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Timing and placement of cattle manure and/or gliricidia affects cotton and sunflower nutrient accumulation and biomass productivity

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ABSTRACT

Organic fertilizers are a viable alternative to increase oilseed productivity in family agriculture systems. The study aimed to evaluate the effects of timing and placement of cattle manure and/or gliricidia (*Gliricidia sepium* Jacq. Walp) prunings on cotton (*Gossipium hirsutum* L.) and sunflower (*Helianthus annuus* L.) nutrient accumulation and biomass productivity. Experiments were carried out in 2010 and 2011 in Taperoá, Paraíba, Brazil. The organic fertilization treatments were: GI - gliricidia incorporated before planting; GS - gliricidia applied on surface 45 days after planting (DAP); MI + GI - manure and gliricidia incorporated before planting; MI + GS - manure incorporated before planting and gliricídia applied on the surface 45 DAP; MI - manure incorporated before planting; and T - with no organic fertilization. In 2010, treatment MI + GS increased N, P, and K accumulation in cotton (12 and 7 kg ha^{-1}) as well as in sunflower (20 and 29 kg ha^{-1}). In 2011, GI and GS treatments resulted in higher N, P, K accumulations in both crops. The highest cotton productivity in 2010 was obtained with MI + GS treatment (198 kg ha^{-1}) and in 2011 with GS treatment (594 kg ha^{-1}). For sunflower, MI + GS treatment yielded the highest productivity in 2010 (466 kg ha^{-1}) and GI treatment in 2011 (3542 kg ha^{-1}). GI and MI + GS treatments increased total biomass productivity for cotton and sunflower. The treatment that combined both cattle manure incorporated into the soil before planting and gliricidia applied on the surface 45 days after planting was the most viable management strategy.

Key words: *Helianthus annuus* L., *Gossypium hirsutum* L., green manure, nutrients, productivity.

INTRODUCTION

Soils in Northeastern Brazil, in general, have intermediate fertility levels with adequate amounts of potassium, calcium, and magnesium but are deficient in organic matter (OM), nitrogen and phosphorus (Menezes and Salcedo 2007). In low input agricultural systems where industrial fertilizers are not applied, such as subsistence agriculture in the semiarid region of northeastern

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Brazil, soil organic matter is the main source of nutrients (Tiessen et al. 2001). The use of manure or crop residues is the most widely used practice of fertilization in this region (Severino et al. 2006), but there are still few articles about organic fertilizer management strategies.

Recently, a few studies were conducted to evaluate the effects of the application of *Gliricidia sepium* Jacq. Walp prunings on the supply of nutrients to maize, beans and cotton (Menezes and Salcedo 2007, Mundus et al. 2008, Primo et al. 2011). Gliricidia is a legume with high ability to produce biomass of rapid decomposition (Handayanto et al. 1994, Marin et al. 2006) and its use as green manure has been recommended in semi-arid NE Brazil (Barreto and Fernandes 2001). However, depending on the management strategy, decomposition can be so rapid that N is released before the period of the greatest need by the crops and can be lost especially by leaching in years with higher rainfall (Palm et al. 2001).

The successful application of gliricidia and other organic fertilizers depends on the simultaneous occurrence of nutrient release from the fertilizer and crop demand throughout its growth cycles. Fertilization with manure before planting followed by application of gliricidia prunings shortly before crop flowering is a strategy that uses cattle manure produced during the dry season and plant material produced during the first weeks of the rainy season. However, there is little information from field studies on the potential impacts of these organic fertilizer management strategies on mineral nutrition and productivity of crops in Brazil, mainly for sunflower and cotton (Zobiole et al. 2010).

In the semiarid region of Brazil, growing attention has been given to intercropped agricultural systems since they may reduce production costs and are more efficient in manpower and land use. Thus, it is important to assess the feasibility of intercropped agricultural systems under organic fertilization to obtain further information. In this context, the aim of the present study was to assess the effects of timing (before or after planting) and placement (incorporated into the soil or surface applied) of manure and/or gliricidia on intercropped cotton and sunflower nutrient uptake and biomass productivity in the semiarid region of NE Brazil.

MATERIALS AND METHODS

The experiment was conducted from February to July both in 2010 and 2011 at the "Vila Maria Rita" Agroecological Station, municipality of Taperoá, Paraíba, Brazil (07°12'10,8' S and 036°49'42,6' W), at an altitude around 520 m above sea level. The average annual temperature is 26°C, and the average annual rainfall is approximately 500 mm, usually distributed between February and June. The daily precipitation was measured during the experimental period (Figure 1). The soil of the experimental area was classified as eutrophic Fluvic Entisol with intermediate texture (Embrapa 2006) and its physicochemical characteristics before treatment (Table I) were determined according to the methodology described by Embrapa (1997).

Growth, nutrient uptake, and biomass productivity of intercropped cotton (*Gossypium hirsutum* L., BRS verde cultivar) and sunflower (*Helianthus annuus* L. Crioula cultivar) were assessed using a randomized block design with six treatments and four replications. The treatments were: GI – gliricidia prunings incorporated into the soil before planting; GS - gliricidia prunings applied on the soil surface 45 days after planting; MI + GI – cattle manure + gliricidia incorporated into the soil before planting; MI + GS - manure incorporated into the soil before planting and gliricidia applied on the soil surface 45 days after planting; MI - manure incorporated into the soil before planting; and T – control treatment without fertilizers. Gliricidia prunings (leaves and twigs with a maximum of 1 cm in diameter) were cut from trees in a gliricidia

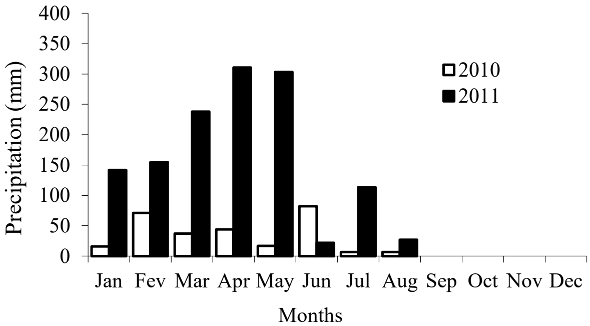

Figure 1 - Total monthly rainfall in 2010 and 2011 in the municipality of Taperoá, PB, Brazil.

TABLE I
Physicochemical characteristics of a Fluvic Entisol before application of organic fertilizers and planting of sunflower and cotton in the municipality of Taperoá, PB, Brazil.

Characteristics	Fluvic entisol
pH (H_2O)	6.74
extractable P (mg kg^{-1})	299
extractable K (cmol$_c$ kg^{-1})	0.25
extractable Ca (cmol$_c$ kg^{-1})	3.95
extractable Mg (cmol$_c$ kg^{-1})	0.62
extractable Na (cmol$_c$ kg^{-1})	0.10
Al (cmol$_c$ kg^{-1})	0.00
Al + H (cmol$_c$ kg^{-1})	1.32
SB (cmol$_c$ kg^{-1})	4.92
CEC at pH 7.0 (cmol$_c$ kg^{-1})	6.24
Effective CEC (cmol$_c$ kg^{-1})	5.02
V(%)	78.0
TOC (g kg^{-1})	8.80
TN (g kg^{-1})	0.50
Sand (g kg^{-1})	532
Silt (g kg^{-1})	203
Clay (g kg^{-1})	265

plot near the experimental area, sliced into pieces of approximately 5-10 cm and applied on the same day they were collected. Manure was collected every year during the dry season from neighboring farms and stored for six months until applied in the planting of the subsequent rainy season. The chemical characteristics of these fertilizers (Table II) were determined according to the methodology described by Embrapa (1997).

Fertilizers applied to the soil before planting were placed on the soil surface and manually incorporated to a depth of 10 cm with the aid of a hoe. This fertilization management had been applied for four consecutive years previous to the present study (2006-2009) when a study with beans and/or maize crops was conducted. The present study, therefore, added two more years (2010 and 2011) of the same treatments in the same plots to test the responses of sunflower and cotton crops. During the whole period (2006 to 2011) the experiments were initiated shortly after the first rains, usually around February and March.

Lignin was determined by the acid detergent fiber method (Van Soest 1963) and total soluble polyphenols according to Anderson and Ingram (1999). Carbon concentration was determined by wet oxidation with potassium dichromate and sodium hydroxide (Snyder and Trofymow 1984); nitrogen by the Kjeldahl method (Bremner and Mulvaney 1982); total phosphorus by sulfuric digestion and colorimetry; total potassium by sulfuric digestion and flame photometry and calcium and magnesium by atomic absorption (Embrapa 1997).

Pre-dried manure with ash content equivalent to 40% and fresh gliricidia biomass were applied at doses of 20 Mg ha^{-1} in treatments with isolated applications, and 10 Mg ha^{-1} of manure and 10 Mg ha^{-1} of gliricidia in combined application treatments. The dose of 20 Mg ha^{-1} of gliricidia corresponds to 4.6 of dry matter and 142.6, 24.8 and 96.6 kg ha^{-1} of N, P, and K, respectively. The manure dose corresponds to 14 Mg ha^{-1} of dry matter and 120, 55.0, and 270.0 kg ha^{-1} of N, P, and K, respectively. These doses of fertilizer were used because they are most widely adopted in organic fertilization in the study region.

The size of the experimental plots was 5 x 8 (40 m^2) with 1 meter of border in each side and working area was 30 m^2. The planting space in the intercropping with sunflower and cotton was 1 m

TABLE II
Chemical characterization of organic fertilizers used in the experiment for cultivation of sunflower and cotton in the municipality of Taperoá, PB, Brazil.

Materiais	PF*	Lig	TOC	N	P	K	Ca	Mg	C/N
	.............%..............		................................gkg^{-1} dry matter						
Gliricidia	2.1	13.1	385	31.0	5.4	21.0	21.0	4.5	12.4
Manure	-	18.6	125	12.0	5.5	27.0	27.0	6.2	10.4

*PF = polyphenols; Lig = lignin; TOC = total carbon; N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = Magnesium; C/N carbon nitrogen relation (Primo et al. 2011).

between holes and 1 m between rows, alternating crops. At sowing, six seeds per hole were placed and later thinning was performed, keeping only four seedlings per hole, totaling 20,000 cotton plants and 20,000 sunflower plant per ha. Three cleanings to remove weeds were performed with hoes along each crop cycle.

Sunflower was harvested 120 days and cotton 150 days after planting. The difference of 30 days for the harvest of the two crops is due to longer period of crop physiological maturity required for cotton. All sunflower plants were collected, separating straw and seeds, and cotton plants were separated into straw, fiber and seeds in both growing seasons. The straw from 15 randomly selected sunflower and cotton plants of each plot were chopped and, for each crop, the material from the 15 plants was ground and combined to form a composite sample for chemical characterization. Straw and seed subsamples were oven dried at 65°C and ground in a Wiley mill. Aliquots of 0.25g of these subsamples were digested with sulfuric acid and hydrogen peroxide (Thomas et al. 1967), and N concentrations were determined by the Kjeldahl method (Bremner and Mulvaney 1982), total phosphorus by colorimetry and total K by flame photometry (Embrapa 1997).

Total biomass was calculated as the sum of dry straw, seeds with 12% moisture content and fiber biomass. The accumulations of nutrients (kg ha^{-1} of N, P, and K) in straw and seeds were calculated based on the nutrient concentration and the total biomass produced. The harvest index was calculated as the ratio between the dry mass of grains and the total dry aboveground biomass.

Data were submitted to analysis of variance using a mixed-model ANOVA with year as a fixed effect and timing and placement as random effects. A probability level of $\alpha = 0.05$ was used for all tests. Post-hoc mean separation was done using the Tukey post-hoc test for equal sample size using the Sisvar statistical software (Ferreira 2003). Data corresponding to the two years of cultivation were analyzed separately for each crop.

RESULTS AND DISCUSSION

SUNFLOWER PRODUCTIVITY

Sunflower straw productivity in the first year (2010) was highest in GI, MI + GI and MI + GS treatments (Table III). Grain yield was greatest in the gliricidia incorporated (GI) treatment. In the second year (2011), the highest straw yield occurred in this same treatment and grain yield in GI, MI and MI + GS treatments. Almost all of these treatments with high productivities included gliricidia applied on the soil surface or incorporated into the soil.

Straw yields were ten times higher in the second (1080-3166 kg ha^{-1}) than in the first year (227-358 kg ha^{-1}) while grain yield increased by about three times (from 68-123 kg ha^{-1} to 235-376 kg ha^{-1}). These yield increases were probably due to the higher rainfall, which was 1.310 mm in 2011 and only 261 mm in 2010 (Figure 1). The low yields in the first year were also explained by the irregular rainfall during the crop cycle, especially in the month of flowering (May), when it rained only 28 mm and in a single day. Rainfall is the factor that most interferes with the growth phase of sunflower (Aguirrezabal et al. 2001). On the other hand, rainfall in the second year was above the historical average and regularly distributed (Figure 1). It is also important to mention that, in the present study, manure and gliricidia were applied for six consecutive years (2006-2011), possibly generating residual effects and hence increased nutrients release over time, and this may also have affected yields in the wet season of 2011.

Grain yields were lower than the regional average in Northeastern of Brazil (1500 kg ha^{-1}). However, it must be considered that the plant density in the intercropping system used in this study was 20,000 $plants.ha^{-1}$, far below the common density of 80,000 plants ha^{-1} in single crops systems. Freire et al. (2007), in the Agreste and Mata regions of the State of Paraíba, obtained productivities ranging from 1000 to 1500 Mg ha^{-1}, but with higher rainfall and higher planting density.

Total sunflower biomass production (straw and grain) in the first year varied among treatments from 295 to 466 kg ha^{-1} and in the second year from 1,323 to 3,542 Mg ha^{-1} and was higher in GI and MI + GS treatments in the first year and in GI treatment the second year (Table III). The total yield in 2011 was lower than that obtained by Jesus (2012) in studies with sunflower in the semiarid region of Paraíba (7850 Mg ha^{-1}) in fields fertilized with cattle manure and gliricidia, but in this case sunflower was not intercropped, and the plant density was three times higher than our intercropped system. The yields of the present study were also lower than those reported by Tomich et al. (2004) in Minas Gerais (3600 to 7700 Mg ha^{-1}), in southeastern Brazil, with thirteen sunflower cultivars planted during the off-season.

Recalculating the yields on the same plant density to allow a comparison with these Minas Gerais results (Tomich et al. 2004), the biomass

TABLE III
Straw, grain and total biomass (straw and grain) production and harvest index HI of sunflower in two consecutive years after different application systems of organic fertilizers in a fluvic entisol in Taperoá, Paraíba, Brazil.

Fertilizers	Straw		Grains		Total production		HI	
	........kg DM ha^{-1}........						%	
	2010	2011	2010	2011	2010	2011	2010	2011
GI	328 aB[1]	3166 aA	123 aB	376 aB	451 aB	3542 aA	31 aA	11 bB
GS	262 bB	2544 bA	98 bB	303 bA	360 bB	2847 bA	27 bA	11 bB
MI+GI	318 aB	1717 dA	104 bB	257 bA	423 bB	1974 cA	25 bA	13 bB
MI+GS	358 aB	2285 cA	107 bB	324 aA	466 aB	2609 bA	23 bA	13 bB
MI	282 bB	2365 cA	100 bB	370 aA	382 bB	2735 bA	28 bA	13 bA
T	227 cB	1080 eA	68 cB	235 cA	295 cB	1323 dA	23 c A	18 aA
VC (%)	39.47	26.86	41.87	23.70	33.77	22.48	40.65	36.75

GI - gliricidia incorporated into the soil before planting; GS - gliricidia applied on the soil surface 45 days after planting; MI + GI - Gliricidia + manure incorporated before planting; MI + GS - manure incorporated before planting and Gliricidia applied on the soil surface 45 days after planting; MI - manure incorporated before planting; T - control treatment without fertilizer and VC - variation coefficient. Lowercase letters in the column compare treatments and capital letters in the line compare years. [1]Means followed by the same letter do not significantly differ by the Tukey test at 5% probability.

productivity in 2011 was of the same order (4000 to 6000 t ha^{-1}) and above the mean yield for northeastern Brazil. This result was due to the high rainfall rate that increased the size of plants, which reached about two meters high, favoring vegetative growth and consequently higher biomass.

The highest total biomass yield with the application of gliricidia can certainly be associated with the high N concentration present in gliricidia and its rapid mineralization, as demonstrated in other previous studies in the same region (Mundus et al. 2008, Giacomini et al. 2007). The N supply during the rapid growth phase of sunflower is of fundamental importance since the highest nutrient uptake rate occurs shortly after the formation of flower buds up to the end of flowering (Castro et al.1997). Application of large amounts of N in the initial development period is not recommended as it can cause rapid shoot growth without a proportional grain yield increase (Larcher 2000).

The harvest indexes of sunflower (Table III) were significantly different among fertilization systems and cultivation years. They were higher in 2011 than in 2010 and higher in GI treatments in 2010 and T in 2011 but with very different values, 31 and 18%, respectively. The harvest index of sunflower usually varies between 25 and 35% (Castro and Farias 2005).

COTTON PRODUCTIVITY

Cotton straw productivity in the first year was significantly higher in MI + GS treatment and in the second year in GI, MI + GS and MI treatments (Table IV). Cotton seed productivity in the first year was higher in MI + GI and MI + GS treatments and in the second year in GS and MI + GI treatments. Fiber productivity was higher in GI, MI + GI and MI + GS treatments in the first year and in GS, GI and MI treatments in the second year.

Garrido (2009) in the semiarid region of Paraíba with intercropped cotton at double the density in our study and organic fertilization found higher seed yield (639 kg ha^{-1}) than in our study, (180 kg ha^{-1}).

The highest total cotton biomass (straw, seed, and fiber) obtained in this study ranged between 562 and 594 kg ha^{-1} (Table IV). Yields between 400 and 1600 kg ha^{-1} were obtained by Silva et al. (2005) in monocropping system with application of cattle manure in the Seridó region, of Paraíba State. A similar response was observed by Garrido (2009), which evaluated an intercropping system with cotton, corn and beans, and reported cotton total biomass yields that ranged between 2487 and 3906 Mg ha^{-1} after fertilization using cattle manure and gliricidia, but with plant density twice of that applied in the present study.

GI and MI + GI treatments in the first year and MI + GI and GS in the second year had harvest indexes higher than the other treatments. In the first year, indexes were between 15 and 28%, similar to 14 and 26% found by Garrido (2009) in intercropping system with cotton, corn and beans in the semiarid region of Paraíba. In the second year, the harvest indexes were higher, between 30 and 37%, clearly due to increased seed and fiber productivity.

Cotton plants have secondary growth, as those of sunflower, but apparently, their development was not impaired when intercropped with sunflower under the conditions of this study, suggesting the feasibility of the intercropping management system adopted.

NUTRIENT ACCUMULATION BY THE CROPS

Nutrient accumulation in both cotton and sunflower crops differed among fertilization systems and cultivation years (Table V). The greatest N accumulation in both cotton and sunflower in the first year was obtained with manure incorporated before planting and gliricidia prunings applied on the soil surface 45 days after planting (MI + GS).

TABLE IV
Straw, seed fiber and total production and harvest index of cotton in two consecutive years after different application systems of organic fertilizers in a Fluvic Entisol.

Fertilizer	(1)Prod. Straw		Seed		Fiber		Total production		HI Seed		HI Fiber	
	kg.ha^{-1}								%		%	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
GI	72 cB[2]	270 aA	32 bB	161 bA	22 aB	101 bA	122 bB	533 bA	26 aB	30 bA	17aA	18aA
GS	93 bB	236 bA	19 cB	220 aA	13 cB	137 aA	126 cB	594 aA	16 cB	36 aA	11cB	23aA
MI+GI	101 bB	228 bA	45 aB	212 aA	20 aB	122 aA	166 bB	562 aA	28 aB	37 aA	13bB	21aA
MI+GS	139 aB	254 aA	38 aB	164 bA	21 aB	101 bA	198 aB	519 bA	19 bB	32 bA	11cB	19aA
MI	65 cB	281 aA	14 dB	165 bA	10 dB	92 bA	88 dB	538 bA	15 cB	31 bA	11cB	17aA
T	96 bB	242 bA	21 cB	162 bA	16 bB	83 bA	132 cB	487 bA	16 cB	34 bA	12bB	18aA
VC (%)	29.05	28.24	6.61	28.57	2.07	28.62	19.55	22.05	21.77	19.24	19.01	18.36

(1)Prod. = Productivity; HI = harvest index. GI - gliricidia incorporated into the soil before planting; GS - gliricidia applied on the soil surface 45 days after planting; MI + GI – Gliricidia + manure, incorporated into the soil before planting; MI + GS - manure incorporated before planting and Gliricidia applied on the soil surface 45 days after planting; MI - manure incorporated before planting; T - control treatment without fertilizer and VC - variation coefficient. Lowercase letters in the column compare treatments and capital letters in the line compare years. [2]Means followed by the same letter do not significantly differ by the Tukey test at 5% probability.

TABLE V
Nitrogen accumulation (N), phosphorus (P) and potassium (K) in total biomass of cotton and sunflower in two consecutive years under different organic fertilization systems in the municipality of Taperoá, PB, Brazil.

Fertilizer	N		P		K	
	kg ha^{-1}					
2010						
	Cotton	Sunflower	Cotton	Sunflower	Cotton	Sunflower
GI	2.9 bB[1]	7.2 bB	0.2 cB	0.7 bB	2.0 bB	18.3 aB
GS	2.5 bB	6.8 bB	0.2 dB	0.7 bB	2.3 bB	17.5 bB
MI+GI	3.7 aB	7.3 bB	0.3 bB	0.9 aB	2.7 bB	16.3 bB
MI+GS	3.9 aB	8.2 aB	0.4 aB	0.8 aB	3.4 aB	19.3 aB
MI	1.6 cB	7.0 bB	0.1 dB	0.8 bB	1.8 cB	12.8 cB
T	2.8 bB	4.7 cB	0.2 cB	0.5 cB	2.2 bB	12.4 cB
VC (%)	23.14	35.64	22.71	39.93	28.96	43.47
2011						
GI	15.3 aA	70.5 aA	10.3 aA	12.6 aA	8.7 bA	104.6 aA
GS	17.6 aA	58.8 bA	11.6 aA	10.1 aA	9.7 aA	78.1 bA
MI+GI	17.6 aA	36.7 cA	10.3 aA	7.5 bA	7.5 bA	55.0 bA
MI+GS	15.5 aA	47.2 bA	11.4 aA	9.0 bA	7.6 bA	80.5 bA
MI	17.7 aA	52.4 bA	11.9 aA	8.9 bA	8.4 bA	85.8 bA
T	13.5 bA	23.5 dA	9.4 bA	4.5 cA	8.1 bA	36.1 cA
VC (%)	22.15	17.11	32.98	27.37	29.71	33.58

GI - gliricidia incorporated into the soil before planting; GS - gliricidia applied on the soil surface 45 days after planting; MI + GI – Gliricidia + manure incorporated before planting; MI + GS - manure incorporated into the soil before planting and Gliricidia on the soil surface 45 days after planting; MI - manure incorporated into the soil before planting; T - treatment without fertilizer and VC - variation coefficient. Lowercase letters in the column compare treatments and capital letters in the line compare years. [1]Means followed by the same letter do not significantly differ by the Tukey test at 5% probability.

This combination of fertilizers is considered the most suitable management due to the possibility of applying manure accumulated in the corral during the dry season and gliricidia shoots that sprout after the first rains.

The period of greatest nutritional demand by cotton occurs up to 50 days after germination (Beltrão and Carvalho 2004) and by sunflower up to 45 days after germination (Tomich et al. 2004). The lower N accumulation in cotton in the first year obtained with the application of manure incorporated into the soil (MI), even lower than in the control treatment (Table V), was probably due to the immobilization of nutrients during the period of greatest demand by the plants and the microbes competing with the plants. Silva and Menezes (2007) claimed that nitrogen in the manure is only released a few weeks after its incorporation.

Accumulations of N in cotton in the second year did not differ among fertilization treatments but were higher than that of the control treatment. In sunflower, N accumulation in the GI treatment was higher than that in the other treatments (Table V). This can be justified by the high nitrogen concentration and plant decomposition of the gliricidia biomass, which increased the supply in the period of greatest nutritional demand by the crop. The use of gliricidia prunings as green manure can be an important strategy for agricultural systems of the semi-arid region by increasing the supply of nutrients, especially N, and because the species has a high biological fixation N efficiency (Salton et al. 2011).

The highest accumulations of P for both crops occurred in plots that received incorporated manure and gliricidia on the soil surface 45 days after planting (MI + GS). In this case, P accumulation increased 20% for cotton and 56% for sunflower compared to the control treatment. This greater P accumulation may be due to the N released from decomposition of GS, which may have enhanced microbial activity and released inorganic P to the soil solution. In the second year, there were no significant differences among treatments for cotton, while for sunflower, GI and GS treatments were higher, increasing P accumulation by 181% and 126% compared to the control treatment (Table V).

The highest accumulation of K found in the biomass of cotton shoots in the first year occurred in MI + GS and MI + GI treatments and for sunflower in GI and MI + GS treatments, which differed from the other treatments. In the second year, the GS treatment resulted in greater accumulation of K for cotton and the GI treatment for sunflower (Table V). The highest accumulation of P and K in the first year occurred in fertilization treatments with manure.

CONCLUSIONS

The relatively recent fertilization practice of using gliricidia prunings as green manure combined with the traditional fertilization practice with cattle manure is a strategy that has the potential for increasing cotton and sunflower productivities in low-input agricultural systems under semi-arid conditions, such as the area of the present study. This high quality, N-rich legume species may act as an N source of rapid decomposition and fast supply compared with cattle manure.

Considering both crop responses and fertilizer availability in the farms throughout the year, the treatment that combined both cattle manure incorporated into the soil before planting (since it accumulates in the corral during the dry season) and gliricidia applied on the soil surface 45 days after planting (since it has time to sprout after the first rains) was the most viable management strategy.

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REFERENCES

AGUIRREZABAL LAN, ORIOLI GA, HERNÁNDEZ LF, PEREYRA VR AND MIRAVÉ JP. 2001. El rendimiento y sus componentes. In: Girassol - Aspectos fisiológicos que determinan el rendimiento. INTA, Buenos Aires, Argentina, p. 10-15.

ANDERSON JM AND INGRAM, JSI. 1999. Tropical soil biology and fertility: a handbook of methods, 2nd ed., CAB International, 221 p.

BARRETO AC AND FERNANDES MF. 2001. Cultivo de *Gliricidia sepium* e *Leucaena leucocephala* em alamedas visando a melhoria dos solos dos tabuleiros costeiros. PAB-Pesquisa Agropecuária Brasileira 36: 1287-1293.

BELTRÃO NEM AND CARVALHO LP. 2004. Algodão colorido no Brasil, e em particular no Nordeste e no Estado da Paraíba. Campina Grande-PB, 17 p. (Embrapa Algodão. Documentos, 128).

BREMNER JM AND MULVANEY CS. 1982. Nitrogen total. In: Page AL, Miller RH and Keney DR (Eds), Methods of soil analysis: Chemical and microbiological properties, 2nd ed., Madison: ASA 31: 595-624.

CASTRO C, CASTIGLIONI VBR, BALLA A, LEITE RMVBC, MELO HC, GUEDES LCA AND FARIAS JR. 1997. A cultura do girassol. Londrina: EMBRAPA-CNPSo, 36 p. (Circular Técnica, 13).

CASTRO C AND FARIAS JRB. 2005. Ecofisiologia do girassol. In: Campos Leite RV (Ed), Girassol no Brasil. Londrina: CNPSo, p. 163-218.

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. 1997. Embrapa solos, Embrapa Informática Agropecuária. Manual de análises químicas de solos, plantas e fertilizantes. Brasília: Embrapa Comunicação para transferência de tecnologia, 370 p.

EMBRAPA. 2006. Sistema brasileiro de classificação de solos, 2a ed., Rio de Janeiro: Embrapa Solos, 306 p.

FERREIRA DF. 2003. Sisvar: versão 4.6. Lavras: DEX/UFLA. Software.

FREIRE AL, MENINO IB, BELARMINO FILHO J AND NETO MB. 2007. Sistema de produção do girassol para as mesorregiões do Agreste Paraibano e da Mata Paraibana. João Pessoa: EMEPA, 17 p.

GARRIDO MS. 2009. Adubação com gliricídia e esterco em culturas do semiárido nordestino. Recife: UFPE-PROTEN, 80 p. Tecnologias Energéticas e Nucleares. Tese de Doutorado.

GIACOMINI SJ, RECOUS S, MARY B AND AITA C. 2007. Simulating the effect of N availability, straw particle size and location in soil on C and N mineralization. Plant Soil 301: 289-301.

HANDAYANTO E, CADISH G AND GILLER KE. 1994. Nitrogen release from prunings of legume trees in relation to quality of the prunings and incubation method. Plant Soil 160: 237-248.

JESUS KN. 2012. Produção de girassol em um Neossolo Flúvico sob adubação orgânica no semiárido paraibano. Recife: UFPE-PROTEN, 82 p. Tecnologias Energéticas e Nucleares. Tese de Mestrado. (Unpublished).

LARCHER W. 2000. Ecofisiologia vegetal. São Carlos: Rima, 531 p.

MARIN AMP, MENEZES RSC, SILVA ED AND SAMPAIO EVSB. 2006. Efeito da *Gliricidia sepium* sobre nutrientes do solo, microclima e produtividade do milho em sistema agroflorestal no Agreste paraibano. Rev Bras Ciênc Solo 30: 555-564.

MENEZES RSC AND SALCEDO IH. 2007. Mineralização de N após incorporação de adubos orgânicos em um Neossolo Regolítico cultivado com milho. Agriambi 11: 361-367.

MUNDUS S, MENEZES RSC, NEERGAARD A AND GARRIDO MS. 2008. Maize growth and soil nitrogen availability after fertilization with cattle manure and/or gliricidia in semiarid NE Brazil. Nutr Cycl Agroecosyst 82: 61-73.

PALM CA, CATHERINE N, GACHENGO RJ, DELVE G AND CADISCH KE. 2001. Organic inputs for soil fertility management in tropical agroecosystems: aplication of an organic resource database. Agric Ecosyst Enviro 83: 27-42.

PRIMO DC, MENEZES RSC AND SILVA TO. 2011. Substâncias húmicas da matéria orgânica do solo: uma revisão de técnicas analíticas e estudos no nordeste brasileiro. Scientia Plena 7: 1-13.

SALTON JC, MIELNICZUK J, BAYER C, FABRÍCIO AC, MACEDO MC AND BROCH DL. 2011. Teor e dinâmica do carbono no solo em sistemas de integração lavoura-pecuária. Pesq Agropec Bras 46: 1349-1356.

SEVERINO LS, FERREIRA GB, MORAES CRA, GODIN TMS, CARDOSO GD, VIRIATO JR AND BELTRÃO NEM. 2006. Produtividade e crescimento da mamoneira em resposta à adubação orgânica e mineral. Pesq Agropec Bras 14: 879-882.

SILVA MNB, BELTRÃO NEM AND CARDOSO GD. 2005. Adubação do algodoeiro colorido BRS 200 em sistema orgânico no Seridó paraibano. Rev Bras Eng Agríc Ambient 9: 222-228.

SILVA TO AND MENEZES RSC. 2007. Adubação orgânica da batata com esterco e, ou, crotalaria juncea. II-Disponibilidade de N, P e K no solo ao longo do ciclo de cultivo. Rev Bras Ciênc Solo 31: 51-61.

SNYDER JD AND TROFYMOW JA. 1984. A rapid accurate wet oxidation diffusion procedure for determining organic and inorganic carbon in plant and soil sample. Comm Soil Science Plant Analysis 15: 587-597.

TIESSEN H, SAMPAIO EVSB AND SALCEDO IH. 2001. Organic matter turnover and management in low input agriculture of NE Brazil. Nutr Cycl Agroecosyst 61: 99-103.

THOMAS RL, SHEARD RW AND MOYER JR. 1967. Comparision of conventional and automated procedures

for N, P and K analysis of plant material using a single digestion. Agron J 59: 240-243.
TOMICH TR, PEREIRA LGR AND GONÇALVES LC. 2004. Alimentos volumosos para o período seco - I: Silagem de girassol. Corumbá: Embrapa Pantanal, 30 p.
VAN SOEST PJ. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J Assoc Off Anal Chem 46: 829-835.
ZOBIOLE LHS, CASTRO C, OLIVEIRA FA AND JUNIOR AO. 2010. Marcha de absorção de macronutrientes na cultura do girassol. Rev Bras Ciênc Solo 34: 425-433.