International Journal of Plant & Soil Science

24(5): 1-9, 2018; Article no.IJPSS.44177
ISSN: 2320-7035

Cotton Growth and Nutrient Uptake after Rock Phosphate, Gliricidia Prunings or Chemical Fertiliser Application in Soils of Semiarid Northeast Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/44177
Editor(s):
(1) Dr. Adamczyk Bartosz, Department of Food and Environmental Sciences, University of Helsinki, Finland.
Reviewers:
(1) Addam Kiari Saidou, Institut National de la Recherche Agronomique du Niger, Niger.
(2) Asmatullah Durani, Nanagrahar University, Afghanistan.
Complete Peer review History: http://www.sciencedomain.org/review-history/26563

Received 14 July 2018
Accepted 30 September 2018
Published 08 October 2018

Original Research Article

ABSTRACT

Several studies have demonstrated that organic fertilisers or ground rocks may be a viable alternative to industrialised chemical fertilisers in some agricultural systems. The present study aimed to compare the effects of ground phosphate rocks, gliricidia prunings and chemical fertilisers as nutrient sources to cotton (*Gossypium hirsutum* L.) cultivated in two types of soil (Fluvic Entisol and Oxisol) of the Brazilian semiarid northeast region. The experiment was conducted in a greenhouse at the Federal University of Pernambuco, in a completely randomised design with twelve treatments and four replications, consisting of three phosphate sources (MB-4 rock powder,

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Bahia rock powder and triple superphosphate), two nitrogen sources (urea and gliricidia) and a control without fertilisation. The aboveground biomass of cotton plants in the second growing cycle showed higher values of nitrogen with the combined use of gliricidia and MB4. The results indicated that the uses of green manure combined with natural phosphate may be a viable alternative to supply phosphorus and nitrogen to cotton plants in the Brazilian semiarid region. This can be a potential source of phosphorus and nitrogen in familiar agriculture and can replace mineral fertilisation.

Keywords: Nitrogen; phosphorus; gliricidia; vegetative cycles cotton.

1. INTRODUCTION

The agricultural system in the semi-arid northeastern region of Brazil has been reducing the use of local organic fertilisers and increasing the use of imported chemical fertilisers in their operations. The consequences of this practice promote an unbalance of energy in the biological cycles at the farm level. Conceptually, this is not a sustainable agricultural practice. Instead, it should be considered as a way to implement the utilisation of local fertilisers aiming for a more sustainable farming system [1].

Most soils of the semiarid region of Brazil present low availability of N and P [2,3]. The use of chemical fertilisers is not feasible due to the high costs for most farmers. Thus, there is a need for the identification and utilisation of local sources of N and P fertilisers to maintain and increase the soil fertility for better crop production. Manure is a good source of N and P. However, the amount of manure available in the semiarid region is not sufficient to meet the demand of areas under crop cultivation. Additionally, fertiliser with low quality could cause N-immobilisation when incorporated into the soil [4].

Ground rocks (GR) have also been used as a source of phosphorus and other nutrients, mainly in organic crop systems. Several types of ground rocks are being used as fertilisers in NE Brazil, such as MB4 and Bahia phosphate, both produced in NE Brazil. MB4 and Bahia phosphate rock show a high concentration of Fe, Ca, Mg, Na, K, P, Mn, Cu, Co, Zn, S and Mo [5]. However, there are rare scientific reports concerning the utilisation of these ground rock fertilisers in the semiarid region of Brazil. According to EMBRAPA [6], the use of phosphate rocks in most cases is limited due to the low solubility of their nutrients. For this reason, it is recommended to use ground rocks mixed with organic fertilisers, which could promote a fast release of nutrients during the process of solubilisation by the organic acids. The biomass of leguminous plants is largely used in Brazil as a source of N in crop fertilisation.

A good example of this practice in NE Brazil is the use of gliricidia (*Gliricidia sepium* Jacq.Walp) leaves as organic fertiliser. The mix of organic fertiliser and GR has a high potentiality to supply the main essential nutrients for plant growth [7]. EMBRAPA [8], described the participation of the organic matter, reduces the adsorption of P in soil, indicating that the organic fertiliser adsorbed acids blocking the adsorption sites or solubilise the oxides and reduce the adsorption surfaces. Nevertheless, the reduction of P adsorption has benefits to the plants [9].

The addition of organic fertilisers in the soil, such as an animal or green manure cause an opposite effect, promoting a reduction of the adsorption and increasing the phosphorus available in the soil [10]. Hence, the study aimed to evaluate the effects of using MB-4 (ground rock), Bahia rock phosphate, isolated or in combination with gliricidia, as the sources of nutrients compared with chemical fertilisation (triple superphosphate or urea) in the growth and nutrient uptake by cotton (*Gossypium hirsutum* L.) cultivated in two soils (Fluvic Entisol and Oxisol) in the Brazilian semiarid NE region.

2. MATERIALS AND METHODS

The experiment was carried out in two successive cycles under greenhouse conditions. The substrates used were two types of soil (Oxisol and Entisol). The Entisol with sandy-loam texture was collected from the first 20 cm of soil from the agroecological village station at Taperoá county located in a semiarid region of the Paraiba State – Brazil (07°12’10,8” S; 036°49’42,6” W, and elevation of 520 m). The average temperature of the site is 26°C, and average of long-term rainfall is 500 mm, distributed between February and June (rainy season). The Oxisol had a clayey texture, and it was collected in the experimental area of the

Federal Rural University of Pernambuco state, in Recife, Pernambuco, Brazil. The experimental area where the greenhouse is located has a humid-hot climate, with an annual average temperature of 24°C, and average annual rainfall precipitation of 1200 mm. The soils were classified according to the methodology [11].

Both soils were characterised to determine the physical and chemical properties [12] before the initiation of the experiment. The Entisol presented the following attributes: pH (H_2O) 6.8; N (g kg^{-1}) 2.3; P - Mehlich-1 (mg dm^{-3}) 129.6; K (mg dm^{-3}) 181.0; Ca (cmolc dm^{-3}) 5.50; Mg (cmolc dm^{-3}) 1.0; Al (cmolc dm^{-3}) 0,0; H+Al (cmolc dm^{-3}) 1.10; S - (mg dm^{-3}) 7.50; SB - base sum (cmolc dm^{-3}) 7.0; T – CEC effective (cmolc dm^{-3}) 7.0; T – CEC pH 7.0 (cmolc dm^{-3}) 8.0; V – base saturation (%) 86.7; m – Saturation by aluminium (%) 0.0; O.M (g kg^{-1}) 14.0; B (mg dm^{-3}) 0.6; Cu (mg dm^{-3}) 0.6; Fe (mg dm^{-3}) 38.5; Mn (mg dm^{-3}) 81.6; Zn (mg dm^{-3}) 6.9. The characteristics of the Oxisol were: pH (H_2O) 5.4; N (g kg^{-1}) 1.8; P-Mehlich-1 (mg dm^{-3}) 2.2; K (mg dm^{-3}) 70.0; Ca (cmolc dm^{-3}) 1.40; Mg (cmolc dm^{-3}) 0,27; Al (cmolc dm^{-3}) 0.70; H+Al (cmolc dm^{-3}) 2.90; S (mg dm^{-3}) 1.88; SB – base sum (cmolc dm^{-3}) 1.85; T- CEC effective (cmolc dm^{-3}) 2.55; CTC pH 7,0 (cmolc dm^{-3}) 4.75; V – base saturation (%) 39.33; m – Saturation by aluminium (%) 14.73; O.M (g kg^{-1}) 8.80; B (mg dm^{-3}) 0.4 ; Cu (mg dm^{-3}) 2.0; Fe (mg dm^{-3}) 240.0; Mn (mg dm^{-3}) 2.80; Zn (mg dm^{-3}) 1.80.

The experiment was conducted under greenhouse conditions using MB-4 and Bahia phosphate rock, triple superphosphate, urea and gliricidia. Before starting the experiment, all rocks used were ground and sieved in an automatic 0,03 mm granulometry sieve. The levels of available phosphate and total nitrogen were determined in all fertilisers using the methodology described by Stefen et al. [12]. The chemical composition (%) of the fertilisers used were: MB4- N (1.1), P (7.6), K (16.0); Bahia phosphate - N (2.1), P (1.0), K (13.5) gliricidia N (37.8), P (2.02), K (1.61); Urea (46% N) and triple superphosphate (42% P_2O_5 and 12% Ca).

A completely randomised design in a factorial distribution of 2 x 12 x 4, representing two types of soil, 12 fertiliser treatments and four replications per treatment was used. The fertiliser treatments consisted of 3 sources of phosphate (MB-4, Bahia phosphate, triple superphosphate), combined with two sources of nitrogen (gliricidia prunings and urea) and control treatments: N sources and P sources (Table 1).

Table 1. Fertilizer treatments applied in cotton plants during the two cycles

Treatments	Doses	
	t ha^{-1}	kg ha^{-1}
C	-	-
G	15	-
S	-	80
MB4	-	300
FB	-	300
U	-	40
G+S	15	80
G+MB4	15	300
G+FB	15	300
U+S	-	40+80
U+MB4	-	40+300
U+FB	-	40+300

C=Control; G=Gliricídia; S= triple super phosphate; MB4 e FB = ground rocks, U= Urea.

Polyethene plastic bags were filled with 2 kilograms of soils, which represented the experimental unit. After the application in the treatments (fertilisation) the vases were seeded with six seeds [13]. Ten days after germination, the vases were thinned to two seedlings per vase. Soil humidity in the vases was maintained to 50% of the total volume of pores, by daily weighing the vases with the addition of deionised water, when necessary. The cotton plants were harvested 60 days after planting.

At harvesting, the height of the plants was measured, and then all biomass was harvested and weighed (green matter). The shoot and root biomass were separated, placed in paper bags, dried in 65° C for 72 hours, and then weighed. After weighing, the dry matter was ground in a grinding mill (Wiley model). The sample was divided into sub-samples for different physical-chemical analysis.
One sub-sample was digested with sulfuric acid and hydrogen peroxide. Another subsample was used to determine the N, P and K absorption in the shoots and roots on the two vegetative cycles. Sub-samples were used to determine the total N using the Kjeldahl method, and the levels of phosphorus by a colourimetric method [12]. The data were analysed using Analysis of Variance, and the means were compared by Turkey test at the 95% level of significance [14].

3. RESULTS AND DISCUSSION

The results showed (Table 2) in the first cycle a significant difference for the plants height and soil type ($p>0.05$).

Table 2. Plant height, aboveground biomass (AB), nitrogen (N) and phosphorus (P) levels of cotton plants 50 days after planting in two soil types, Oxisol (OXI) or Entisol (ENT), after fertilisation with rock phosphate, gliricidia prunings or chemical fertilisers

	Height (cm)		AB (g)		N (g kg^{-1})		P (g kg^{-1})	
	OXI	ENT	OXI	ENT	OXI	ENT	OXI	ENT
C	30.25aB bB	58.00 bA	3.17 dB	8.08 cA	8.60 aB	13.12 aA	1.14 bB	2.20 aA
G	41.50 aB	65.25 aA	5.43 cB	14.50 aA	9.47 aA	8.75 aA	1.02 bB	1.76 aA
S	38.25 aB	57.25 bA	6.54 bB	9.03 cA	7.25 aA	9.30 aA	1.51 aA	2.14 aA
MB4	37.00 aB	57.00 bA	4.98 cB	8.78 cA	9.20 aA	9.55 aA	1.58 aB	2.45 aA
FB	32.00 bB	58.25 bA	2.99 dB	8.09 cA	9.77 aA	8.10 aA	1.30 bB	2.01 aA
U	35.75 aB	59.25 bA	4.83 cB	10.11 cA	10.97 aA	8.35 aA	1.14 bB	1.92 aA
G+S	43.25 aB	63.75 aA	8.72 aB	12.37 bA	7.82 aA	8.75 aA	1.32 bA	1.58 aA
G+MB4	41.50 aB	64.75 aA	6.81 bB	11.03 bA	8.85 aA	9.92 aA	1.70 aA	2.11 aA
G+FB	38.00 aB	64.50 aA	4.47 cB	11.62 bA	8.47 aA	7.70 aA	1.13 bB	1.77 aA
U+S	41.50 aB	64.25 aA	6.73 bB	11.38 bA	9.20 aA	7.97 aA	1.44 aA	1.70 aA
U+MB4	38.00 aB	57.75 bA	6.64 bB	10.44 bA	8.10 aA	8.87 aA	1.74 aA	1.59 aA
U+FB	38.50 aB	60.00 bA	4.47 cB	10.94 bA	9.95 aA	9.17 aA	1.35 bA	1.39 aA
CV (%)	10.03	6.10	19.84	15.42	19.49	24.74	18.36	27.71

OXI = Oxisol; ENT = Fluvic Entisol; C = Control; G = Gliricídia; S = Super triple phosphate; MB4 = ground rock; FB = Bahia phosphate; U = Urea. Means followed by the same lowercase letters indicate that there was no statistical difference between treatments in the same column and same uppercase letters indicate that there was no statistical difference between treatments in the same line by Turkey test (P≤0.05).

The treatments with only gliricidia manure and gliricidia manure mixed with triple superphosphate had the highest value regarding plants height with the cotton cultivated in Fluvic Entisol. Paula [15] stated that gliricidia is a perennial legume tree with high nitrogen content in their tissues. When gliricidia is decomposed in the soil, its N is easily absorbed by the plants. Overall, plants in Oxisol were shorter than plants in Entisol. The lowest plant height was observed in cotton plants in the control treatments (absence of fertilisation).

The aboveground biomass had also shown a difference between fertilisation treatments and soil type. The aboveground biomass was higher in Entisols than Oxisols. The highest biomass yield was achieved under Entisols fertilised with gliricidia manure mixed with triple superphosphate. High levels of nitrogen were caused by gliricidia manure and their interaction with a mineral phosphate source, favouring a good development of cotton plants [16,17,18,19]. Additionally, gliricidia manure has low levels of secondary compounds and high rates of mineralisation by soil micro-organisms that also help in the phosphorus solubilisation [20,17].

The levels of nitrogen in the aboveground biomass were statistically different between the fertilising treatments and type of soil. The highest value for nitrogen in the above-ground biomass was observed in Entisols with the application of urea mixed with gliricidia manure (Table 2). This may be due to the availability of nitrogen from the urea as well as the gliricidia. The research findings corroborate those observed by Moreira et al. [21], which concluded that soil close to gliricidia trees had higher concentration of P. In addition, Eiras et al. [22] concluded that a gliricidia/maize has proportionately more significant positive effects on rebuilding soil fertility.

The application of MB4, whether isolated or mixed with gliricidia manure promoted the highest values for phosphorus accumulation in the aboveground tissues of cotton plants (Table 2). The results observed were due to the availability of phosphorus in the MB4, but also because the effect of the phosphorus in the MB4 is increased when mixed with an organic fertiliser source such as gliricidia manure [23]. For this reason, Queiroz et al. [24] drew attention to the need for further studies involving organic fertilisers combined with mineral fertiliser sources as an alternative to crops with short-cycle.

During the second cycle, the cotton plants were highest in those treatments with gliricidia manure mixed with Bahia phosphate under Fluvic Entisol (Table 3).

However, the average values for the height of plants during the second cycle were lower than the average of the first cycle. The different solubility rates in the phosphates sources used, promoted differences in their acquisition and absorption by the cotton plants. These results corroborated those reported by Novais et al. [25]. In addition, Garrido et al. [26] reported that when phosphate sources are mixed with legume-plants manure, the plant showed an increase in nutrient accumulation in their tissues.

On average, the biomass production in the second cycle was lower than that in the first cycle (Table 3). The largest biomass production was observed in the Oxisol when only MB4 was applied. The effect of phosphorus on the biomass production and hence in the accumulation of nutrients could be explained because the phosphorus facilitates several metabolic activities in the plant, mainly in the process of energy transference [27].

The levels of nitrogen were higher in the second cycle when compared with the first cycle. The highest levels of nitrogen were found in the first cycle of the treatment with gliricidia manure mixed with Bahia phosphate in the Oxisol. More phosphate available in the soil promoted an increase in the metabolic and photosynthetic reactions, consequently more absorption of nitrogen [28]. On the other hand, Fageria and Moreira [29] stated that gliricidia manure has high levels of nitrogen which it could be used by the plant. More extraction of nitrogen from the soil was observed in the treatment with urea mixed with super triple phosphate under Oxisol. The level of phosphorus absorbed by the cotton plants is related to the nutrient availability in the soil, in which with the increase in the amount of phosphorus available in the soil increases the phosphorus absorption [8,30].

The biomass of the root system in the first cycle in Fluvic Entisol, the treatment using only gliricidia manure promoted the highest ground biomass accumulation in the treatments studied (Table 4).

This result indicates that gliricidia manure exhibited high potential for the use as fertiliser. Primo et al. [1] and Faucon et al. [31] studied the soil fertilisation with gliricidia manure in several types of soil in the Brazilian semiarid cultivated with cotton and concluded that the productivity of cotton plume increased 100% when gliricidia manure was incorporated in the soil.

The level of nitrogen in Oxisol was higher than in Fluvic Entisol. Under optimal mineral nutrition conditions, the plant tends to absorb more phosphorus when Nitrogen is available considerably [32]. In Fluvic Entisol, the levels of phosphorus found in the roots were higher in the treatment with gliricidia manure mixed with super triple phosphate. The radicular system pattern has an effect in the phosphorus absorption in the plant, and the level of phosphorus stimulates the root growth ([33,34]).

Table 3. The height of plant, aboveground biomass (AB), nitrogen and phosphorus levels extracted from the soil by cotton plants under two different types of soil and fertilisers in the second cycle of cultivation

	Height (cm)		AB (g)		N (g kg^{-1})		P (g kg^{-1})	
	OXI	ENT	OXI	ENT	OXI	ENT	OXI	ENT
C	20.5 bB	34.7 bA	1.626 cA	1.286 bA	7.32 bB	19.87 bA	1.11 bB	3.28 bA
G	27.5 aA	30.7 bA	2.696 aA	1.286 bB	7.25 bB	22.12 bA	0.98 bB	2.96 bA
S	23.2 bB	31.2 bA	2.116 bA	1.355 bB	6.85 bB	20.72 bA	1.45 aB	2.77 bA
MB4	24.0 bB	35.2 bA	2.930 bA	1.481 aA	7.77 bB	17.80 bA	1.51 aB	2.90 bA
FB	24.0 bB	33.7 bA	2.040 bA	1.221 bB	9.77 aB	18.50 bA	1.25 bB	2.66 bB
U	27.0 aB	37.2 aA	2.049 bA	1.797 aA	9.70 aB	21.27 bA	1.09 bB	2.64 bA
G+S	30.7 aB	37.2 aA	2.831 aA	1.729 aB	10.15 aA	18.52 bA	1.27 bB	2.58 bA
G+MB4	28.5 aB	40.5 aA	2.323 bB	1.774 aA	12.22 aB	27.30 aA	1.67 aB	3.75 aA
G+FB	26.0 aB	42.5 aA	2.260 bA	2.262 aA	12.07 aB	21.25 bA	1.09 bB	2.94 bA
U+S	23.5 bB	37.7 aA	2.109 bA	1.771 aB	8.62 bB	17.97 bA	1.38 aB	4.84 aA
U+MB4	24.5. bB	39.7 aA	2.417 aA	1.927 aA	8.12 bB	19.35 bA	1.67 bB	4.03 aA
U+FB	23.0 bB	40.0 aA	2.195 bA	2.132 aA	8.12 bB	18.60 bA	1.30 bB	3.59 aA
CV (%)	14.2	10.39	17.42	22.14	20.48	19.75	18.36	19.13

OXI = Oxisol; ENT = Fluvic Entisol; C = Control; G = Gliricídia; S = Super triple phosphate; MB4 = ground rock; FB = Bahia phosphate; U = Urea. Means followed by the same lowercase letters indicate that there was no statistical difference between treatments in the same column and same uppercase letters indicate that there was no statistical difference between treatments in the same line by Turkey test (P≤0.05).

Tabela 4. Below ground biomass production (BG), and nitrogen and phosphorus levels extracted from the soil by cotton plants under two different types of soil and fertilisers during the first cycle of cultivation

	BG (g)		N (g kg^{-1})		P (g kg^{-1})	
	OXI	ENT	OXI	ENT	OXI	ENT
C	0.516 bB	0.942 bA	6.00 bA	4.55 aB	2.41 bA	1.79 bB
G	0.777 bB	1.551 aA	5.25 bA	4.65 aA	2.12 bA	1.92 bB
S	1.020 aA	1.074 bA	5.00 bA	5.17 aA	3.06 aA	2.03 aB
MB4	0.669 bA	0.964 bA	5.75 aA	4.85 aA	2.66 aA	1.89 bB
FB	0.514 bB	0.827 bA	5.75 aA	4.95 aA	2.17bA	1.41 dB
U	0.666 bB	1.135 bA	6.00 aA	5.35 aA	1.97 bA	1.89 bA
G+S	1.371 aA	1.292 aA	4.75 bA	4.80 aA	3.14 aA	1.71 bB
G+MB4	1.200 aA	1.321 aA	4.75 bA	4.92 aA	2.93 aA	1.77 bB
G+FB	0.742 bB	1.077 bA	5.75 aA	4.97 aA	1.77 bA	1.67 bB
U+S	1.080 aA	1.316 aA	4.50 bA	4.97 aA	2.87aA	1.57 cA
U+MB4	1.105 aA	0.943 bA	4.50 bB	6.02 aA	2.82 aA	1.54 cB
U+FB	0.832 bB	1.145 bA	5.00 bA	5.10 aA	2.37 bA	1.55 cB
CV (%)	26.82	10.57	15.71	10.6	20.35	14.3

OXI= Oxisol; ENT = Fluvic Entisol C = Control; G = Gliricídia; S = Super triple phosphate; MB4 = ground rock; FB = Bahia phosphate; U = Urea. Means followed by the same lowercase letters indicate that there was no statistical difference between treatments in the same column and same uppercase letters indicate that there was no statistical difference between treatments in the same line by Turkey test (P≤0.05).

Table 5. Below ground biomass (BG) and levels of N and P extracted by cotton plants under different sources of nitrogen and phosphorus in the second cycle

	BG (g)		N (g kg^{-1})		P (g kg^{-1})	
	OXI	ENT	OXI	ENT	OXI	ENT
C	0.395 aA	0.132 bB	4.12 aA	3.00 aB	0.86 aB	1.74 aA
G	0.512 aA	0.111 bB	4.30 aA	2.80 aB	0.89 aB	1.62 aA
S	0.463 aA	0.115 bB	4.35 aA	3.20 aB	1.11 aB	1.68 aA
MB4	0.465 aA	0.134 bB	4.43 aA	2.80 aB	1.08 aB	1.68 aA
FB	0.467 aA	0.137 bB	4.22 aA	3.02 aB	0.89 aB	1.51 aA
U	0.364 aA	0.156 bB	4.32 aA	3.62 aA	0.86 aB	1.97 aA
G+S	0.510 aA	0.154 bB	4.40 aA	3.67 aA	0.64 bB	1.53 aA
G+MB4	0.475 aA	0.186 aB	4.17 aA	3.57 aA	0.55 bB	1.83 aA
G+FB	0.459 aA	0.225 aB	4.52 aA	3.90 aA	0.47 bB	2.24 aA
U+S	0.402 aA	0.167 bB	4.15 aA	3.47 aA	0.60bB	2.26 aA
U+MB4	0.524 aA	0.179 aB	4.25 aA	3.75 aA	0.54 aB	1.58 aA
U+FB	0.467 aA	0.228aB	4.30 aA	4.05 aA	0.52 bB	1.67 aA
CV (%)	18.91	26.18	12.97	21.88	16.8	30.03

OXI = Oxisol; ENT = Fluvic Entisol; C = Control; G = Gliricidia; S = Super triple phosphate; MB4 = ground rock; FB = Bahia phosphate; U = Urea. Means followed by the same lowercase letters indicate that there was no statistical difference between treatments in the same column and same uppercase letters indicate that there was no statistical difference between treatments in the same line by Turkey test (P≤0.05).

The root system of cotton plants during the second cycle was more expressive in the treatment of urea mixed with MB4 exhibited highest below ground accumulation in cotton plants under the Oxisol (Table 5).

However, the below ground biomass in the second cycle was lower than the biomass production in the first reported period. The differentiated responses to cultivated plants when submitted to fertilisation are related to their characteristics that influence the ability to use light and CO_2, affecting the absorption, transport and interaction of nutrients within the plant [35] to achieve maximum MSR increments. Similar results are described by Faucon et al. [36] using legume to enhance fertility on cotton cropping systems wherein all types of fertilisers used they have higher below ground biomass accumulation on the first crop cycle.

In the fertiliser treatments studied, the gliricidia mixed with Bahia phosphate showed the highest values of the nitrogen accumulated for below-ground biomass in the Oxisol. It should be mentioned that the nitrogen accumulated in the root tissues were lower than those nitrogen levels observed in cotton plants during the first cycle. Surprisingly the results found that the Bahia phosphate (source of phosphorus) helps to increase the nitrogen accumulation on belowground biomass of cotton plants in the Fluvic Entisol.

In addition, the application of nitrogen reduces the cost of phosphorus for the of plants roots ([37,38]) stated that the phosphorus plays key roles in many plant processes such as energy metabolism, the synthesis of nucleic acids and membranes, photosynthesis, respiration, and nitrogen fixation. The level of phosphorus in the below-ground tissues is shown in Table 5. The highest phosphorus accumulation was observed under Fluvic Entisol when the fertiliser treatment was the super triple phosphate mixed with urea. However, there were no differences observed in the phosphorus accumulation between the first and second cycle. It was expected that the use of sources of phosphate would increase the concentration of this mineral in the soil.

4. CONCLUSIONS

The use of green manure mixed with natural phosphate is a new economic idea for agricultural practices in the Brazilian semiarid area as sources of phosphorus and nitrogen in the soil. The results found in the present study demonstrated the positive and potential effects of rock powder mixed with green branches of gliricidia as sources of phosphorus and nitrogen in the cotton crop, replacing mineral fertilisation. Future studies will be carried out in the field to improve this alternative in other cultures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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