávez, Research Center of Environmental Sciences-Autonomous, University of Carmen Street 56 No. 4 Carmen, Campeche, Mexico C.P. 24180, Mexico

Sustainable nutrient management includes economizing on finite natural resources such as fossil energy and limited phosphorus resources. There is a strong need to design cropping systems which take into consideration the emerging social, economical and ecological or environmental concerns (Batie and Ervin, 2001). Arable farms with exclusively crop production are characterized by large nutrient export in farm products and the continuous use of the same area reduces nutrient availability and increases the incidence of weeds (Tilman *et al*., 2002). In long term, nutrient export from soils and losses must be balanced by adequate inputs of fertilizers and biological Nitrogen (Oenema *et al*., 2004; Wivstad *et al*., 2005). In nature, phosphorus flows can be defined as a series of biogeochemical processes involving both mechanical transfer and physical, chemical and biological transformations (Shane and Lamberts, 2005; Liu *et al*., 2008).

The differences in nitrogen and phosphorus absorption in soils with *Clitoria* are also related to their capacity to modify the pH in the rhizosphere by means of exudation rates of organic acid anions. A major difference between plant species was found in root-surface of acid phosphatase activity (Kamh *et al*., 2002; Moura *et al*., 2009).

This approach would have added value if functionally different vegetation types defined mainly on the basis of suites of morphological and regenerative traits were shown to possess characteristic tissue nutrient signatures consistent with their preferred growing conditions and the type of nutrient limitation faced (Willby *et al*., 2001; Alderete-Chavez *et al*., 2010). Closely related with the acidification are the transformation of nutrients between organic and inorganic, given through the fact that inorganic forms providing food for microorganisms and as well as plants (Gahoonia and Nielsen, 2004). Following the discovery of dauciform roots, the impact of varied nitrogen supply on dauciform root formation has been tested as well as their anatomy. However, there is a lack of information on the physiological aspects of dauciform root function and development (Playsted *et al*., 2006).

The existence of alterations of carbon metabolism within proteoid roots explains also the amount of acid exuded by plants subjected to phosphorus deficiency (Zhou *et al*., 2008). Phosphorus is an essential nutrient required for plants growth and development, it is intimately involved in a wide range of physiological and biochemical processes (Richardson, 2009). This investigation explores the potential of *Clitoria ternatea* L. to incorporated nitrogen and phosphorus and to improve the fertility in tropical soil, in Carmen Island, Campeche State, Mexico.

MATERIALS AND METHODS

This experiment was conducted from October 2009 to May 2010. Seeds of *C. ternatea* were evaluated to know their potential to be used in field trials. Seeds with previous treatments of scarification were put in water at 75°C for 3 min and seed the same day under natural conditions in a experimental field in Carmen Island, Campeche State, Mexico, N 18°67' 52.1", W 91°74' 33.9" at altitude of 3 m.a.s.l. The region has a warm and sub humid climate with a mean precipitation of 1300-1500 mm year^{-1}, the rainy season is from June to October and the dry season (rain absence), from January to middle of May. The annual average temperature is 27°C appearing the maximum levels before the solstice of summer with an average of 28°C being reached an historical maximum temperature of 43°C; frosts do not appear and as far as hurricanes, its coast is the one of smaller incidence (Ramos-Miranda *et al*., 2009).

The plantation was made in spaced to 80 cm and lots of 6×6, placing the seeds in the furrow of 2 cm depth during October of 2009, with a density of 9 seeds per square meter, two irrigations at 10 days intervals were applied. The treatment arrangement was a completely randomized experimental design with six replications.

Soil samples of 200 g were taken with a clean drill and with a slight inclination towards the rhizosphere of the plants at the sowing and after 180 days in May of 2010. The samples were dried in the sifted through a wire mesh 2 mm. The following properties were determinate in laboratory: Percentage of organic matter (White and Black), Total Nitrogen by Micro-Kjeldahl, Phosphorus by Bray I and Potassium by flame photometry.

Statistical analysis: Germination was registered by six replications per treatment during the experiment. Germination frequencies for the same treatment were grouped and expressed as percentage. SAS (2003) program (v. 2003) for personal computers was employed to conduct the ANOVA test (Proc mixed) and mean comparisons LSD (Less Significant Difference). The treatments were considered as fixed effects, the blocks as random effects.

RESULTS AND DISCUSSION

Clitoria ternatea showed potential to liberate essential nutrients from the soil in available forms, usually soil receives micronutrients from atmospheric deposition irrigation water and phosphate rock fertilizer and farmyard manure, this situation can improve the growth of plants around the *Clitoria* genus, the evaluations were carried out among the evaluation months when the plants were in the middle of development. The statistical analysis shows that significant differences exist for OM, N, P and K variables. Organic matter increase from 6.05 to 9.91%. Nitrogen increase 0.3 to 0.48%; phosphorus increase from 2 to 10.2 mg g^{-1} and potassium also increase from 0.06 to 0.16 mg g^{-1} compared with the controls (Table 1).

Table 1: ANOVA for Organic Matter (OM), nitrogenous (N), phosphorus (P) and potassium (K)

Source	df	SS	MS	F-value
OM				
Effect	1	40.996	40.996	146.537*
Error	10	2.798	0.279	
Total	11	43.794	41.275	
N				
Effect	1	0.095	0.0954	190.18*
Error	10	0.005	0.0005	
Total	11	0.100	0.0959	
P				
Effect	1	206.255	206.255	4829.39*
Error	10	0.427	0.0427	
Total	11	206.682	206.298	
K				
Effect	1	0.028	0.0276	216.23*
Error	10	0.001	0.0001	
Total	11	0.029	0.0277	

*Significant difference at p = 0.0001

Table 2: Effects of *C. ternatea* plants in the increase of nutrients in the soil

Treatments	Organic matter (%)	Total N (%)	P (mg kg^{-1})	K(cmolkg^{-1})
Testing	6.1	0.30	2.0	0.06
C. ternatea	9.9	0.48	10.2	0.16

Total soil Organic matter (OM) and nitrogenous (N): The initial low content of OM 6.1% and N 0.3% with a high increase at 180 days amount 60% content of OM and N in the soil (Table 2). This situation could indicate that *C. ternatea* increase its capacity of fixation of atmospheric nitrogen 180 days after planting. Also have a significant influence on soil quality of *C. ternatea*.

The differences in the soils of plant effects can be due to absorption of Nitrogen and seems to be related to the capacity of the plant to modify pH from the rhizosphere by means of proton liberation. As a consequence of normal growth and development, a large range of organic and inorganic substances are exchanged between the root and soil, which inevitably leads to changes in the biochemical and physical properties of the rhizosphere. This study found that *C. ternatea* shows similar conditions of growth as previous research (De Albuquerque *et al*., 2006).

The nutrient increases and changes in soil conditions depend of some factor like soil temperature, humidity, aeration and low pH which promotes denitrification (Alderete-Chavez *et al*., 2009). Nitric oxide is also produced by denitrification, but its diffusion to the soil surface is greatly reduced by the low gas diffusivity, usually prevailing during denitrification episodes. It is thus likely to be reduced to N_2 under such anaerobic conditions *C. ternatea* shows similar condition (Rolland *et al*., 2008). As signaled by Fontaine *et al*. (2003) in poor soils this mechanism is more active as the plant grows and the requirements of N are lower. *C. ternatea* probably have the positive impact on soil fertility and incorporation of the residues from grain legumes supports to maintain soil N levels. Deposition of N by the cover crop will gradually increase the level of soil N and thus reduce the proportion of plant biomass derived from N_2 fixation of according with Jensen and Hauggaard-Nielsen (2003) and Sanginga (2003).

Total soil phosphorus (P) and potassium (K): The initial concentration of P in the soil is 2 mg kg^{-1}. Changes in until 10.2 mg kg^{-1} is in agreement with George *et al*. (2008), the behavior of the amount of P with a high increase at 180 days amount to 10.2 mg kg^{-1} (Table 2). The results observed were differentiated between the experimental (*C. ternatea*) and the natural soil due to the large range in the initial concentrations of potentially available P. This effect is of particular relevance for representing a substantial increment in the content of P in the soils; phosphorus deficiency induced metabolic changes related to exudation of carboxylic acids and protons in roots.

The significant increases of the phosphorus concentration, can be due to the mechanisms of liberation of phosphorus by *C. ternatea* and is similar to the results of Ye *et al*. (2006) that found the differences in the absorption of phosphorus could be related to two main mechanisms: (1) plant's capacity to modify the pH of the rhizosphere by means of proton liberation which causes soil acidification, the principal factor driving P liberation was acidity. The concentration of (H^+) ions increased rapidly in the systems where microorganisms were present. (2) 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 (Baluska *et al*., 2010).

The activity of the acid phosphatase has been demonstrated in the rhizosphere of plants cultivated in soils with low levels of phosphorus (Sas *et al*., 2003). The results obtained in this research agree with those with *Cajanus*, *Chamaecrista* (Kamh *et al*., 2002) *L. consentinni* and *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 by other crops (Derry *et al*., 2005; Playsted *et al*., 2006).

This study showed that potassium has an initial value of 0.06 cmol kg^{-1} low of the limits of critical value for numerous crops (0.15-0.30 cmol kg^{-1}) (Table 2). These values suggested the capacity of the fixation of quality K of the ground is limiting worked grounds; as well as the values suggest that the soil quality K fixing capacity is limiting the cultivated soils (Masto *et al*., 2006; Schneider, 2005). In this research, *C. ternatea* increased the amount of potassium (Kehlenbeck and Maass, 2003), in more than 100% of the initial content in the soil. This represents a high increase to the soil reservoir of nutrients.

CONCLUSIONS

Clitoria ternatea plants are able to increase the levels of OM, N, P and K in soils during its period of growth with higher increase at 180 days after planting. The results of this study reflected a tendency of the species evaluated to improve the mineral nutrients in the soil during the period of growth of *C. ternatea*. However, only in the case of K the amount of this nutrient was higher than 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 *C. ternatea*. Successful establishment and growth of plantations improve the fertility of soil. But depend largely on correct species selection and soil-working methods. Thus correctly perceive the role of *C. ternatea* in enhancing of soil fertility because of its ability to transform atmospheric N_2, which can be used by species different of plants.

ACKNOWLEDGMENTS

Special thanks To the National Science and Technology Council (CONACyT) for financing project FORDECyT No. 137942 and thanks to PROMEP for financing project PROMEP/103.5/09/416, without financing the development of this research would not be possible. DES: DACNAT: Autonomous University of Carmen by the granted facilities to carry out this work.

REFERENCES

Aguiar, A.D.C.F., S.J. Bicudo, J.R.S.C. Sobrinho, A.L.S. Martins, K.P. Coelho and E.G. De Moura, 2010. Nutrient recycling and physical indicators of an alley cropping system in a sandy loam soil in the pre-Amazon region of Brazil. Nutr. Cycling Agroecosyst., 86: 189-198.

Alderete-Chavez, A., E. Vicente, L. Nancy De, T.E. Ojeda and V.H. Brito, 2009. Evaluation of two *Lupinus* species native from central Mexico in relation with solubilization of nitrogen, phosphorus and potassium in an andosol. J. Applied Sci., 9: 1583-1587.

Alderete-Chavez, A., L. Aguilar-Marin, N. De la Cruz-Landero, J.J. Guerra-Santos, R. Brito, E. Guevara and R. Gelabert, 2010. Effects of scarification chemical treatments on the germination of *Crotalaria retusa* L. seeds. J. Biol. Sci., 10: 541-544.

Baluska, F., S. Mancuso, D. Volkmann and P.W. Barlow, 2010. Root apex transition zone: A signalling-response nexus in the root. Trends Plant Sci., 15: 402-408.

Batie, S.S. and D.E. Ervin, 2001. Transgenic crops and the environment: Missing markets and public roles. Environ. Dev. Econ., 6: 435-457.

Brito-Vega, H., E.V. David, F. Carlos, M. Daniel, L. Nancy De la Cruz and A.C. Angel, 2009. Soil organic matter particle and presence of earthworm under different tillage systems. J. Biol. Sci., 9: 180-183.

De Albuquerque, J.P., F.F. da Mota, I. von der Weid and L. Seldin, 2006. Diversity of *Paenibacillus durus* strains isolated from soil and different plant rhizospheres evaluated by ARDRA and gyrB-RFLP analysis. Eur. J. Soil Biol., 42: 200-207.

De La Cruz-Landero, N., V.E. Hernandez, E. Guevara, M.A. Lopez-Lopez, A.T. Santos, E. Ojeda-Trejo and A. Alderete-Chavez, 2010. *Lupinus versicolor* response in soils contaminated with heavy metals from a petroleum extraction field. J. Applied Sci., 10: 694-698.

De Moura, E.G., S.S. Serpa, J.G.D. Dos Santos, J.R.S.C. Sobrinho and A.D.C.F. Aguiar, 2010. Nutrient use efficiency in alley cropping systems in the Amazonian periphery. Plant Soil, 335: 363-371.

Derry, D.D., R.P. Voroney and J.U.A. Briceno, 2005. Long-term effects of short-fallow *Frijol tapado* on soil phosphorus pools in Costa Rica. Agric. Ecosyst. Environ., 110: 91-103.

Fontaine, S., A. Mariotti and L. Abbadie, 2003. The priming effect of organic matter: A question of microbial competition. Soil Biol. Biochem., 35: 837-843.

Gahoonia, S.T. and N.E. Nielsen, 2004. Root traits as tools for creating phosphorus efficient crop varieties. Plant Soil, 260: 47-50.

George, T.S., P.J. Gregory, P. Hocking and A.E. Richardson, 2008. Variation in root-associated phosphatase activities in wheat contributes to the utilization of organic P substrates *in vitro*, but does not explain differences in the P-nutrition of plants when grown in soils. Environ. Exp. Bot., 64: 239-249.

Gomez, S.M. and A. Kalamani, 2003. Butterfly pea (*Clitoria ternatea*): A nutritive multipurpose forage legume for the tropics: An over view. Pak. J. Nutr., 2: 374-379.

Ibeawuchi, I.I., 2007. Landrace legumes: Synopsis of the culture, importance, potentials and roles in agricultural production systems. J. Boil. Sci., 7: 464-474.

Jensen, E.S. and H. Hauggaard-Nielsen, 2003. How can increased use of biological N2 fixation in agriculture benefit the environment. Plant Soil, 252: 177-186.

Kamh, M., M. Abdou, V. Chude, F. Wiesler and W.J. Horst, 2002. Mobilization of phosphorus contributes to positive rotational effects of leguminous cover crops on maize grown on soils from Northern Nigeria. J. Plant Nutr. Soil Sci., 165: 566-572.

Kehlenbeck, K. and B.L. Maass, 2003. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. Agrofor. Syst., 63: 53-62.

Liu, Y., G. Villalba, R.U. Ayres and H. Schroder, 2008. Global Phosphorus flows and environmental impacts from a consumption perspective. J. Ind. Ecol., 12: 229-247.

Masto, R.E., P.K. Chhonkar, D. Singh and A.K. Patra, 2006. Soil quality response to long-term nutrient and crop management on a semi-arid Inceptisol. Agric. Ecosyst. Environ., 118: 130-142.

Molumeli, P.A., V.E. Hernandez, M. Ehsan, S.B. Valdez and E.O. Trejo *et al*., 2008. Lupines-invaded pine forest and cultivated scrublands in volcanic ash soils in mexico dry-sieved aggregation and macroaggregate instability indices. Int. J. Bot., 8: 390-405.

Morris, J.B., 2009. Characterization of butterfly pea (*Clitoria ternatea* L.) accessions for morphology, phenology, reproduction and potential nutraceutical, pharmaceutical trait utilization. Genet. Resour. Crop Evol., 56: 421-427.

Moura, E.G., N.G. Moura, E.S. Marques, K.M. Pinheiro, J.R.S. Costa Sobrino and A.C.F. Aguiar, 2009. Evaluating chemical and physical quality indicators for a structurally fragile tropical soil. Soil Use Manage., 25: 368-375.

Oenema, O., L.V. Lowie and O. Schoumans, 2004. Effects of lowering nitrogen and phosphorus surpluses in agriculture on the quality of groundwater and surface water in the Netherlands. J. Hydrol., 304: 289-301.

Playsted, C.W., M.E. Johnston, C.M. Ramage, D.G. Edwards, G.R. Cawthray and H. Lambers, 2006. Functional significance of dauciform roots: Exudation of carboxylates and acid phosphatase under phosphorus deficiency in *Caustis blakeim* (Cyperaceae). New Phytol., 170: 491-500.

Ramos-Miranda, J., K. Bejarano-Hau, D. Flores-Hernandez and L.A. Ayala-Perez, 2009. Growth, mortality, maturity and recruitment of the star drum (*Stellifer lanceolatus*) in the Southern Gulf of Mexico. Ciencias Marinas, 35: 245-257.

Richardson, A.E., 2009. Regulating the phosphorus nutrition of plants: Molecular, biology meeting agronomic needs. Plant Soil., 322: 17-24.

Rolland, M.N., B. Gabrielle, P. Laville, D. Serca and J. Cortinovis *et al*., 2008. Modeling of nitric oxide emissions from temperate agricultural soils. Nutr. Cycl. Agroecosyst., 80: 75-93.

SAS, 2003. SAS/STAT Users Guide. 8th Edn., Statistical Analysis Institute Inc., Cary North, Carolina.

Sanginga, N., 2003. Role of biological nitrogen fixation in legume-based cropping systems; a case study of West Africa farming systems. Plant Soil, 252: 25-39.

Sas, L., H. Marschner, V. Romheld and S. Mercik, 2003. Effect of nitrogen forms on growth and chemical changes in the rhizosphere of strawberry plants. Acta Physiol. Planta., 25: 241-247.

Schneider, A., 2005. Release and fixation of potassium by a loamy soil as affected by initial water content and potassium status of soil samples. Eur. J. Soil Sci., 48: 263-271.

Shane, M.W. and H. Lamberts, 2005. Clusters roots: A curiosity in context. Plant Soil, 274: 101-125.

Tilman, D., K .G. Cassman, P.A. Matson, R. Naylor and S. Polasky, 2002. Agricultural sustainability and intensive production practices. Nature, 418: 671-677.

Willby, N.J., I.D. Pulford and T.H. Flowers, 2001. Tissue nutrient signatures predict herbaceous-wetland community responses to nutrient availability. New Phytol., 152: 463-481.

Wivstad, M., A.S. Dahlin and C. Grant, 2005. Perspectives on nutrient management in arable farming systems. Soil Use Manage., 21: 113-121.

Ye, H.P., F.Z. Chen, Y.Q. Sheng, G.Y. Sheng and J.M. Fu, 2006. Suppression of phosphate liberation from eutrophic Lakev sediment by using fly ash and ordinary Portland Cement. J. Environ. Sci. Health A Tox. Hazard. Subst. Environ. Eng., 41: 1655-1666.

Zhou, Z., M. Yamagishi, M. Osaki and K. Masuda, 2008. Sugar signalling mediates cluster root formation and phosphorus starvation-induced gene expression in white lupin. J. Exp. Bot., 59: 2749-2756.