Short Note [Nota corta]

RENDIMIENTO DE BANANO DÁTIL EN SISTEMA DE CALLEJONES DE *Inga* spp., A DIFERENTES DOSIS DE FERTILIZANTES DE POTASIO Y FOSFORO †

[YIELD OF LADY FINGER BANANA ALLEY CROPPED IN A SYSTEM WITH *Inga* spp., AT VARYING LEVELS OF POTASSIUM AND PHOSPHORUS FERTILIZERS]

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SUMMARY

Background: the agronomic yield of crops of importance for rural households in the humid tropics, such as banana, cultivated in association with leguminous trees, such as Inga spp., must be studied because of the little available information on that association, especially with regards to yield response to the application of P and K under agroforestry systems, and the interaction between organic (leguminous residues) and inorganic sources of nutrients. **Objective:** the objective of this study was to evaluate the yield of lady finger banana alley cropped with *Inga* spp., under several levels of natural fertilizers such as K_2SO_4 + Mg, and phosphoric rock (RF). **Methodology:** Yield response of lady finger banana (*Musa acuminata* Colla) under an alley cropping system with guama (*Inga* spp.). Prior to the establishment of the crop, dolomitic lime ($Ca_3(PO_4)_2CaF_2$) at a rate of 2 ton ha^{-1} was applied. In addition, phosphoric rock (RF) was added to the crop at diverse levels (0, 20, 40, 80 kg ha^{-1}), and potassium sulphate and magnesium (K_2SO_4 + Mg) at three levels (0, 45, 90 kg ha^{-1}) with five replicates in a total of 35 alleys for treatments. *Inga* spp. trees provided with nitrogen (N). Two crop cycles were evaluated, cycle 1 (2015) and cycle 2 (2017). **Results:** the highest average weight per bunch were obtained with 80 FP and 0 RF in the first cycle, and with 90 K and 45 K in the second cycle, which were significantly higher than other levels. The highest yield on yearly basis was 45 K among the treatments during the first cycle, and the highest yields during the second cycle were obtained with 45 y 90 K_2SO_4 + Mg. **Implications:** There are no prior studies for lady finger banana crop associated with *Inga* spp. trees under alley cropping, this reflects that the study is an original contribution to nutrient-response studies under agroforestry system with Inga. **Conclusion:** the highest yields were obtained with 90 and 45 kg ha^{-1} of potassium sulphate and magnesium. The application of dolomitic lime promoted P and K availability for the crop, and better use of applied K_2SO_4 + Mg and of RF in the treatments.
Keywords: *Musa acuminate*; Inga spp; guama; phosphate rock; potassium and magnesium sulphate.

RESUMEN

Antecedentes: La respuesta agronómica de los cultivos de importancia para las familias rurales en el trópico húmedo, como es el banano, asociado con árboles de leguminosas, como la *Inga* spp., debe ser estudiada por la escasa información que se tiene, especialmente en relación de la respuesta a la aplicación de P y K en sistemas agroforestales, la interacción entre fuentes de nutrientes orgánicas (residuos de leguminosas) y las inorgánicas. **Objetivo:** Evaluar el rendimiento del banano dátil bajo el sistema de callejones de *Inga* spp. con diferentes dosis de fertilizantes naturales como K_2SO_4 + Mg, y roca fosfórica (RF). **Metodología:** Se evaluó la respuesta al rendimiento del cultivo de banano dátil (*Musa acuminata* Colla), en un sistema de callejones de guama (*Inga* spp.). Previa a la siembra se aplicó 2 ton ha^{-1} de cal dolomítica ($Ca_3(PO_4)_2CaF_2$). El número de callejones empleados para el cultivo del banano dátil fue de 35; se distribuyeron en el campo en un diseño de parcelas divididas: A. Parcelas grandes: Ciclo 1 (se estableció del 25 marzo de 2014 a 8 de diciembre de 2015) y Ciclo 2 (del 5 junio

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2016 a 8 febrero de 2018), B. bloques: tipo de fertilizantes naturales: (i) roca fosfórica (RF), a cuatro dosis (0, 20, 40, 80 kg ha^{-1}), y (ii) sulfato de potasio y magnesio con tres dosis (0, 45, 90 kg ha^{-1}), C. subparcela: dosis, con 7 tratamientos y 5 repeticiones. **Resultados:** Los mayores pesos promedios obtenidos por racimo se reportaron para 80 RF y 0 RF del Ciclo 1, para el Ciclo 2 los tratamientos significativamente mayor fueron de 90 K y 45 K. El mayor rendimiento por años, de los tratamientos del Ciclo 1, es la dosis de 45 K, Para el Ciclo 2, los mayores rendimientos se obtuvieron con las dosis altas 45 y 90 K_2SO_4 + Mg. **Implicaciones:** No hay referencia de estudios previos realizados en el cultivo de banano dátil en callejones de árboles de guama, por lo que es una aportación original de datos bajo dicho sistema. **Conclusión:** Los mejores tratamientos fueron los que se complementaron con dosis altas (90 y 45 kg ha^{-1}) de sulfato de Potasio y Magnesio. La aplicación de cal dolomítica favoreció la disponibilidad de P y K, y un mejor aprovechamiento K_2SO_4 + Mg y de la RF aplicada en los tratamientos.
Palabras claves: *Musa acuminata; Inga* spp; guama; roca fosfórica; Sulfato de Potasio y Magnesio.

INTRODUCTION

Soil degradation and food security are some of the problems that small farmers have to face every day in Honduras, this is due to factors such as climate change, bad agronomical practices, steep terrains, little opportunity to access urban markets -where they could get better prices for their produce-, little or null technical assistance about sustainable soil management, and land use changes (e.g. due to deforestation), among others. Because of these, it is necessary to strengthen the resilience of these agricultural systems. The majority of small farmers live in mountainous regions where steep slopes favour loss of soil organic matter and nutrients, in these regions soil is exposed to severe weather events, bringing about fragile soils in most of the cases, fertilizer applications does not meet the requirement of crops because of soil erosion ((Ruiz y Davey, 2003). In dry soils, root growth is reduced considerably (Rosenzweig y Hillel, 1998). In addition, projected annual precipitation for Honduras, suggests that there will be a reduction of it between 9 and 14% for 2050, and between 20 and 31% for 2100, with prolonged drought spells (Canicula) (USAID Climate Risk, 2017).

A production system envisaged in Honduras is the Quesungal, this system is based on the no-till technique in small farms located on steep slopes with drought and erosion problems. Generally, this system is implemented in arid regions of Honduras, and includes crops such as maize (*Zea mays* L.), beans (*Phaseolus vulgaris* L., Sp. Pl.), sorghum (*Sorghum* sp. L.) and vegetables, but also trees, fruit trees and/or timber trees, these provide farmers with fruits and timber for furniture or firewood. This combination of plants brings about an equilibrium in the productive system favouring food security, strengthening resilience of socio-ecological systems and carbon fixing as a strategy to mitigate climate change (Colon-García, 2021). On the other hand, the Guama Model, is an agricultural production system in alleys, using Inga trees, this system is an option for achieving sustainable rural development in the humid tropics (Hands, 2021) because it increases water storage in the soil, improves soil fertility, increases cation exchange capacity (CEC) of the soil, decreases soil temperature due to litter accumulation on the surface and blocks the growth of weeds. Even though these systems offer advantages, they require external fertilization, such as in maize (Catari-Yujra *et al*., 2022), coffee (Sanchez, 2017), and cacao (López, 2015).

Most small farmers in Honduras sow mainly maize, beans and manioc (*Manihot esculenta* Cranzt) for subsistence. The implementation of more profitable crops such as lady finger banana (*Musa acuminata* Colla) for market obtaining extra income, helps get more carbohydrates in the local economic systems (Stover y Simmonds, 1987). Lady finger banana is native of Malaysia; wild species of diploid bananas and plantains (*M. balbisiana* Colla) originated commercial bananas and plantains (Azofeifa 2007; Smith *et al*., 2010; Álvarez 2013). Lady finger banana can measure up to 7.5 m (Vargas y Sandoval, 2005), but there are shorter species as well, the pseudo-stem is reddish in colour, leaves are straight lanceolate, fruits are small and oval-shaped (Pérez, 2012). The large amounts of fertilizers needed in commercial farms of lady finger banana, this practice makes it less profitable to be implemented for small farmers, for instance, the required potassium by the crop is estimated to be 400 kg ha^{-1} año^{-1} which is removed by fruits only to obtain a yield of 70 t ha^{-1}, because of this and even though the soil might have some potassium for the crop, supplementation of this element is still required (López y Espinosa 1998). In farms with average yield it is harvested 70 t of fruit ha^{-1} year^{-1}, for this the fruit can remove 400, 125 y 15 kg ha^{-1} year^{-1} of potassium (K), nitrogen (N) and phosphorus (P), respectively, using as a source of K_2O, potassium chloride (López and Espinosa 1995). In another study, the crop requires 1625 kg ha^{-1} of potassium to achieve a yield of 50 t ha^{-1} (Munson 1985). The nitrogen provided by the *Inga spp*. alley cropping system is approximately 100 kg ha^{-1} (Leblanc *et al*., 2007), which can vary between 56 and 555 kg ha^{-1} (Nygren *et al*., 2012). Smith (2010) suggests the application of 15-3-31 at a rate of 40 g per plant after 112 and 140 days after sowing with a plant density of 2000 plants ha^{-1}, in a harvesting period that varies between 243-254 days.

Due to its tropical geographical location, the amount of solar radiation in Honduras is almost the same throughout the year, which causes similar monthly temperatures. Some variation in temperature is due to the closeness to the ocean and altitude (Argeñal, 2010). Annual precipitation varies between 2500 and 3000 mm, and most rainfall occurs from September to November (Sánchez, *et al*., 2017).

The agronomic yield of crops of importance for rural families in the humid tropics, such as banana, cropped with leguminous trees, such as Inga spp., need to be studied due to little available information, especially with regards to the response to the application of P and K in agroforestry systems, and the interaction between organic (leguminous residues) and inorganic nutrient sources. The objectives of this research were: to evaluate the yield of lady finger banana alley cropped with Inga spp. to several levels of natural fertilizers such as K_2SO_4 + Mg, and phosphoric rock (FR).

MATERIALS AND METHODS

Study area

The study was carried out at the Experimental Station at Centro Universitario Regional del Litoral Atlántico (CURLA, UNAH), La Ceiba, Atlántida, Honduras. The study area has 9000 m^2, and it is coordinates are 15°46′N 86°50′W, the site is 2.5 km away from the coast. The climate is classified as tropical premontane rainforest, annual average precipitation varies between 2500 and 3000 mm distributed uniformly throughout the year, and average annual temperature is 25 ºC (Sánchez, *et al*., 2017).

Soil sampling

Composite soil samples for analysis were collected at depths: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, this was based on a study of root depth of Inga, and root depth of lady finger banana. Blomme *et al*., (2001) indicates that most of the roots are between 15 to 20 cm depth. Soil samples were analysed at the WHAL laboratory of Standard Fruit Company S.A, La Ceiba, Honduras.

Results of soil sample analyses were: N 0.23 %, P 10 mg kg^{-1}, K 0.22 cmol kg^{-1}, Ca 0.74 cmol kg^{-1} and Mg 0.33 cmol kg^{-1}. Micronutrients contents were: Cu 1 mg kg^{-1}; Fe 95 mg kg^{-1}; Zn 2 mg kg^{-1}, Mn 102 mg kg^{-1}, and Al 1.6 cmol kg^{-1}. The pH of the soil at the study area was 4.5 (1:1 in water). As reference for interpretation of foliar analysis was used the critical foliar levels provided by Soto (1992), and Molina and Meléndez (2002) who reviewed the work of several authors. According to that reference the following levels are considered as normal: N 2.60-3.50 %, P 20-50 mg kg^{-1}, K 0.5-0.8 cmol kg^{-1}, Ca 6-15, Mg 3-6, S cmol kg^{-1}, Fe 70 mg kg^{-1}, Cu 11 to 24 mg kg^{-l}, Zn 18-43 mg kg^{-1} and Mn 650 mg kg^{-1}, consequently the soil at the study area presents low levels of macronutrients and high levels of Al, Fe, Mn and Zn resulting in an acid pH (4.5). In a similar situation Kumar *et al*. (2020) found that application of lime in combination with fertilizers are recommended for increasing soil fertility, yield and quality of banana.

Genotype of lady finger banana

Smith *et al*., (2010) indicates that lady finger banana (*Musa acuminata* Colla) is native of Malaysia, it is a variety of small fruits but the plant can grow up to a height of 7.5 m, its stem is narrow, with a dense root system which can reach up to 90 cm depth. A bunch contains 10 to 14 hands, each hand contains 12 to 20 fingers, the finger measures from 10 to 12.5 cm (Vargas y Sandoval, 2005). The plant is resistant to drought and Panama disease but it is prone to Sigatoka (Daniells y Bryde, 1995). It adapts to acidic soils with pH values less than 5.0. In relation to fertilization, Smith (2010) suggests application of 15-3-31 formulation at a rate of 40 g per plant at 112 and 140 days after sowing with a plant density of 2000 plants ha^{-1} for a harvesting time between 243 and 254 days. The plant characteristics contributed to select it for the present study.

Design and size of experimental plots

The existing plantation of Inga trees, at the time of the study, was 20 years old; the existing species were *Inga edulis* Mart., *I. punctata* Willd., *I. vera* Willd. é *I. osteriana* Persy. Two months prior to sowing lady finger banana plants, dolomitic lime was applied at a rate of 2 t ha^{-1}.

The number of alleys used for growing lady finger banana were 35; alleys were distributed in the area in a split-plot design with randomized blocks: A. Whole plots: cycle 1 (from the 25th of March 2014 to 8th of December 2015) and cycle 2 (from the 5th of June 2016 to 8th February 2018); B. Subplots: type of natural fertilizers: (i) phosphoric rock (FR) at four levels (0, 20, 40, 80 kg ha^{-1}), and (ii) potassium and magnesium sulphate at three levels (0, 45, 90 kg ha^{-1}), with 5 replicates, distributed in the alleys. Each alley has an area of 120 m^2 (4 m width x 30 m length). The yield of each alley was expressed in kg ha^{-1} to prevent bias on data due to the large cropping area.

Agronomic management

Prior to transplanting, the suckers of lady finger banana (*Musa acuminata* Colla) were placed in bags under a net house for 72 days. For transplanting, holes with dimensions 30 cm x 30 cm x 50 cm were dug were plants were placed. One week prior to transplanting the banana plants, the Inga spp. trees were pruned at a height of 1.5 m; at the time of pruning, first application of fertilizers were made.

Measured variables

The following variables were evaluated: crop cycle, days to harvest, weight of bunch and yield.

Weighting of bunches was made on a Gutstark® scale of 200 kg and it was used for both cycles.

Statistical analysis

Data was analysed with SAS (Statistical Analysis System Inc.) program version N.N. 2002. For comparison of means of studied variables, a Tukey ((P < 0.05) was used.

RESULTS AND DISCUSION

For crop cycle 1 of lady finger banana, the smallest average of number of days (cycle) with signifcant difference ($p < 0.05$; r^2= 65) was found with 90 and 45 K treatment levels, with 401.8 and 442 days repectively, and time to harvesting were 103.8 and 133.8 días respectively. For crop cycle 2, the same treatments (90 y 45 K) had the smallest average number of days, 478.5 y 473.3 days, and time to harvesting were 164 and 154 days repectively, these values are less to the reported by Soto (2010) who indicates that it takes 500 days until harvesting, but they are longer than the reported by Smith (2010) who suggest a cropping cycle between 243 and 254 days. There are several factors that play a role in the lower values in yield, such as the decreasing intrinsic productivity associated to lady finger banana (Vargas y Sandoval 2005) which is similar to what happens to plantain, type fake horn (AAB) (Perea 2003; Pantoja *et al*. 1995 y Swennen *et al*. 1984), another factor influencing the decreasing yield in lady finger banana might be the specific behaviour of genotype due to a reduced root system (Vargas y Sandoval, 2005). However, in our experiment, the banana crops were newly set up and the cropping plots rested one year, and therefore, the aforementioned factors could not have played a role in the decreasing yield of lady finger banana. Nevertheless, possible factors that might have been crucial are precipitation and temperature during both cropping cycles. For cycle 1, annual precipitation was 5595 mm and average temperature 26 °C, for cycle 2 annual precipitation was 5206 mm and average temperature was 29 °C (Figure 2). The cycle with the highest yield was the first.

Analyses by years has shown that the treatments in cycle 1, el aporte de K_2SO_4 + Mg (K), y RF, do not show significant differences ($p < 0.05$; r^2 = 74) among each other, and the highest yield was obtained with level 45 K, this is higher than the yield reported by Smith (2010) which was 14827 kg ha^{-1} with 1,666 plants ha^{-1}. However, there are differences when comparing treatments of K_2SO_4 + Mg to the control plot (Table 1).

For cycle 2, the highest yields were obtained with 45 y 90 K_2SO_4 + Mg; the mean differences were significant ($p < 0.05$; r^2 = 86). In relation to cycle 1, treatments with FR, control and 20 kg ha^{-1} exhibited the lowest yields, 9,759 and 11,167 kg ha^{-1} respectively, and the highest yields were obtained with the highest treatment levels. In cycle 2, the control of FR had the lowest yield (4,154 kg ha^{-1}) (Table 1).

Lady finger banana is highly demanding for K, with a critical content (a point from where it does not absorb anymore) between 0.30 cmol kg^{-1} to 1.4 cmol kg^{-1} (Stover y Simmonds, 1987). Even though in this study it was not cuantified, it is assumed K extraction by the crop continued from K_2SO_4 + Mg, as yield decreased in cycle 2. When comparing the total yields from the added values from all treatments of cycle 1 and 2, it is observed that the yield from cycle 1 is significantly higher ($p < 0.05$; r^2= 69) with regards to cycle 2, with 13,226.6 Kg ha^{-1} and 10,048.3 kg ha^{-1} respectively (Figure 1) ocurring a decrease of 3,178.3 kg ha^{-1}.

Table 1. Average values of variables as response to fertilization with phosphoric rock (RF) and potassium and magnesium sulphate (K) on lady finger banana, during two cropping cycles in La Ceiba, Honduras.

		Cycle 1				Cycle 2			
Treatment	N	Crop duration (days)	Days to harvest	Bunch weight kg	Yield kg ha^{-1}	Crop duration (days)	Days to harvest	Bunch weight kg	Yield kg ha^{-1}
80 RF	5	520.6 ^{a}	169 ^{a}	8 ^{bc}	14660 ^{abc}	513 ^{bc}	128.6 ^{b}	7.7 ^{c}	9051 ^{b}
0 RF	5	556.8 ^{a}	201.8 ^{a}	6.2 ^{d}	9759 ^{d}	525.2 ^{abc}	177 ^{ab}	4.7 ^{e}	4154 ^{c}
40 RF	5	511 ^{ab}	162.2 ^{ab}	8 ^{bc}	12895 ^{bcd}	544.2 ^{abc}	157 ^{ab}	6.4 ^{d}	10706 ^{b}
0 K	5	500.7 ^{ab}	169.5 ^{ab}	7.9 ^{bc}	11046 ^{cd}	589.8 ^{a}	201.5 ^{a}	6 ^{d}	9270 ^{b}
20 RF	5	476.4 ^{abc}	140.8 ^{ab}	7.3 ^{c}	11167 ^{cd}	562.6 ^{ab}	188 ^{a}	5.9 ^{d}	8344 ^{bc}
45 K	5	442 ^{bc}	133.8 ^{ab}	9 ^{a}	17432 ^{a}	473 ^{c}	154.8 ^{a}	8.8 ^{b}	16287 ^{a}
90 K	5	401.8 ^{c}	103.8 ^{b}	8.6 ^{ab}	16734 ^{ab}	478.5 ^{c}	164 ^{a}	9.5 ^{a}	16721 ^{a}

Average values with different letter in the same column are statistically different (Tukey, = $P \leq 0.05$).

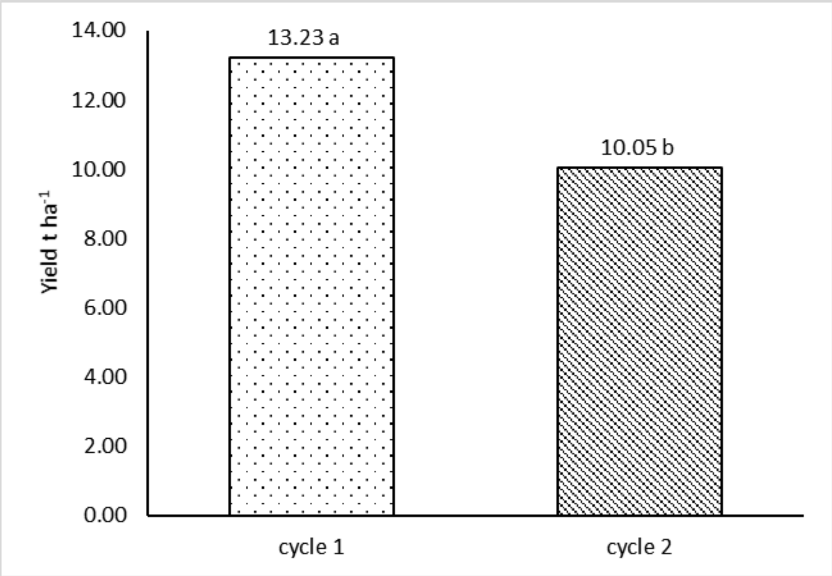

Figure 1. Yield of lady finger banana as response to application of phosphoric rock (RF), and potassium and magnesium sulphate (K) sown in cycles 1 and 2 in La Ceiba, Honduras. Average values with different letter in each column are statistically different (Tukey, P < 0.05).

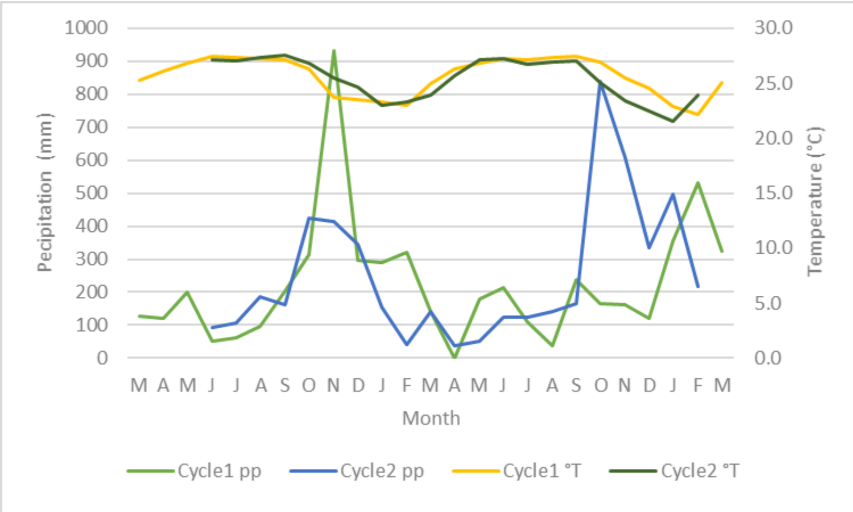

Figure 2. Precipitation (pp) and temperature (°T) during cycles 1 and 2 of lady finger banana crop in La Ceiba, Honduras. The letters indicate months, starting in March. Data are from the weather station at CURLA.

Regarding the variable average yield by bunch, the treatments that were significantly higher ($p < 0.05$; $r^2= 75$) were 80 FR and 0 FR from cycle 1, with an average weight of 9 and 8.5 kg respectively; for cycle 2, the treatments that were significantly higher were 90 K and 45K with average weight of 9.5 and 8.8 kg respectively (Table 1); Vargas and Sandoval (2015) in their study have found that the weight of lady finger banana to be 9.7 kg, which is similar to the weight obtained in this study. In another study, by Furcal-Beriguete y Barquero-Badilla (2013) with 250 y 375 kg ha^{-1} levels of KO_2 y PO_2 applied to plantain (Musa AAB) reported a positive trend in yield in response to the higher level, with weight of 10 to 12 kg per bunch, this value is higher to the one obtained in this study, however, on both studies species were different, it must be considered that the agroecological system allows evaluation of lower levels of fertilization and determine their effects on yields.

Application of potassium fertilizers on lady finger banana crops is necessary, due to its decreasing yield when there is no such application. The importance of loss of potassium by removal, relies on the fact the fruits do not return to the plot as residue, therefore, there is no return of this element to the soil; Menchú and Méndez, (2007) indicate that the potassium removal by the banana crop is about 358 mg 100 g^{-1} of the edible portion or 400 kg ha^{-1} year^{-1} of potassium removed by the fruit only (López y Espinosa 1998). In Honduras, lady finger banana is a profitable crop and considering that getting an extra economical income in rural regions is difficult, applications of natural fertilizers such as K_2SO_4 + Mg, and phosphoric rock are recommended, even if it is at low levels in order to increase the average yield of banana. There are no prior studies on lady finger banana alley cropped with Inga trees, and therefore this study is an original contribution to research under such agroforestry system.

CONCLUSIONS

The highest yields were obtained with the highest fertilization levels (90 and 45) of potassium and magnesium sulphate. Assuming that lady finger banana is highly demanding on K, it is necessary to provide to the crop with this element in quantities higher than the levels used in this study. In order to study the response on yield of lady finger banana under an agroforestry (with Inga) and organic system to fertilization with phosphoric rock and K_2SO_4 + Mg, research must be of long term. On the other hand, the amount of water demanded by the banana crop is crucial to obtain yield, thus, it is also necessary to conduct research on more efficient irrigation systems to obtain optimum crop yields. Lady finger banana alley cropped with Inga trees, as an agroforestry and organic system, contributes to achieve food security for farmers and their families, and obtain extra income by selling the surplus production.

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Compliance with ethical standards. Do not apply.

Data availability. Data are available with Dra. Maribel Reyes-Osornio (maribel_osornio@yahoo.com.mx.) upon reasonable request.

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