https://doi.org/10.48047/AFJBS.6.Si4.2024.4781-4793

African Journal of Biological Sciences
Journal homepage: http://www.afjbs.com

Research Paper Open Access

Evaluation of Organic Matter with Different Phosphorus Sources in Two Rice Varieties (Oryza sativa L) Fortaleza 5-30 and Chino Grande for an Entisol in the Pacific Andes

Dagoberto Torres Valencia
dtorres@unipacifico.edu.co
Universidad del Pacífico
https://orcid.org/0000-0001-8111-0647?lang=en

Article History
Volume 6, Issue Si4, 2024
Received: 1 July 2024
Accepted: 20 July 2024
Doi:
10.48047/AFJBS.6.Si4.2024.4781-4793

Abstract
The behavior of soil organic matter was evaluated in the rural area of the municipality of Buenaventura, specifically in the Zacarías district, which belongs to township #8 of the Dagua river, in the department of Valle del Cauca. This evaluation was conducted using different sources of phosphorus in the cultivation of rice (Oryza sativa L.). Two rice varieties were utilized in this study: a large Chinese variety from Guapi and a Fortaleza 5-30 variety from Jamundí. These were planted at a density of 110 kg/ha. A split plot design with three replications and eight treatments was employed, wherein the main plot represented the phosphate fertilization levels and the subplots represented the rice varieties. The phosphorus sources utilized in the course of this research were as follows: Diammonium phosphate (DAP 46%), Huila Phosphorite (22%), and Thomas Slag (10%) were applied to the soil at a rate of 50 kg/ha. The nitrogen source utilized was urea (46%) applied at a rate of 44 kg/ha, while potassium was applied as KCl (60%) at a rate of 100 kg. The findings of the study indicated that the rice variety that exhibited the greatest efficacy in utilizing phosphorus sources was the 5-30 strength variety. This variety demonstrated superior efficiency in utilizing this element in comparison to the large Chinese variety. No notable differences were observed between the soil treatments and the application of phosphorus fertilizers with respect to the variation of organic matter. The correlation between grain production (yield) and soil organic matter was 0.6.
Keywords: Organic Matter, Phosphorus, Rice, Phosphate Sources, Soil, Crop.

1. Introduction

The soils of the Colombian Pacific region exhibit characteristics derived from their climate and landscapes, indicating the prevalence of acid and poorly evolved, highly weathered soils with low fertility (Anderson et al., 1993). In light of these observations, it becomes evident that the significance of organic matter in relation to soil fertility is amplified in humid tropical climate regions when compared to temperate zones. This underscores the crucial role that organic matter plays in shaping the multifaceted properties of soil, exerting a direct or indirect influence on the physical, chemical, and biological attributes of the soil (Denef et al., 2004).

These climatic conditions have resulted in the intense alteration of the primary minerals of the parent material and the mineralization of organic matter, as well as the intense leaching of soluble materials in water. These processes result in the formation of an inorganic colloidal complex of low activity, dominated by kaolinitic clays; a limited accumulation of colloidal organic matter of low quality; and an impoverishment of the soil in bases, which leads to a decrease in pH and a subsequent reduction in soil fertility (IGAC, 2004).

It is crucial to conduct research that elucidates the behavior of organic matter in response to phosphorus fertilization in rice cultivation. This research should aim to enhance crop yields in a technically and economically viable manner. This research should be conducted concurrently with an evaluation to propose an agro-productive approach in a region with distinctive climatic characteristics.

Despite the numerous studies conducted to assess the efficacy of phosphorus sources globally, there has been a dearth of research in the Colombian Pacific region that specifically delineates the significance and utilization of these sources. This presents a significant opportunity to enhance the activity of organic matter and, consequently, its utilization by plants.

Accordingly, the objective has been to evaluate the behavior of organic matter in the presence of various phosphate fertilizers in an Inceptisol of the Colombian Pacific.

2. Objectives

2.1 General objective

The objective of this study is to evaluate the performance of organic matter in two rice varieties (Oryza sativa L.)—Fortaleza 5-30 and Chino Grande—using three phosphate sources in an Inceptisol of the Colombian Pacific.

2.2 Specific objectives

- To determine the effect of different sources of phosphorus on the soil organic matter contents of two rice varieties.
- To check whether there is any relationship between the organic matter contents determined by various applications of phosphorus sources and the grain yields of two rice varieties.

3. Materials and methods

3.1 Location

The following study was conducted in the rural area of the Municipality of Buenaventura, specifically in the Zacarías district, which is part of the Dagua River district 8, in the Department of Valle del Cauca. This area is situated 10 km from the urban perimeter and has an altitude of 23 meters above sea level. Its longitude is 3°, The coordinates are 48° N and 76° W, with an average annual rainfall between 5,000 and 7,000 mm, an average temperature between 26° and 28° C, three hours of insolation per day, and a relative humidity of 86% (Eslava, 1994).

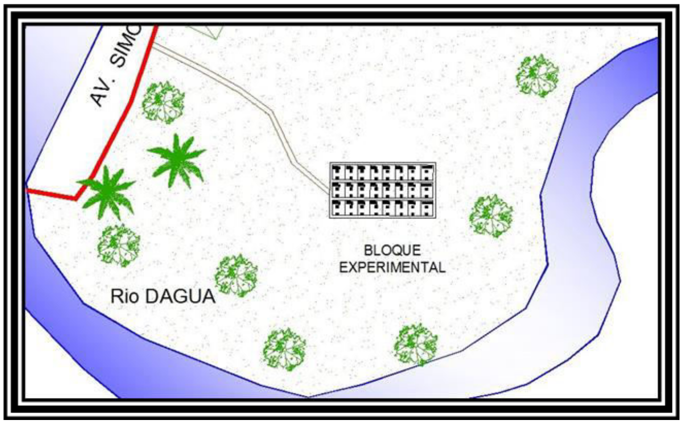

Figure 1. Geographical location of the experimental site.

According to IGAC (1977), the plant formations of the Pacific region are those corresponding to tropical rainforests and very humid tropical forests and tropical rainforests in areas with less precipitation.

3.2 Materials used

Planting material

The experimental material comprised two varieties of rice: one from Guapi-Cauca (local variety V1), a large Chinese variety, and the second from Jamundí-Valle (commercial variety V2), with strength 5-30.

The large Chinese variety was selected for its suitability for the Colombian Pacific region, where it is cultivated. It is a late cycle variety, exhibiting high size and thickness, a long panicle, and excellent storage qualities. These attributes are particularly beneficial for a product destined for family consumption and storage over extended periods (Pronatta, 2003).

The Fortaleza variety 5-30 is a rustic variety with good initial vigor and a plant height of 101 cm. It exhibits stable behavior in different environments and a vegetative period similar to that of Oryzica 1, which lasts 126 days from germination to harvest. For optimal plant development and yield, the plant must receive sufficient water and nutrients for optimal growth. The application of fertilizer should be based on the results of a soil analysis, with subsequent adjustments made according to the findings of a foliar analysis conducted between 12 and 15 days and 35 and 40 days after germination (www.semillano.com).

Prior to sowing, a germination test was conducted on the two varieties, with 100 seeds of each variety planted using damp paper towels. The results of the germination test demonstrated a 99% germination rate for both rice varieties.

Phosphorus sources

The phosphorus sources used in the experiment were Diammonium Phosphate (DAP) (46% phosphorus and 18% nitrogen), Thomas Slag (Paz del Rio Fertilizer) (APR) (10%) and Roca Fosfórica del Huila (RFH) (22%), applied by jet in each furrow of the experiment at a rate of 50 kg/ha, at the time of sowing.

The nitrogen source used was Urea (46%), at a rate of 44 kg/ha fragmented in 3 applications (15-45-60) days after emergence (DDE).

For potassium fertilization, 60% (KCL) was used as a source at a rate of 100 kg/ha applied in each furrow, making two equal applications, the first at 30 days after emergence (DDE) and the second at 60 days after emergence (DDE).

Table 1 shows the treatments of the experiment and their respective mixtures.

Treatment	Amount of fertilizer to be applied	Phosphorus Sources			Percentage ratios by source of (P) Phosphorus to be applied			
Tr	**Kg/ha**	**DAP**	**RFH**	**APR**	**70% RFH 30% DAP**	**30%RFH 70%DAP**	**70% RFH 30%APR**	**30%RFH 70%APR**
1	50	**100% 747gr**	0	0	0	0	0	0
2	50	0	**100% 1562gr**	0	0	0	0	0
3	50	0	0	**100% 3435gr**	0	0	0	0
4	50	0	0	0	**1094gr RFH 224gr DAP**	0	0	0
5	50	0	0	0	0	**469gr RFH 523gr DAP**	0	0
6	50	0	0	0	0	0	**1094gr RFH 1031gr APR**	0
7	50	0	0	0	0	0	0	**469gr RFH 1031gr APR**
8	0	0	0	0	0	0	0	0

Table 1. Treatment List for the Two (2) Rice Varieties

3.3 Experimental design

An experimental design was employed in plots that were divided into three replications. Each replication consisted of eight treatments and one control, resulting in a total of 24 experimental units. The total area of the experiment was 931 m², with each plot measuring 30 m² (6 m wide x 5 m long), as illustrated in Figure 2.

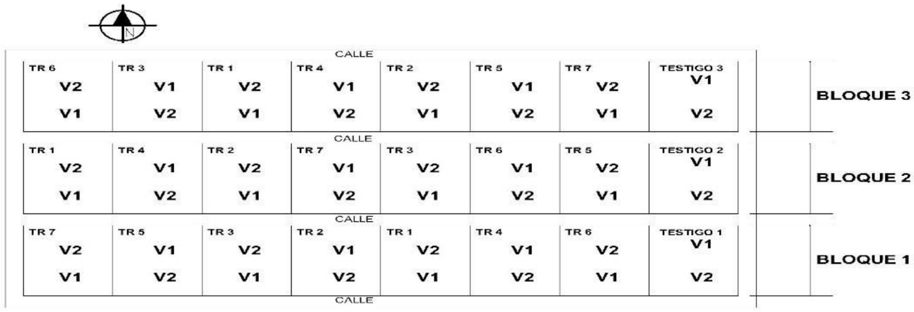

Figure 2. Graphic design of the experimental plots

Where:
ART: Treatments
VI is: Large Chinese Rice Variety
V2 is: Fortaleza Rice Variety 5-30
The sowing system was manual in a drip, with 22 furrows/plot defined, 11 rows per variety, separated by 20 centimeters, and a density of 110 kg/ha of seed. The planting distance between the varieties of large Chinese rice and Fortaleza 3-50 was 50 centimeters.

3.4 Selection and suitability of the terrain

A crop was cultivated under rainfed conditions on a soil of Inceptisol origin, a clay loam soil type that does not flood during periods of precipitation.

The land was prepared by manual means, with a machete used to clear the weeds and bushes, a rake employed to collect and dispose of the plant material, and a shovel and rake used to level the land. A total of 30 soil samples were then taken from across the experimental area for chemical and physical analysis. This was done prior to planting and fertilization.

Subsequently, the plot was delineated and marked with a tape measure, compass, and ropes. Finally, all the plots were harrowed with a rake.

4. Results and discussion

4.1 Analysis of the results of soil samples at the beginning and end of the experiment.

COMPONENTS	UNITS	RESULTS
pH (1:1 ratio)		5.4 Acid
Organic matter	%	5.17 High
Interchangeable Calcium	Cmol/Kg	24.3 High
Interchangeable Magnesium	Cmol/Kg	6.7 High
Interchangeable Potassium	Cmol/Kg	0.16 Low
Exchangeable Sodium	Cmol/Kg	0.15 Good
CIC	Cmol/Kg	27, 08 Up

Interchangeable Match	mg/Kg	1 very low
Copper	mg/Kg	19.8 High
Zinc	mg/Kg	2.8 Medium
Manganese	mg/Kg	79.3 High
Iron	mg/Kg	150.2 High
Boron	mg/Kg	0.47 medium

Table 2. Chemical results of soil samples taken at the experimental site, before planting.
Source: Analytical Services Laboratory of the International Center for Tropical Agriculture CIAT.

COMPONENTS	UNITS	RESULTS
pH (1:1 ratio)		5.5 Acid
Organic matter	%	8.1 High
Interchangeable Calcium	Cmol/Kg	11.1 Height
Interchangeable Magnesium	Cmol/Kg	4.7 High
Interchangeable Potassium	Cmol/Kg	0.1 Low
Exchangeable Sodium	Cmol/Kg	0.03 Good
CIC	Cmol/Kg	23.6 High
Interchangeable Match	mg/Kg	2.2 Low
Copper	mg/Kg	6.6 High
Zinc	mg/Kg	3.4 High
Manganese	mg/Kg	187.6 High
Iron	mg/Kg	72.8 High
Boron	mg/Kg	0.48 High

Table 3. Chemical results of soil samples taken at the experimental site. After planting.
Source: Analytical Services Laboratory of the International Center for Tropical Agriculture CIAT.

Tables 2 and 3 illustrate the outcomes of the chemical analysis, documented at the outset of the experimental trial and subsequently at its conclusion in the municipality of Zacarias.
The chemical analysis revealed that the acid range of the soil exhibited no notable alterations in its chemical percentage, both at the outset and at the conclusion of the trial. The values remained consistent at 5.4 and 5.5, respectively, at the end of the trial. The pH of the soil can be altered as a consequence of the addition of fertilizers, by the decomposition of organic matter, or due to washing by rainwater. However, in this case, these factors did not affect the acidity of the soil to any degree, and the percentage of pH did not appear to vary.
The percentage of organic matter at the outset of the experiment was 5.17%, while at the conclusion of the trial, it had increased to 8.1%. This represented a notable rise over the

course of the trial. The cation exchange capacity (CEC) demonstrated a notable increase from the initial value of 27.08 (Cmol/kg) to 23.6 (Cmol/kg) at the conclusion of the study. This suggests that elevated CEC levels may contribute to reduced leaching losses, enhancing the efficacy of fertilization and consequently promoting the accumulation of organic matter. It is noteworthy that potassium levels exhibited a consistent decline throughout the experimental period.

With regard to exchange bases, calcium and magnesium exhibited elevated levels at the outset, though this value subsequently increased. Potassium, however, demonstrated low levels both prior to and following the experiment.

The initial phosphorus content was observed to be low at 1 mg/kg, indicating an initial phosphorus deficiency in the soil. However, this element exhibited an increase at the conclusion of the trial, following the addition of fertilizers, reaching a high level of 2.2 mg/kg.

The minor elements, including iron and manganese, exhibited a notable increase from the initial analysis throughout the experimental period. Similarly, boron demonstrated a consistent elevation in its initial value, which was sustained until the conclusion of the study.

Effect of the treatments on the variables evaluated (organic matter and production)

As illustrated in Figure 3, a notable discrepancy is evident between the varieties employed in the study and their utilization of organic matter levels during the experimental trial. The data indicate that the 5-30 strength variety demonstrates superior efficiency in the utilization of organic matter present in the soil. This observation may be attributed to the fact that it is a high-yielding variety, suggesting that the commercial variety, when subjected to adequate fertilization, exhibits its optimal performance. The results demonstrated that the large Chinese variety exhibited a delayed cycle, although it was of a superior size to the Fortaleza variety. However, this did not result in the best outcomes in terms of more efficient organic matter utilization.

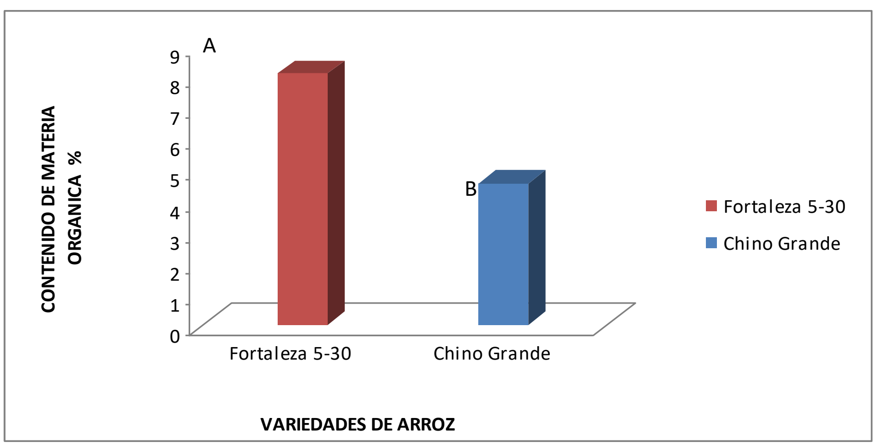

Figure 3. Comparison of organic matter contents in 2 varieties of rice, strength 5 -30 and large Chinese.

Figure 4 shows that there were no significant differences. By adding phosphate fertilizers to the crop, they did not promote a sudden change in soil organic matter.

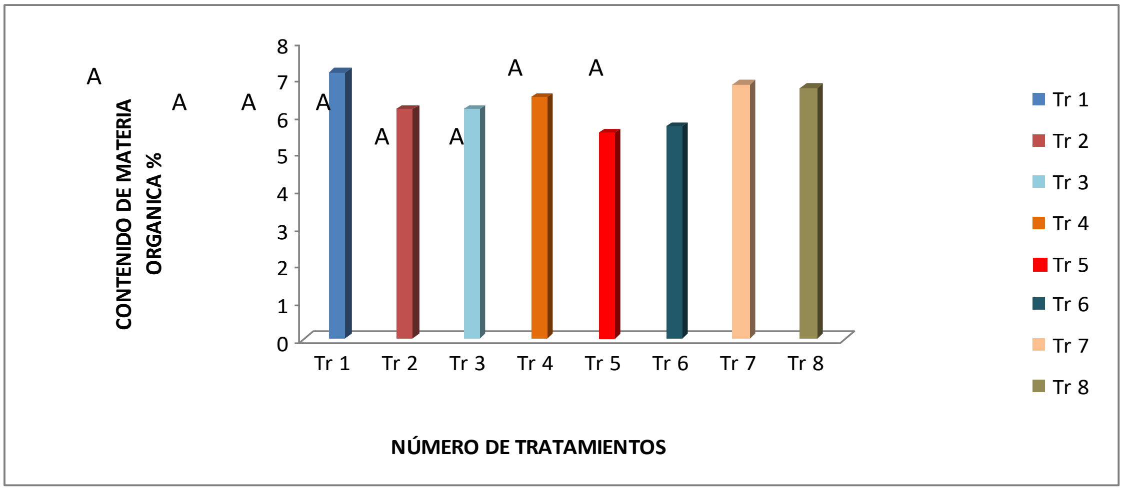

Figure 4. Effect on the organic matter contents on the treatments.

Where:

Tr1 : DAP Tr3: APR Tr5: RFH Tr7: RFH + APR
Tr2: RFH Tr4: RFH + DAP Tr6: RFH + APR Tr8: Testigo

In some very weathered soils and in younger soils with light textures (inceptisol), there are typically medium or low contents of organic matter. Additionally, the cation exchange capacity can be a highly dependent factor, particularly in relation to the organic fraction. This is due to the influence of clay type and quantity on the CEC of the mineral fraction, which can be relatively limited.

Therefore, this would indicate that no significant changes in organic matter occurred for this study.

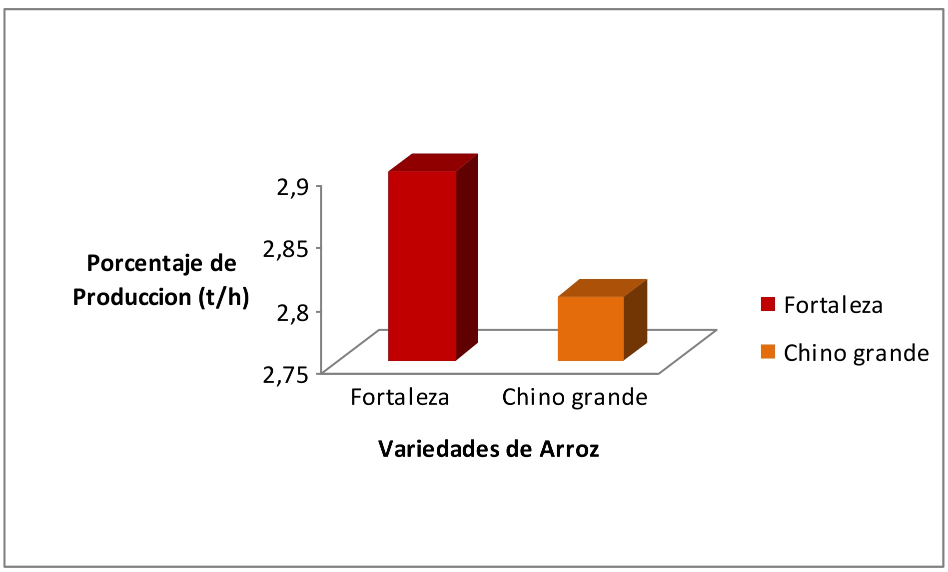

Figure 5. Production level according to variety.

As illustrated in Figure 5, the variety that demonstrated the highest level of production was force 5-30, with a yield of 2.99%. This outcome is consistent with the observation that force 5-30 is a commercial variety, an improved and certified variety.

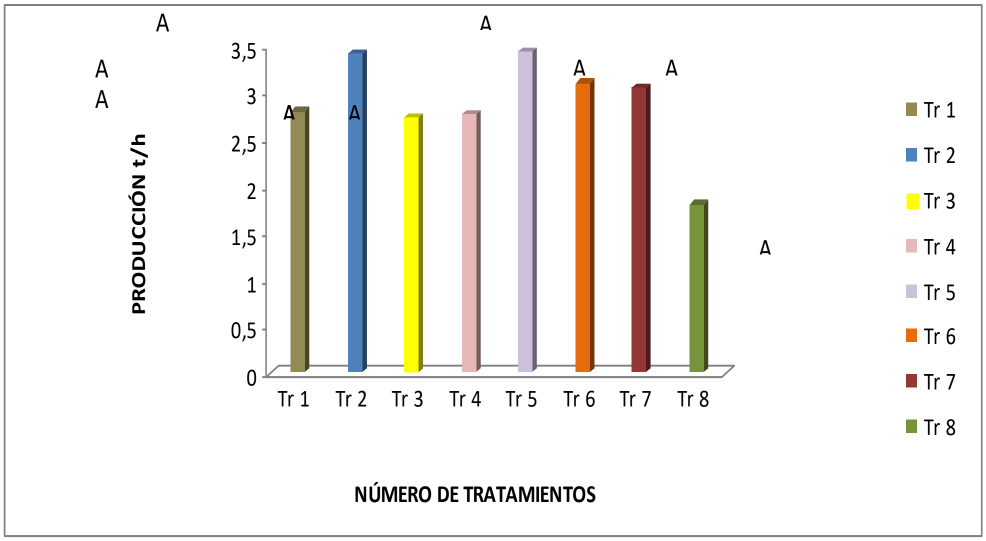

Figure 6. Effect of treatments on production.

Where:

Tr1 : DAP Tr3: APR Tr5: RFH Tr7: RFH + APR
Tr2: RFH Tr4: RFH + DAP Tr6: RFH + APR Tr8: Testigo

	PROD	*Mo*	*P*
PROD	1		
Mo	-0,11152001	1	
P	0,2679787	0,58328848	1

Table 4. Yield in the crop.

Source: Own elaboration.

In Figure 6, there are no relatively significant differences, the yield in the crop was low.

As evidenced, treatment 8 (control) demonstrated a superior outcome in comparison to treatments 2, 3, 5, and 6. This suggests that the climatic conditions of the area, characterized by rainfall and high relative humidity, have led to an increase in soil microbial activity, which in turn has resulted in elevated levels of phosphorus and a subsequent increase in soil organic matter. In accordance with Smith (2010), in specific subtropical and tropical regions where the mean temperature is consistently high throughout the year, soil organisms are perpetually active. Consequently, the soil organic layer is thin and nutrient recycling is relatively fast and continuous. Enckevort (1995) asserts that organic matter (OM) is a crucial component of soil, influencing its physical, chemical, and biological characteristics (humification). Therefore, it is essential to consider that the amount of biomass available in the soil at the time of planting would enhance the availability of P for the plant.

As posited by Montenegro (1991), soil structure exerts a profound influence on plant growth, with the potential to act as a limiting factor in production in certain instances. An unfavorable structure can cause a number of problems in plant development, including excess or deficiency of water, lack of air, incidence of diseases, low microbial activity, impediment to root development, and so forth. Conversely, a favorable structure will allow the growth factors to act effectively, thereby promoting optimal plant growth. This allows for the most effective and optimal crop yields to be obtained.

As evidenced by the studies conducted by Black (1968) and Mikelser and Pactrick (1968), when examining the effects of soil moisture conditions on flooded rice, it was determined that a) the solubilization of soil phosphorus during plant development would be impeded, and thus, low soil phosphorus availability rates would not be related to crop performance; b) the significant interaction of phosphates provided by the phosphorus source with soil solid phases results in the instantaneous utilization of the applied P being relatively low; c) the efficiency of a phosphorus source varies depending on the soil type, the applied phosphorus source, and the application technique; and d) the correlation between soil organic matter content was also analyzed, resulting in a correlation coefficient of -0.6 (Figure 6). This implies that as soil organic matter content increases, relative yields decrease.

Upon closer examination of the control plants, which had not been fertilized with phosphorus, the typical symptoms of phosphorus deficiency were observed. These included rickets, erect green leaves, and, in some cases, necrosis of the leaf apices, as documented in 1981.

5. Conclusions

- The short-term study, which corresponds to approximately one crop cycle, revealed that the fertilizer fractions did not contribute to the increase in organic matter available for the crop, both in the control and in the fertilized treatments. Conversely, an increase in soil content was observed at the conclusion of the trial. However, statistical analysis indicated that the observed increase was not statistically significant and did not contribute to the growth of the plants.
- The rice crop yielded poorly due to a lack of significant organic matter accumulation in the soil, despite the application of phosphorus sources such as Roca Fosforita Huila, Paz del Río Fertilizer, and Diammonium Phosphate, which failed to elicit substantial alterations.

6. Recommendations

- It is recommended that phosphorite from Huila be used as the phosphorus source for rice planting in Colombian Pacific soils, as this is expected to yield superior results.
- The utilization of alternative mixtures to ascertain their impact on crop yield was deemed necessary, as the initial mixtures did not elicit the desired increase in rice production.

References

- ANGLADETTE, H.1969. El arroz Colección Agricultura Tropical. Editorial Blume, Primera Edición. Barcelona. 867p.

- ANÓNIMO, 1988. Manual de fertilidad de suelos. Potash & Phosphate Institute. Georgia. USA, 85 p.
- ARENS, P. L., 1983. En: El reciclaje de materias orgánicas en la agricultura de América Latina. FAO. Roma. Italia.
- BRENES, L. 2003. Producción orgánica: algunas limitaciones que enfrentan los pequeños productores. Manejo Integrado de Plagas y Agroecología 70: 7-18.
- BOSCHETTI, N.G.; Quintero C.E.; Benavidez, R.A. Giuffre, L. 2001. Destino del fósforo proveniente de diferentes fuentes de fertilizante fosfatado en suelos de la provincia de Entre Ríos. Revista Científica Agropecuaria, FCA, UNER. Vol. 5: 23 - 30.
- Beck, M. A. ; Sanchez, P. A. 1994. Soil phosphorus fraction dynamics during 18 years of cultivation on a Typic Paleudult. Soil Sci. Soc. Am. J 58: 1424-1431.
- BURBANO H. 1989. El Suelo: Una visión sobre sus componentes biorganicos. Pasto, Colombia Universidad de Nariño.447p.
- BOHN L. HINRICH; McNEAL L. BRIAN; O´CONNOR A.George. 1993. Qumica del Suelo. Editorial Limusa.mexico D.F.157p.
- CIAT. 1988. Centro Internacional de Agricultura Tropical. Arroz: Investigación y Producción/CIAT. Santiago de Cali.
- CHAPMAN, HOMER D. 2000. Fertilización de Cultivos en Clima Cálido. 18p.
- CHEAEY, R.L.1974.Historia del arroz Como Cultivo Importante. CIAT. Programa de Arroz.

- DUNCAN, R., and BALIGAR, V.C. 1990. Genetics, breeding and physiological mechanisms of nutrient uptake and use efficiency: an overview. In: Crops as enhancers of nutrient use. V.C .Baligar and Duncan R.R. (Ed), p. 3-35. Academic Press, San Diego, C.A. USA+
- ESLAVA R.,Jesus A. 1994. Climatologia del Pacifico Colombiano. Academia Colombiana de Ciencias Geofisicas. Bogotá.
- ENCKEVORT, P. 1995. Manual para la realización de diagnósticos agroecológicos. Proyecto de Conservación de Suelos y Aguas (MAG/FAO-GCP/COS/012/NET). San José, Costa Rica.
- FOUNDATION FOR AGRONOMIC RESEARCH, 1988. Manual de fertilidad de los suelos. Santa Fe de Bogotá .85p.
- GROS, A. Y DOMÍNGUEZ, A., 1992. Abonos guía práctica de la fertilización. 8va. edición. Ediciones Mundi-Prensa. Madrid. 450 p.
-
- GONZALES H.1981.Origen Y Morfología De La Planta De Arroz. Curso de Adiestramiento en Producción de Arroz. INIPA, Chiclayo, Peru.1-29p
- HEDLEY, M.J ; STWART, J.W.B, CHAUHAN,B.S.1982. Changes in Inorganics and Organic Soil Phosphorws Fractions Induced by Cultivation Practice and Laboratory Incubations soils.
- JUSTUS VON LIEBIG. 1843. En: Navarro Pedreño, J., Moral Herrero, Gómez Lucas y Mataix Beneyto., 1995. Residuos orgánicos y agricultura. Universidad de Alicante. Servicio de Publicaciones. 108 p.

- MELENDEZ, G. 2003. Indicadores químicos de calidad de abonos orgánicos. En: Abonos orgánicos: Principios, características e impacto en la agricultura. Ed Meléndez, G. San José, Costa Rica. pp. 50-63.
- MONTENEGRO G., H. 1991. Interpretación de las propiedades Físicas del Suelo (Textura, Estructura, Densidad, Aireación, etc.) En: Seminario-Taller "Fundamentos para la interpretación de Análisis de Suelos, Plantas y Aguas para riego". Sociedad Colombiana de la Ciencia del Suelo, Bogotá D.E. Colombia.
- MUSTIN, M., 1987. Le compost. Ed. François Dubusc. París, 954 p.
- NAVARRO. B. S; GINES N. G. 2003. Quimica agrícola: suelos y los elementos químicos esenciales para la vida vegetal. Ediciones Munidi-prens. Madrid – España.53p.
- NAVARRO PEDREÑO, J., MORAL HERRERO, GÓMEZ LUCAS Y MATAIX BENEYTO., 1995. Residuos orgánicos y agricultura. Universidad de Alicante. Servicio de Publicaciones. Alicante. España, 108 pp.
- PORTER, C.D.1959.Taxonomy Of Flowering Plants. San Francisco.
- PRONATA 2003. Reactivación del cultivo del Arroz en los Municipios De Guapi y Timbiquí en la Costa Pacifica Cucana. Variedades, manejo, pos cosecha, validación y difusión participativa. Proyecto colaborativo CIRAD y CIAT informe final UMATHA, Guapi – Cauca.
- RAMOS Nestor, DELGADO Sigifredo. 2007. Producción de Arroz y Su Relación Con la Planta y EL Medio Ambiente. Semillano. Villavicencio, Meta. 1-2-3p.
- ROBAYO, R.1971. La Siembra Como Factor de Producción. ICA. Universidad del Tolima. 187p.
- Alan Smith, (Anaerobic Microsites in the Rhizosphere of Plants as Mechanisms for Increasing Phosphate Availability, Reviews in Rural Science #3
- TETZU CHANG Y ELISEO A. BARDENAS. 1965. Morphology and Varietal Characteristics of the Rice Plant. Lagunas, Filipinas.
- UNIVERSIDAD DEL FILIPINAS, 1975. Cultivo del Arroz: Escuela de Agricultura. Editorial Limusa. México.
- ZEIGLER, R,S; WEBER, G; and PULVER, E; 1986: Identification of Constraints to Rice Production and the Development of an Integrated Crop Management Program. Caribbean Rice Improvement Network. Proceedings of the First Meeting of the Technical Advisory Committee. Centro de Investigaciones Arroceras (CEDIA). Juma, Bonao. República Dominicana. 152 p.

Electronic References

- www. avepagro.org.2010 .Instituto Nacional de Investigaciones de la Caña de Azúcar (INICA), La Habana, Cuba. Rafael Villegas[1]; Regla Chang[1]
- www.fao.org.com.2010
- www.ipni.net.com2010
- Infoagro, 2000.
- http://www.smart-fertilizer.com/articulos/fosforo.
- http://www.semillano.com/index.php?option=com_content&view=article&id=83&Itemid=92

Accoe, F., P. Boeckx, J. Busschaert, G. Hofman y O. Van. 2004. Gross N transformation rates and net N mineralisation rates related to the C and N contens of soil organic matter fractions in grassland soils of different age. Soil Biol. Biochem. 36: 2075-2087.

Denef, K., J. Six, R. Merckx y K. Paustian. 2004. Carbon sequestration in microaggregates of no tillage soils with different clay mineralogy. Soil Sci. Soc. Am. J. 68: 1935-1944.

INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI. (IGAC). 2004. Programa 2004. [En línea]. IGAC.
Bogotá.