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Organic fertiliser and the use of mulch in cowpea production under semiarid conditions[1]

Adubação orgânica e utilização da cobertura morta na produção do feijão caupi em condições semiáridas

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ABSTRACT - The reduction on crop production observed in semiarid conditions is closely linked to soils degradation in their physical, microbiological and fertility aspects. Based on this premise, the effects of different types of organic fertilizers associated to the use of mulching in the production of cowpea grown in Paraíba state, Brazil, under semiarid conditions, was studied. The research was conducted under field conditions in the municipality of Casserengue, PB, from April to July 2010. The statistical design in randomized block design with five treatments and five replicates was used, totaling 25 experimental units. Treatments consisted on application of cattle manure or biofertilizer on presence or absence of mulch, plus a control treatment, without fertilization or mulching. It was found that cowpea plants grown under the interaction between manure and mulch had higher phytomass and grain production.

Key words: Brazilian semiarid. Cattle manure. Biofertilizer.

RESUMO - A redução na produção das culturas, observada em condições semiáridas, está intimamente associada à degradação dos solos em seus aspectos físicos, microbiológicos e de fertilidade. Alicerçado nesta premissa, buscou-se com o presente trabalho estudar os efeitos de diferentes tipos de adubação de origem orgânica associadas à utilização de cobertura morta na produção do feijão caupi, cultivado no semiárido paraibano. A pesquisa foi desenvolvida em condições de campo, no município de Casserengue, PB, no período de abril a julho de 2010. Foi utilizado delineamento estatístico em blocos ao acaso, com cinco tratamentos e cinco repetições, totalizando 25 unidades experimentais. Os tratamentos consistiram na aplicação do esterco bovino ou do biofertilizante na presença ou ausência de cobertura morta, além de um tratamento testemunha, sem adubação e sem cobertura morta. Verificou-se que as plantas de feijão caupi cultivadas sob a interação entre o esterco bovino e a cobertura morta apresentaram maiores índices de produção de fitomassa e de grãos.

Palavras-chave: Semiárido Brasileiro. Esterco Bovino. Biofertilizante.

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INTRODUCTION

Producing food under semiarid conditions requires the adoption of suitable practices in the use and management of the soil, since continuous withdrawal of products from cultivated areas without replacement of nutrients leads to a reduction in fertility, intensifying the processes of degradation in agro-ecosystems (BRITO *et al*., 2012). As a result, the development of forms of nutrient replacement, and of soil conservation practices that consider the characteristics of semiarid regions, and at the same time maintain levels of agricultural production while conserving the physical, chemical and microbiological properties of soils in the region, become essential.

For rainfed crops, a situation which is commonly found in the semiarid region of the State of Paraiba, the association of rainfall with edaphic qualities, and its impact on water content and soil solution, acts as a catalyser for the processes of leaching, volatilisation and/or the precipitation of nutrients, hindering the management of mineral fertilisation, and resulting in impacts on the environment that reduce the productive capacity of the soil. In contrast, the use of organic waste as fertiliser under appropriate management increases the ability of the soil to store water and nutrients, and results in improvements to the soil structure (BARROS *et al*., 2009).

Crop production under different types of organic fertiliser has been studied by several authors (BARROS *et al.*, 2009; LEITE *et al.*, 2009), who suggest organic materials as an alternative to mineral fertilisers when the intention is to improve the chemical, physical and microbial attributes of the soil (GRUTKA *et al*., 2012). Among these materials, Mata *et al*. (2010) point out that cattle manure has the potential for use as a fertiliser, especially by small farmers. Another fertiliser, mentioned by different authors (DIAS *et al*., 2011; GONDIM *et al.*, 2010), is biofertiliser, a by-product of the process of biogas production by the anaerobic fermentation of organic waste. Pereira *et al*. (2010) add that when applied to the leaves, biofertilisers can be used as supplements to fertilisers applied to the soil, and in the more rapid correction of possible deficiencies.

Many management techniques can be employed in relation to soil conservation. Pimentel *et al*. (2011) state that the use of plant mulch, because it is simple and effective, is an economical way of reducing the damage caused by the erosive action of rainfall, as it protects the soil from the direct impact of the raindrops and reduces the speed of surface runoff, also favouring the process of water infiltration into the soil profile and the reduction of water loss through evapotranspiration (PIMENTEL *et al.*, 2011; SILVA *et al.*, 2012).

Despite the promising results in the use of biofertiliser and manure in agriculture, results relating the effects of the interaction between different types of organic fertiliser and the use of mulch in the production of the cowpea are still scarce in the literature, for the specific conditions of the semiarid region of Paraiba. In this region, the crop is of high social importance, despite the low level for average productivity of 382 kg ha^{-1} (SANTOS *et al*., 2009). Currently, the northeast region is the main producer of this legume in Brazil, with an estimated area of 55.8 million hectares (BORGES *et al*., 2012).

Based on the above information, this study sought to evaluate the effects of organic fertiliser and mulching on the productivity of the cowpea under semiarid conditions.

MATERIAL AND METHODS

Spatial, temporal and climatic conditions of the experiment

The experiment took place from April to July 2010, and was located in a rural area (community of Salgado) of the municipality of Casserengue, in the semiarid *Agreste* region of the State of Paraiba (PB). The climate is classified as Bsh under the Köppen system of climate classification adapted for Brazil. The experimental area is located at 06°46’58” S and 35°49’15” W, at an average altitude of 635 m. The region presents a hot climate, with summer rains concentrated from March to July, and an accumulated average annual rainfall of 412 mm (Table 1). The average temperature varies between 20 and 35 °C, and the relative humidity between 60 and 75% (EFSA, 2013).

Experimental design and treatments

The experimental design was in randomised blocks, with five treatments and five replications. The treatments were: (*i*) cultivation with no fertiliser (control) and no mulching - C; (*ii*) foliar application of 500 L biofertiliser solution ha^{-1} - BF; (*iii*) application of 20 t manure ha^{-1} - CM; (*iv*) foliar application of 500 L biofertiliser solution ha^{-1} + uniform distribution of 10 t mulch ha^{-1} - BF+MH and (*v*) application of 20 t manure ha^{-1} + uniform distribution 10 t mulch ha^{-1} - CM+MH.

The soil of the experimental area was classified as a Regolithic Neosol (EMBRAPA, 2006). The area was divided into five blocks, with five plots, one for each specific treatment; a total of 25 plots of 5.0 x 4.0 m, covering an area of 20 m^2 $plot^{-1}$ and a total area of 500 m^2. The experimental unit consisted of four rows, 5.0 metres in length, spaced 1.0 m between rows and 0.50 m between

Table 1 - Monthly and annual average rainfall (mm) from January 2005 to December 2010, in Casserengue, PB

YEAR	2005	2006	2007	2008	2009	2010
Month	Rainfall (mm)					
January	23.30	0.00	16.20	30.40	37.90	89.80
February	6.30	2.30	44.00	0.10	41.30	42.40
March	43.90	86.60	32.10	208.90	21.00	19.00
April	26.20	88.70	74.90	83.40	78.00	129.90*
May	51.70	32.00	35.20	48.30	114.80	18.20*
June	78.90	69.10	101.80	49.70	52.80	18.20*
July	13.90	10.30	19.10	70.00	84.40	24.60*
August	33.50	21.70	13.50	58.50	60.90	17.80
September	3.40	2.80	19.90	6.40	2.30	4.00
October	1.80	0.60	2.50	1.00	6.30	30.30
November	0.00	4.60	10.30	0.00	0.10	0.60
December	21.20	9.10	8.40	0.30	6.30	4.60
Accumulated	304.10	327.80	377.90	557.00	506.10	399.40

Source: AESA, 2013. *Observed rainfall for the experimental period

plants, with the 2 central rows being subdivided for sampling.

The manure was from cattle, at an estimated dose of 20 t ha^{-1} of well-rotted manure, distributed over the surface and then incorporated into the soil at a depth of 0.5 cm. The results of the chemical analysis of the manure can be found in Table 2.

The biofertiliser was anaerobically prepared for 35 days in a 200 L plastic drum, according to the methodology proposed by Claro (2001), using different organic materials (cattle manure, poultry manure, wood ash, cow's milk, *rapadura* [a block of unrefined cane sugar], and green plants), and then strained through fine mesh sieves. In preparing the biofertiliser solution, a ratio of 10 L biofertiliser to 100 L water was used, and uniformly applied at 1 L per 20 m^2, corresponding to 500 L h^{-1} (Table 3).

Application of the biofertiliser solution to the leaves was in three phases, and took place at different growth stages in the crop. The first application was with the appearance of the expanded primary leaves (V_2); the second took place with the emergence of the flower buds at pre-flowering (R_5); the third application took place at the grain-filling stage (R_8). Spraying was always carried out between 06:00 and 08:00 hours, thereby avoiding the hours of high insolation and wind.

Table 2 - Chemical composition of the manure used

N	P_2O_5	K_2O	O.M.	C/N
g kg^{-1}				
7.20	3.60	4.10	182.07	14/1

Table 3 - Chemical composition of the biofertiliser used

N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	O.M.
g L^{-1}											
0.41	0.10	0.36	0.14	0.15	0.66	1.70	1.13	27.24	19.06	2.11	19.02

The mulch used came from crop residue and from the herbaceous strata obtained when weeding cultivated areas near the experimental area. After collection, the material was air dried and homogenised by applying an estimated quantity of 10 t ha^{-1}, distributed at a ratio of 20 kg for each experimental plot of 20 m^2. Distribution of the material in the plots took place after weeding out the cowpea for the second time, when the plants had reached between 18 and 22 cm in height, and formed a layer, 5 to 10 cm above the surface of the soil.

Preparation of the soil, planting, thinning and crop treatments

Preparation of the soil consisted of mechanised ploughing with a disc-plough. To analyse soil fertility, random trenches were dug for the collection of 20 sub-samples at a depth 0-20 cm; these were mixed together and homogenised, resulting in a composite sample, which was sent to the Laboratory of the Department of Soil Science and Rural Engineering at the Centre for Agricultural Sciences of UFPB in Areia, PB, for analysis following a methodology by EMBRAPA (1999). This procedure was carried out before implementing, and at the end of the research. The soil in the area presented the following chemical characteristics before implementation of the experiment (Table 4).

Table 4 - Chemical characteristics of the soil before implementation of the experiment

Parameters analysed	Values obtained
Organic Matter (g kg^{-1})	3.77
pH in water (1:2.5)	5.83
P^- Mehlich (mg dm^{-3})	6.96
K^+ (mg dm^{-3})	134.44
Na^+ ($cmol_c$ dm^{-3})	0.33
H^+Al^{+3} ($cmol_c$ dm^{-3})	0.16
Al^{+3} ($cmol_c$ dm^{-3})	0.00
Ca^+ ($cmol_c$ dm^{-3})	1.55
Mg^+ ($cmol_c$ dm^{-3})	1.25
V ($cmol_c$ dm^{-3})	74.95
M ($cmol_c$ dm^{-3})	0.00
SB ($cmol_c$ dm^{-3})	3.47
CTC ($cmol_c$ dm^{-3})	4.63

Seeds of the cowpea (*Vigna unguiculata* L.) cultivar pau-ferro, were obtained from areas adjoining the experiment, having been produced during the 2009 growing season. They were stored in plastic bottles, which at the time of sowing displayed 83% germination, a value obtained by preliminary testing. When sowing, five seeds were used per hole, at a spacing of 1.0 x 0.5 m in single rows; at 10 days after emergence (DAE) the plants were thinned, leaving three plants per hole in each plot.

During development of the crop, handling consisted of manual weeding, carried out twice with the help of hoes, with a view to keeping the crop free of weeds, and preventing competition for water, light and nutrients.

As regards plant health, four applications, based on natural products, were given as follows:

(i) At 15 DAE, neem oil (*Azadirachta indica*) was used in the proportion 100 ml of oil to 10 L of water, with a 1 L dose of the mixture applied per 20 m^2;

(ii) At 30 DAE, nettle extract (*Urtica urens* L.) was used: 1 kg of crushed green nettle mixed into 5 L of water, diluted in the proportion 1 L of concentrated extract to 10 L of water, with a 1 L dose of the mixture applied per plot;

(iii) At 45 DAE, lye water and lime were used: 1 kg of vegetable ash and 500 g of lime diluted in 5 L of water, with 1 L of the mixture added to 10 L of water. The plants were sprayed with a dose of 1 L of the mixture per plot;

(iv) At 60 DAE, onion extract (*Allium cepa* L.) was used: 1 kg of chopped onion added to 5 L of water (and left for 24 hours). 1 L of extract was used per 10 L of water, with a dose of 1 L of the mixture applied per plot.

Each application aimed at carrying out the preventive control of common pests in the cowpea crop, such as: the aphid, leafhopper, mealybug, caterpillar, ant and leaf beetle (SILVA *et al*., 2011).

Variables analysed

Production and bromatological composition of shoot biomass

At 45 DAE, the bromatological composition of shoot biomass was determined in the cowpea. The accumulation of dry matter (DM), the accumulation of ash (AH), crude protein (CP) and ether extract (EE) were all determined. The data were analysed based on the methodology proposed by Silva and Queiroz (2002).

At 90 DAE, the average production of pod phytomass after grain removal (PP), and the total production of dry phytomass by the plant (TDP) were evaluated.

Final phytomass production and bromatological composition of the grain

When harvesting, at 90 days DAE, the following variables were analysed: (*i*) number of pods per plant (NP) - ratio between the total number of pods in the usable area and the number of plants in the same area; (*ii*) number of grains per pod (NG) - average number of grains for 10 pods in the usable area; (*iii*) pod length (PL) - taking the length of the convex face of 10 pods in the usable area; and (*iv*) grain yield (GY) at 13% humidity - obtained from the ratio of the weight of grain produced to unit area.

After drying the grains in a forced ventilation oven at 60 °C to constant weight, average levels were measured for dry matter (LDM), crude protein (LCP), starch (LS), ether extract (LEE), calcium (LCa) and magnesium (LMg), for analysis of the bromatological composition (SILVA and QUEIROZ, 2002).

Analysis of the data

The results were submitted to variance analysis (ANOVA), with mean values compared by Tukey's test at 0.05% probability. Statistical analysis was performed using statistical software (FERREIRA, 2011).

RESULTS AND DISCUSSION

Production and bromatological composition of shoot biomass

The treatments under test did not significantly influence ($p>0.05$) the behaviour of DM, AS, CP or EE, however, the variables PP and TDP were significantly affected (Table 5).

There was no significant difference ($p>0.05$) in the behaviour of the TDP of those plants under BF and CM with no mulching. When comparing the TDP of cowpea plants fertilised with BF and CM with mulching, it can be seen that plants under CM produced a TDP 1.33 times greater than plants fertilised with BF, which can be attributed to enhancement of the moisture retention capacity of the soil by the CM, resulting from the combination of CM and mulch. The greatest indices for TDP were seen in those plants under CM+MH (1,690 kg ha^{-1}), a result 52.95% greater than the average observed for the control treatment. Leite *et al*. (2009), studying phytomass production in the cowpea under organic fertilisation in semiarid conditions, reported an increase of up to 76% compared to plants without any fertilisation.

Both the PP and the TDP achieved higher production rates when cowpea plants were cultivated under a combination of CM+MV. According to Silva *et al*. (2011), the CM acts as a powerful enhancing agent in the soil, capable of substantially improving many of the physical and chemical characteristics, promoting a reduction in soil density, improving permeability, infiltration and water retention, and minimising variations in soil temperature, extremely relevant in semiarid conditions (and increased when combined with mulch), as it results in reduced rates for evapotranspiration and consequently, more time for the retention and availability of moisture to the plants.

Plants fertilised with CM displayed a higher value for PP, with the plants with mulch producing 29% more compared to those grown without mulch. Under the action of BF, plants grown with mulch produced 1.17 times more PP than plants with no mulch. When comparing the results for PP as a function of the fertilisers being tested (both with mulch), it can be seen that the plants fertilised with CM produced 1.5 times more PP compared to plants under the biofertiliser. There was however a greater difference seen in PP (56%) when comparing plants under CM+MH, compared to the control.

Table 5 - Mean values for the accumulation of dry matter (DM), ash (AH), crude protein (CP) and ether extract (EE) for the flowering stage at 45 DAE, and total dry phytomass (TDP) and pod phytomass (PP) when harvesting at 90 DAE, in cowpea plants (cultivar pau-ferro) under the effects of fertilising with cattle manure or biofertiliser, both with and without mulching

Source of Variation	DM	AH	CP	EE	TDP	PP
	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	kg ha^{-1}	kg ha^{-1}
Control (C)	89.73 a	12.62 a	26.82 a	1.83 a	795 c	201 c
Biofertiliser (BF)	89.10 a	13.07 a	27.56 a	1.73 a	1.011 b	260 bc
Cattle Manure (CM)	89.77 a	12.63 a	26.17 a	1.96 a	1.219 b	327 b
BF + Mulch (BF+MH)	79.58 a	12.89 a	27.46 a	1.87 a	1.263 b	306 b
CM + Mulch (CM+MH)	87.52 a	14.16 a	26.85 a	2.13 a	1.690 a	461 a
CV(%)	11.55	8.83	8.17	20.06	26.70	19.13

Mean values followed by the same letter in a column do not differ at 5% probability by Tukey's test

Final phytomass production and bromatological composition of the grain

The treatments under test significantly influenced ($p<0.05$) the variables NP, NG, PL and GY (Table 6). There was no significant difference seen for the variable NP for the cowpea when fertilised with BF or CM, or when compared individually both with or without mulching; however, plants fertilised with CM+MH produced double the pods (an average of 12 units) compared to plants under the control treatment (an average of 6 units). Similar results were observed by Santos *et al.* (2009), who, when studying the production of cowpea varieties under organic fertiliser in the micro-region of Cariri in Paraiba, found an average for NP which varied from ten to seven pods per plant. Beltrão Júnior *et al*. (2012), combining mineral fertilisation with the application of biofertiliser from cattle manure, got an average yield of up to 11.5 pods per plant at a dose of 1 L biofertiliser m^{-2}.

There was no significant variation ($p>0.05$) in NG for the cowpea plants when comparing the treatments under fertilisation with CM and BF, both with or without mulch; However, the plants grown under organic fertiliser differed significantly from those under the control treatment, presenting a real gain in production of up to 10.25%. Alves *et al*. (2009), when evaluating growth performance in the common bean (*Vigna unguiculada* L. Walp.), for different doses and concentrations of biofertiliser under field conditions in the semiarid region of Paraiba, saw on average, 344.5 grains $plant^{-1}$ at a dose of 50 ml of biofertiliser, a result which is 51.9% higher than that observed under the best conditions (CM+MH) of the present study (165.7 grains $plant^{-1}$). These results show that, despite improving the physical characteristics of the soil, and retaining and making the moisture available for longer to the plants, cattle manure, even in combination with mulch, needs to be associated with other forms of nutritional supplementation that meet the requirements of the plants, and do not compromise their rates of production.

Similar behaviour to that for NG was observed for the variable PL; the results of testing the mean values (Table 6) indicate that there is no significant difference ($p>0.05$) for this variable in plants under the effect of organic fertilisation, regardless of the type being tested, or whether with or without mulch; however, the organic fertilisation associated with mulching resulted in gains of up to 9.63% compared to plants under the control treatment. Beltrão Júnior *et al*. (2012), in a similar way to the results seen here, did not find any variation in PL when the plants were subjected to different doses and concentrations of biofertiliser.

The cowpea plants grown under CM+MH showed an average yield of 1,093 kg grain ha^{-1} (GY), a result 19.3% higher than seen in the plants under BF+MH, being 1.12 and 1.28 times greater than the values found in the plants under CM and BF respectively, without mulch; however, the difference in GY in plants under the control treatment reached 49.67%. Santos *et al*. (2009), studying the behaviour of cowpea cultivars under the soil and climatic conditions of São João de Cariri, PB, found an average grain yield of 409 kg ha^{-1} in the pau-ferro cultivar.

No significant effect ($p>0.05$) was seen from the treatments under test on the variables LCP, LS, LEE and LCa in the cowpea grain, however the behaviour of the variables LDM and LMg was affected by the factors being tested (Table 7).

The largest indices for LDM in the grain were seen in those plants fertilised with cattle manure with no mulch

Table 6 - Mean values for the number of pods per plant (NP), number of grains per pod (NG), pod length (PL) and grain yield (GY) in cowpea plants (cultivar pau-ferro) at 90 DAE, under the effects of fertilisation with cattle manure or biofertiliser, both with or without mulch

Source of Variation	NP	NG	PL	GY
	Unit	Unit	cm	kg ha^{-1}
Control (C)	6.24 c	12.25 b	17.54 b	550 b
Biofertiliser (BF)	8.46 b	12.82 a	18.71 a	849 ab
Cattle Manure (CM)	10.13 ab	12.92 a	18.64 a	977 ab
BF + Mulch (BF+MH)	11.03 a	13.15 a	18.84 a	882 ab
EB + Mulch (CM+MH)	12.14 a	13.65 a	19.41 a	1.093 a
CV(%)	21.74	6.95	6.60	29.36

Mean values followed by the same letter in a column do not differ at 5% probability by Tukey’s test

Table 7 - Average levels for dry matter (LDM), crude protein (LCP), starch (LS), ether extract (LEE), calcium (LCa) and magnesium (LMg) in the grain of cowpea plants under the effects of fertilisation with cattle manure or biofertiliser, both with and without mulch

Source of Variation	LDM	LCP	LS	LEE	LCa	LMg
	$g\ kg^{-1}$	$mg\ kg^{-1}$	%	%	$mg\ kg^{-1}$	$mg\ kg^{-1}$
Control (C)	91.35 b	25.52 a	48.65 a	1.28 a	303.68 a	672.82 d
Biofertiliser (BF)	90.03 b	26.08 a	46.18 a	1.22 a	280.72 a	641.82 cd
Cattle Manure (CM)	96.36 a	27.04 a	48.62 a	1.51 a	278.22 a	698.16 bc
BF + Mulch (BF+MH)	92.03 ab	28.11 a	49.88 a	1.52 a	269.52 a	746.15 ab
EB + Mulch (CM+MH)	91.02 b	27.70 a	50.56 a	1.21 a	281.12 a	784.39 a
CV(%)	2.56	6.81	5.58	36.99	10.68	4.04

Mean values followed by the same letter in a column do not differ at 5% probability by Tukey's test

(96.36 g kg^{-1}), which did not differ significantly ($p>0.05$) from the LDM in the grain of the plants grown under BF+MH (92.03 g kg^{-1}); the difference observed between the plants under CM and the control however, was 5.2%.

There was no significant difference ($p>0.05$) found for LMg in the grain of plants grown under BF and CM with mulch, significant variations being observed ($p<0.05$) when comparing these results to those of the other treatments under test, with a difference of 14.22% for LMg being seen even in the grain of those plants under the control treatment. Fonseca *et al*. (2010), studying the level and accumulation of nutrients in cowpea plants due to phosphorus and base saturation in the grain, observed that there was a decrease in the absorption of Mg at the highest dose of P_2O_5 (100 kg ha^{-1}). Even with this discrepancy between the above results (an average greater than 1.5 g kg^{-1}) and those of the present work (the maximum value found under CM+MH was 0.784 g kg^{-1}), the authors (FONSECA *et al*., 2010) infer that the high levels seen for Mg in their study may be related to the synergetic effect caused by interaction with the P, a fact which was not studied in the present work.

CONCLUSIONS

1. Cowpea plants grown under the interaction of cattle manure and mulch, displayed greater production indices for phytomass and grain;
2. The treatments under test did not affect the accumulation of dry matter, ash, crude protein or ether extract in the cowpea shoots;
3. The average levels for crude protein, starch, ether extract and calcium in cowpea grain was not affected by organic fertilisation and / or the use of mulch.

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