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GROWTH AND DEVELOPMENT OF COWPEA (Vigna *unguiculata* L.) LIMING WITH CALCITIC LIMESTONE IN THE MUNICIPALITY OF CAPANEMA, PARÁ

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ABSTRACT
Cowpea is one of the most important legumes in the diet of the population with lower purchasing power in the northern region, and limestone is one of the most used inputs for agricultural production. The objective of this study was to evaluate the performance of cowpea plants submitted to base saturation levels in the soil, using calcitic and dolomitic limestone as soil acidity correctives, and Ca and Mg suppliers in the soil. The work was carried out in a greenhouse, at the Federal Rural University of the Amazon, Capanema Campus. The experimental design adopted was a completely randomized design, in a 5 x 2 factorial scheme, with five levels of base saturation (0%, 20%, 40%, 60% and 80%) and two types of limestone (calcitic and dolomitic), with 50 experimental units. The cultivar used in

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the work was BR3-Tracuateua. The following biometric and dry mass parameters were evaluated: plant height (ALT), stem diameter (DC), number of leaves (NF), leaf area (FA), root length (CR), number of pods (NV), leaf dry mass (MSF), pod dry mass (MSV), stem dry mass (MSC), shoot dry mass (MSPA), root dry mass (MSR) and total dry mass (MST). There was interaction between limestone sources and base saturation for MSV and MSR. It was found that cowpea responds positively to liming with calcitic and dolomitic limestone. It is recommended to adopt base saturation ranging between 60% and 80% to obtain better crop performances.

Keywords: Grain production, Acidity corrective, Soil fertility.

INTRODUCTION

According to Freire Filho (1988), cowpea (*Vigna unguiculata* (L.) Walp.) has its center of origin in Africa. Its arrival in Brazil took place by the Portuguese in the sixteenth century, more precisely in Bahia. Cowpea is also known as cowpea, beach bean, road bean, cowpea, black-eyed pea or macassar, macaça, or macaçar bean (Neves *et al.* 2011).

Normative Instruction No. 12 of March 28, 2008 of the Ministry of Agriculture, Livestock and Supply, in its article 2, item I, considers that there are only two species of beans in Brazil, namely: *Phaseolus vulgaris* L. and *Vigna unguiculata* (L) Walp. The first is known as common bean, while the second is more popularly called cowpea, which is more cultivated by producers in Pará and therefore was the object of study in this work.

It is one of the most cultivated legumes in the world, with an annual cycle that belongs to the Fabaceae family (Gupta *et al.* 2019). Although in the first classifications it was placed in other genres, such as *Phaseolus* and *Dolichos*, today its placement in *Vigna* is accepted worldwide (Freire Filho, 1988). It is a dicotyledonean plant of the order Fabales, family Fabaceae, subfamily Faboideae, tribe *Phaseoleae*, subtribe *Phaseolineae*, genus *Vigna* (Freire Filho *et al.* 2011).

The cowpea is of great importance to the North and Northeast regions of Brazil. However, due to its rusticity, low production cost and advances in the improvement of cultivars, its cultivation has expanded to the Midwest region, which uses it as a second crop crop in succession to soybean or corn crops. In Pará, this crop is configured as a commercial alternative, becoming commonly cultivated in the off-season by small, medium and large farmers (Silva, M. V. 2017; Rodrigues *et al.* 2020).

Although cowpea is one of the main sources of vegetable protein for Brazilians, it is still a crop that has been little scientifically studied in relation to the response to fertilization and liming (Santos *et al.* 2021). According to Cruz *et al.* (2021) The soils in which cowpea is cultivated are generally of low fertility. This reality, together with the absence of a nutrient management program and the lack of knowledge of our producers, are some of the factors that contribute to the low yield of cowpea crops (Freire Filho *et al*., 2005).

Soil acidity is one of the factors that limit crop production in highly weathered soils, such as most soils that occur in Brazil (Holzschuh, 2007). The practice of liming is essential for obtaining high yields for most crops of economic interest, and is responsible for faster productive responses, especially in annual crops (Nascimento, 2018). In addition to raising

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the pH of the soil, liming reduces the toxicity of some chemical elements (Nahass; Severino, 2003) and provides calcium and magnesium to plants (Rodrigues *et al*. 2021).

In Pará there is a great potential for the use of limestone as a corrective, due to the acidic characteristics of the region's soils, however, according to Carvalho (2004), Guimarães and Santos (1968) and Maués (2017), since this product is imported from other states in Brazil such as Tocantins, for example, this increases the cost of production due to the high value of the ton of limestone paid by the producer, made more expensive by freight costs from the producing region to the final consumer.

Calcitic and dolomitic limestone differ by the chemical composition of the rocks from which these inputs are extracted, more precisely by the concentration of calcium oxides (CaO) and magnesium oxides (MgO). The calcite rock is mostly composed of calcium oxides and therefore the chemical formula that represents it is CaCO3, the dolomite rock, in turn, has a higher concentration of magnesium oxide being represented by the chemical formula CaMg(CO3)2 (Almeida A. *et al.* 2016; Almeida C. 2008).

Capanema is a city that is located in the Northeast region of Pará, in the formation of Pirabas; geologically rich region because it is formed by sedimentary limestone deposits. The limestone present in this region is 100% extracted to serve the civil construction industry with the production of cement. In this context, the purpose of this research is to promote knowledge about the limestone extracted from the B-17 mine, by the company Cimentos do Brasil S/A (CIBRASA), evaluating the quality of this product for the production of soil acidity corrective.

In this sense, the present study is essential, because knowing the potential of this limestone and the scarcity of agricultural corrective in Pará, it is essential to produce this input in the region to meet the demand of local agriculture in order to reduce its importation. Therefore, base saturation levels were tested using calcitic limestone (extracted from the B-17 mine, of the company CIBRASA) and dolomitic limestone (commercially acquired limestone) and the growth and development of cowpea were evaluated as a function of the application of these correctives in the soil.

Based on the above, this research considered the following hypothesis: the calcitic limestone extracted from the B-17 mine, in the municipality of Capanema, promotes soil correction and improves the development of cowpea.

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OBJECTIVE

To evaluate the growth and development of cowpea plants in a greenhouse, after soil correction with the use of calcitic and dolomitic limestone to reach levels of saturation by soil bases, as well as to evaluate the chemical modifications in the soil promoted by liming.

THEORETICAL FRAMEWORK

SOCIAL AND ECONOMIC ASPECTS OF COWPEA CULTIVATION

Cowpea is widely cultivated in family farming systems and has great social and economic importance, being considered one of the main food crops, especially for needy populations in the North and Northeast regions (Silva, F. M. *et al.* 2020). In addition to participating in the generation of employment and income (Fernandes; Foster; Braz, 2013), tends to play an increasingly important role in the context of food security for peoples in tropical and subtropical regions with high rainfall instability and low technological level (Bezerra *et al.* 2014).

According to the grain harvest monitoring bulletin of the National Supply Company (Conab, 2023), in the 2022/2023 harvest the total planted area of cowpea in Brazil was 1271.3 hectares. In terms of production, according to Conab (2023), Brazil reached a total of 613.5 thousand tons in the 2022/2023 harvest, with the Northeast and North regions representing 411.8 and 96.8 thousand tons, respectively. Pará produced 18.6 thousand tons and according to the latest data on the agricultural panorama of the state released by the Secretary of State for Agricultural Development and Fisheries (Sedap, 2019), the largest producer of cowpea in the state was the municipality of Capanema (2,000 tons of grains), followed by Santana do Araguaia (1,700 tons of grains) and Tracuateua (1,620 tons of grains)

AGRONOMIC CHARACTERISTICS OF THE BR3-TRACUATEUA CULTIVAR

BR3-Tracuateua is a cultivar presented in 1984 by the Agricultural Research Center of the Humid Tropics (CPATU), which is now known as Embrapa Eastern Amazon. This cultivar is one of the main crops in the Bragança region, with great acceptance by farmers. It has poor tolerance to drought and is moderately tolerant to high temperatures, fitting into the Amazonian conditions (Cultivarweb, 2022; Freire Filho *et al*. 2011; Freire Filho *et al.*, 2005).

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The size of this cultivar is of the prostrate type and has its growth indeterminate. Flowering can happen 40 days after sowing. The maturation period varies from 70 to 80 days after sowing, being classified as an average cycle. Pods in the final stage of maturation can have about 10 seeds each. It can reach 914 kg $^{ha-1}$ under rainfed conditions and 1698 kg $^{ha-1}$ under irrigated conditions (Freire Filho *et al*. 2011 Freire Filho *et al*., 2005).

THE IMPORTANCE OF LIMESTONE EXTRACTION IN PARÁ AND ITS POSSIBILITY OF USE IN AGRICULTURE

There may not be other rocks with as wide a variety of uses as calcite and dolomite. The most commercialized carbonate rocks in the world are limestones. Limestones are sedimentary rocks composed basically of calcite (CaCO3), while dolomites are also sedimentary rocks composed basically of the mineral dolomite (CaMg(CO3)2) (Sampaio, Almeida, 2008).

Limestone ore has been used economically for various purposes, thus, the productive sectors associate its importance with civil construction activities, in the manufacture of lime and cement, acid soil correctives, among others (Resuenho, 2017). The need to meet market demands, due to the varieties of products that limestone offers, requires a long production process, from its extraction to the final product marketed (Camargos, 2020).

The increase in agricultural activity and civil construction in Brazil drives an equivalent increase in the cement industry and agricultural correctives, which subsequently exposes the areas of occurrence of carbonate rocks from which the raw material for these inputs is extracted: limestone (Chaves, 2013). Mineable limestone reserves in Brazil are relatively well distributed across the states (Martins Júnior, 2015). The Amazon region has rich mineral deposits in its composition (Andrade, 2011).

The rocks of the B-17 Mine constitute an important limestone deposit and are currently exploited for the cement industry by Empresa de Cimentos do Brasil S/A (CIBRASA) (Távora, Silveira, Neto, 2007), which, according to Ribeiro (2018) plays an important role in the generation of employment and in the composition of the city's Gross Domestic Product (GDP).

The limestone currently extracted in the Bragantina region has as its main target to serve the civil construction sector. This same limestone may have the potential to produce

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agricultural correctives to meet the local demand of farmers. However, to this day there is a great lack of research related to the quality of limestone in the region in soil correction for the development of plants and their extraction to meet the needs of local agriculture and its surroundings.

SOIL ACIDITY CORRECTIVES AND THE IMPORTANCE OF LIMESTONE FOR PARÁ'S AGRICULTURE

The materials that can be used to correct soil acidity are those that contain calcium and/or magnesium oxides, hydroxides, carbonates and silicates as a "neutralizing constituent" or "active ingredient" (Veloso *et al.* 2020). According to SDA Normative Instruction No. 35, of July 4, 2006, article 1, item I, an acidity corrective is considered to be any product that promotes the correction of soil acidity and provides calcium, magnesium or both.

Acidity can be controlled with the application of substances that release hydroxyl (OH^-) capable of neutralizing the protons (H+) present in the soil solution (Nolla, 2003). Limestone is the most used material as a corrective of soil acidity, where the calculation of the amount to be added to the soil can be done based on the potential acidity, resulting from the activity of H+ and Al3+ ions (Araujo, D., *et al.* 2014).

The quality-related parameters that must be considered when choosing limestone are, for example, neutralization power (PN), reactivity (RE) and CaO and MgO contents, as well as the particle size that is determined by ABNT sieves No. 10 (2 mm), No. 20 (0.84 mm) and No. 50 (0.30 mm). These last two parameters confer the neutralizing efficiency of limestone and are represented by a single value, the relative total neutralizing power (PRNT) (Veloso Et *al.* 2020, Oliveira, 2022).

In the Amazon, the soil classes commonly found are Latosols and Ultisols. The chemical properties of these soils are characterized by acidity, low fertility, high saturation of aluminum (Al) and low saturation of bases, generally caused by high leaching rates or absence of primary and secondary minerals. Acidity is a determining factor in plant performance and consequently in crop production (Benedetti *Et Al*. 2011; Campos *et al.* 2012; Pantoja *et al*. 2019; Veloso *et al.* 2020).

In Pará, the Yellow, Red and Red-Yellow dystrophic Latosols are the main ones and occupy about 40.75% of the state's surface (Gama *et al.* 2020). They are very weathered soils, with a small reserve of nutrients for plants, usually represented by their low to medium

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cation exchange capacity (Resende *et al*. 1995). Soil acidity can be caused during the process of soil formation due to processes that contribute to the removal of basic cations such as Ca2+, Mg2+, Na+ and K+, also from the lack of bases of the parent material (Lopes *et al*. 1991) or due to anthropic action, soils can have their acidity increased by crops and fertilizations. which can lead to the loss of basic cations (Raij, 1983). As a result, the root system is limited to exploiting a smaller area of soil, which causes less absorption of nutrients and water (Nolla; Anghinoni, 2004) directly influencing the development of cowpea, which may cause a decrease in its production potential, caused by the presence of exchangeable aluminum (Ribeiro; Peloso, 2009), causing a decrease in the average grain yield (Cardoso, Melo, Andrade, Junior 1997).

Soil acidity also impairs the availability of N, P, K, Mg, S, and Mo to plants and can cause Mn toxicity (Rodrighero; Barth; Caires, 2015). Therefore, considering that a soil with excess aluminum and low levels of Ca2+ limits the growth of the root system and crop productivity (Lobato; Souza, 2004), it is necessary to adopt pH corrective practices with improvements in the supply of nutrients to plants (Pantoja *et al*. 2019).

Liming aims to raise the pH of the soil to a certain value (pH 5.5–6.5) (Veloso *et al.* 2020), promoting the neutralization of Al3+ and the supply of Ca and Mg, enabling the proliferation of roots, with positive effects on the growth of the aerial part of plants (Natale *et al*. 2007) and improving the efficiency of use of nutrients and water that are in the soil (Raij, 2011). Therefore, the application of limestone has shown an effect on neutralizing soil acidity on the surface (Gonçalves *et al.* 2011).

In addition to calcium, magnesium is also added to the soil from the application of limestone and plays a fundamental role in the production of plant biomass. Magnesium is mobile inside the vegetable, but the largest portion absorbed remains in the stem and especially in the leaves, given that this is the place with the greatest accumulation of chlorophyll (Alves, 2022). It is of paramount importance to make it available by liming.

MATERIAL AND METHODS

CHARACTERIZATION OF THE EXPERIMENTAL AREA

The work was carried out in a greenhouse from May to September 2022, located in the experimental area of the Federal Rural University of the Amazon (UFRA), Capanema Campus, located in the Northeast region of Pará, under the geographic coordinates 1° 11' 45'' S latitude, 47° 10' 50'' W longitude and 32 m altitude (Figure 1).

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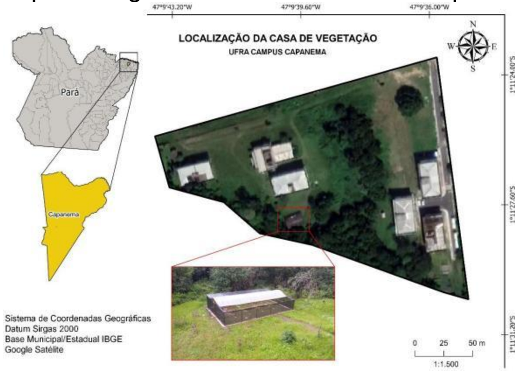
Figure 1. Location map of the greenhouse in which the experiment was carried out.



Source: Authors (2023)

The climate is classified as Am according to Kopper, with an average temperature of 26°C and average annual rainfall ranging between 1750 and 2500 mm.

EXPERIMENTAL DESIGN

The experiment was carried out in a Completely Randomized Design, 5 x 2 factorial scheme with five replications, totaling 50 experimental units. The treatments consisted of five levels of base saturation (V%) and two sources of limestone. The limestone sources used were: calcitic (doses of 0, 2.45, 6.79, 11.12 and 15.46 kg $^{ha-1}$) and dolomitic (0, 2.05, 5.60, 9.35 and 13.0 kg $^{ha-1}$), corresponding to 0%, 20%, 40%, 60% and 80% of the recommendation to achieve soil base saturations, recommended by Cravo and Souza (2020).

CONDUCTING THE EXPERIMENT

The limestone rock used as a source of calcitic limestone was extracted from the B-17 Mine of the company CIBRASA – Cimentos do Brasil S.A., located in the city of Capanema, Pará. Subsequently, in the soil laboratory of the Federal Rural University of the Amazon, Capanema Campus, the rock fragment underwent a process of crushing, grinding and analysis to determine the relative power of total neutralization (PRNT) (Table 1). The dolomitic limestone used was purchased at the agricultural input market of Capanema/PA.

Table 1. Chemical and physical characterization of the limestones used in the experiment.

Limestone	**Dog**	**$CaCO_3$**	**MgO**	**$MgCO_3$**	**ABNT/Aperture (mm)**			**PN**	**HE**	**PRNT**
					10/2,00	**20/0,84**	**50/0,3**			
	--------------%----------------							---------%---------		
Sieve passthrough (%)										
Calditic	49,5	88,5	0,90	2	100	100	59,7	90	83,9	75,5

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Home Automation	35,2	63	16	40	100	26	55	42,5	76	78,0

Source: Authors (2022).

A soil sample collected from the 0 to 0.20 m depth layer of a dystrophic Yellow Latosol near the experimental area was used. The soil sample was sieved with a 2.0 mm mesh sieve dried in the air, and subsequently, pots with a capacity of 5kg of soil were filled with the soil sample collected. Table 2 presents the chemical characterization of the soil sample.

Table 2. Chemical characterization of the soil, collected in the 0-0.20 m layer, 30 days before the installation of the experiment.

Macronutrients						**Acidity**			**Other**	
P	K	On	Ca	Mg	pH	To the	H+Al	CTC	Saturation	
----mg dm^{-3}----			---cmolc dm^{-3}---		H2O	---cmolc dm^{-3}---		cmolc dm^{-3}	Base V%	To the m%
1,2	0,30	2,4	1,5	1,5	4,1	0,48	9,13	5,7	9,00	67,8

Source: Pro-Soils Laboratory, Capitão Poço-PA, 2022.

Based on the results in Table 2, mineral fertilization and liming were recommended to increase base saturation to the predetermined amounts for each treatment, following the proposal of Cravo and Souza (2020). For this, calcitic limestone (PRNT 75.5%) and dolomitic limestone (PRNT 78%) were applied, adopting the method of saturation by exchangeable bases, according to the equation below:

$$NC = \frac{CTC\,(V2 - V1)}{PRNT} \quad (1)$$

Where:

NC = Liming requirement, in t $^{ha-1}$, with PRNT corrected to 100%;

CEC = Soil cation exchange capacity at pH 7.0 [Ca2+ + Mg2+ + K+ + Na+ + (H+ + Al3+)], in cmolc dm-3;

V2 = Recommended base saturation percentage.

V1 = Percentage of current base saturation of the soil, calculated by the formula: SB x 100 /CEC;

SB = Sum of exchangeable bases (Ca2+ + Mg2+ + K+ + Na+), in cmolc dm-3. PRNT = Relative power of total neutralization of limestone.

The amounts of lime for each treatment were weighed on a precision scale and the application was carried out 30 days before sowing, respecting the incubation period for soil correction, always keeping the soil moist in all pots, which were covered with plastic bags (Figure 2).

Figure 2. Weighing the amount of limestone on the precision scale, liming and soil incubation

Source: Authors (2022)

At 30 days after lime application, before sowing, soil samples were collected from each experimental unit for chemical analysis (Table 3). The same procedure was performed after harvest.

Table 3. Results of soil chemical analysis of treatments with calcitic (CaCO3) and dolomitic (CaMg (CO3)2) limestone collected after the 30-day incubation period (before) and after harvest (after).

Atrib.	V0%		V20%		V40%		V60%		V80%	
	Before	After	Before	After	Before	After	Before	After	Before	After
Calditic (CaCO3)										
P	1,20	0,36	2,68	3,13	4,11	0,69	4,05	4,83	4,93	1,99
K	0,30	1,00	3,99	76,28	18,47	9,98	9,78	77,88	40,63	39,94
Ca	1,50	0,88	1,92	0,76	2,68	1,92	3,12	2,28	4,56	2,40
Mg	1,50	0,68	1,28	0,60	2,00	0,56	1,80	0,52	0,44	0,40
pH	4,10	4,34	5,80	4,26	6,40	5,62	6,60	5,62	7,03	5,60
To the	0,48	0,25	0,25	0,25	0,05	0,25	0,05	0,25	0,05	0,25
H+Al	9,13	4,00	3,10	3,50	2,75	2,50	2,50	2,50	1,40	2,10
CTC	5,70	5,56	6,31	5,06	7,48	5,01	7,45	5,50	6,50	5,00
V%	9,00	28,09	50,87	30,77	63,22	50,06	66,42	54,54	78,48	58,02
m%	67,8	13,79	7,22	13,85	1,05	9,07	1,00	7,69	0,05	7,93
Dolomitic (CaMg (CO3)2)										
P	1,20	0,36	1,57	1,66	3,91	1,99	5,64	1,14	6,01	1,47
K	0,30	1,00	34,15	82,87	52,15	49,92	56,91	59,90	54,91	99,84
Ca	1,50	0,88	1,00	1,12	1,40	2,24	2,60	1,64	2,80	1,40
Mg	1,50	0,68	0,60	2,00	0,28	2,72	2,20	2,48	2,60	1,48
pH	4,10	4,34	3,79	4,72	3,91	4,63	5,64	5,57	6,01	5,72
To the	0,48	0,25	0,35	0,25	0,35	0,25	0,05	0,25	0,05	0,25
H+Al	9,13	4,00	4,20	2,30	2,30	1,80	1,80	1,80	1,50	2,00
CTC	5,70	5,56	6,42	4,51	6,54	4,65	6,56	4,43	6,93	5,14

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V%	9,00	28,09	61,07	49,03	63,30	61,27	64,92	59,40	78,35	61,06
m%	67,8	13,79	2,49	10,15	2,36	8,07	1,16	8,67	0,91	7,38

P em mg dm^{-3}; K, Ca, Mg, Al, H+Al, CTC em cmolc dm^{-3}; pH em H2O.

Then, sowing was carried out, with three seeds per pot. The plants emerged four days after sowing and after seven days thinning was carried out, leaving only one plant per pot.

After 10 days of plant emergence, fertilization was carried out with macro and micro nutrients in liquid form, calculated based on the results of the chemical analysis of the soil presented previously in Table 2. The quantities are shown in Table 4.

Table 4. Nutrients and their respective doses and sources applied for cowpea fertilization in a dystrophic Yellow Latosol with calcitic (CaCO3) and dolomitic (CaMg (CO3)2 limestone.

Nutrients	**Doses (**mg.dm^{-3}**)**	**Symbol**	**Source**
N	29	CO(NH2)2	Urea
P	178	Na2HPO4	Sodium phosphate
K	51	KCl	Potassium chloride
S	59	SO4Na	Sodium Sulfate
B	1,5	H3BO3	Boric acid
Mn	3,2	SO4Mn	Manganese Sulfate
Zn	12	SO4Zn	Sulfato de zinco

Cast Iron: Viégas (2022).

20 ml were applied for each experimental unit (Figure 3). Because nitrogen is very mobile in the soil, urea application was divided into two installments, with 10 ml each application in an interval of 10 days. The other fertilizations were carried out with a single application.

Figure 3. Application of nutrient solution for soil fertilization

Source: Authors (2022).

Crop and phytosanitary treatments

Biological control was carried out with the application of bioinsecticide with *Bacillus thuringiensis*. The proportion adopted was 32 g/L. During the experiment, the application was performed every 10 days. No control was carried out with chemical insecticide, as it could influence plant nutrition, since the experiment worked on soil fertility and plant nutrition, therefore, any control using chemical product could cause disorder in the composition of the nutrient solution.

The cultural treatments and phytosanitary management carried out during the experiment were weeding and weeding to control the incidence of weeds inside the pots and the greenhouse. In addition, staking was carried out to conduct plant growth.

VARIABLES EVALUATED

Vegetative growth data were collected at the end of the experiment, 70 days after sowing. The variables and collection procedures are highlighted below: Plant height (ALT), It was measured from the soil to the intersection of the last leaf of the plant.

For this, a tape measure was used and the measurement was in centimeters (cm); Stem diameter (DC),The stem diameter was obtained with the aid of a digital caliper placed 5 cm above the base of the stem, being measured in millimeters (mm); Number of leaves (NF),All the leaves in the plants were manually counted and expressed in units (un); Leaf area (PA), leaf area was measured by the non-destructive method using a tape measure. 3 most developed leaves were selected from each experimental unit to calculate the product of width by the length of each leaflet to determine the follicular area (cm2). Subsequently, Equation 3 was used, according to Lima *et al.* (2008) and Figueiredo, Santos and Garcia (2012) to obtain PA measured in cm2 unit ($^{\text{plant-1}}$); Root length (CR);Following the methodology proposed by Schmitt (2022), the roots were carefully collected from the soil and later washed, with attention to avoiding maximum losses. Then, using napkin paper, excess water was removed from the roots. The CR was measured from the hypocoltyl to the radicle of the root system. For this, a measuring tape measure was used.

Production variables: cowpea started the production phase 55 days after sowing and was harvested at 75 days. To obtain the dry matter data of the plant parts, described below, crepe paper bags were used to collect the plant materials, which were collected separately by the destructive method and, later, were taken to the genetics and biotechnology laboratory (LAGEB) of the Federal Rural University of the Amazon, Capanema Campus-PA.

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The dry mass measurements were carried out according to the methodology of Fernandes, Fonseca and Braz (2013). Number of pods,All mature pods were collected and quantified individually by plants, in $^{plant-1}$ units. Leaf dry mass (FSM): After collection, the leaves were placed in a forced circulation oven at 64°C and then weighed on a precision scale.

The leaves were weighed at an interval of 4 days until they reached constant weight. The unit adopted was in g $^{plants-1}$. Dry mass of pods (MSV): The pods were placed in a forced circulation oven at 64°C and weighed every 4 days until they reached a constant weight in g $^{plants-1.dry}$ mass of the stem (MSC):Once collected, the herds were packed in a forced circulation oven at 64°C and weighed every 4 days until they reached a constant weight in g $^{plants-1}$. Root dry mass (SRM): The roots were stored in an oven with forced circulation at 64°C and weighed every 4 days until they reached a constant weight in g $^{plants-1.}$Shoot dry mass (MSPA)Shoot dry mass was obtained by the sum of the MSF, MSV and MSC values, expressed in (g $^{plants-1}$)Total dry mass (MST)Total dry mass was obtained by the sum of the MSF, MSV, MSC and MSR values expressed in (g $^{plants-1}$).

STATISTICAL ANALYSIS

The collected data were submitted to analysis of variance and F-test, when significant For the organization of data and preparation of tables, the Excel 2019 Software was used. The analyses and graphs were performed with the aid of the AgroEstat 1.1.0.712 and SigmaPlot 11.0 software, respectively.

RESULTS AND DISCUSSION

BIOMETRIC VARIABLES

According to the results obtained in the analysis of variance, it was found that there was a significant difference in the variable leaf area (FA) for base saturation levels (V%) at the level of 5% of significance (Table 5).

Liming had a positive influence on the development of leaf area (FA) of cowpea as a function of base saturation levels (V%), regardless of the source of limestone applied. The leaf area followed a quadratic trend curve ($P < 0.05$), which adjusted to the equation with R2 > 0.8 (Figure 5)

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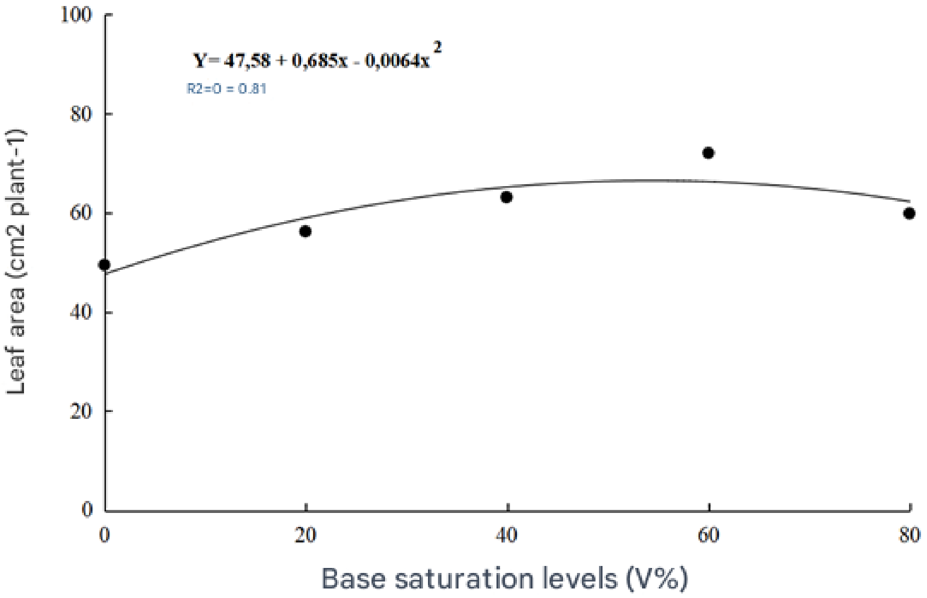
Table 5. Summary of the analysis of variance for plant height (ALT), stem diameter (DC), number of leaves (NF), leaf area (FA), root length (CR) as a function of base saturation levels and lime sources (CaCO3 and CaMg (CO3)2) in cowpea crop.

F values					
Source of variation	OLD	DC	NF	OF	CR
	-------Cm------		Unit Plant-1	cm2 plants-1	Cm
Limestone sources (FC)	1,72ns	0,08ns	3,30ns	0,58ns	0,01ns
Base saturation levels (V%)	0,45ns	0,92ns	2,15ns	5,92*	0,55ns
HR x V% Interaction	1,87ns	0,50ns	2,48ns	0,50ns	0,42ns
CV (%)	23,39	12,31	22,91	17,67	24,23

*significant at the level of 5% probability; ns not significant.

Figure 5. Leaf area (FA) of cowpea, cultivar BR3-Tracuateua, as a function of base saturation levels (V%).



From the adjustment equation it was possible to estimate that base saturation at 53.52% promoted maximum leaf area growth, reaching 65.91 cm2. There was an increase of 33.58% in leaf area in relation to the control treatment (49.34 cm2). Santos (2010) states that the increase in leaf area can be influenced by the increase in nutrients in the soil from the soil correction by the application of limestone. Limestone, consisting of calcium and magnesium carbonates, when applied to the soil dissociates into Ca2+ Mg2+ and CO32- (carbonate) ions, thus providing calcium and magnesium (Prezotti; Guarçoni, 2013) and improving nutrient uptake by the plant (Holland *et al.* 2018).

PRODUCTION VARIABLES

Table 6 presents the results of the analysis of variance for the dry mass variables. An interaction was found between lime sources and base saturation levels for the variables pod dry mass (VSM) and root dry mass (SRM). The variables leaf dry mass (FSM), shoot

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dry mass (MSPA) and total dry mass (TSM) showed significant differences only for base saturation levels (V%). All dry mass variables were analyzed at 5% significance.

Table 6. Summary of the analysis of variance for pod number (LB), leaf dry mass (FSM), pod dry mass (VSM), stem dry mass (CSM), shoot dry mass (MSPA), root dry mass (SRM) and total dry mass (TSM) as a function of base saturation levels and lime sources ($CaCO_3$ and $CaMg(CO_3)_2$) in cowpea crop.

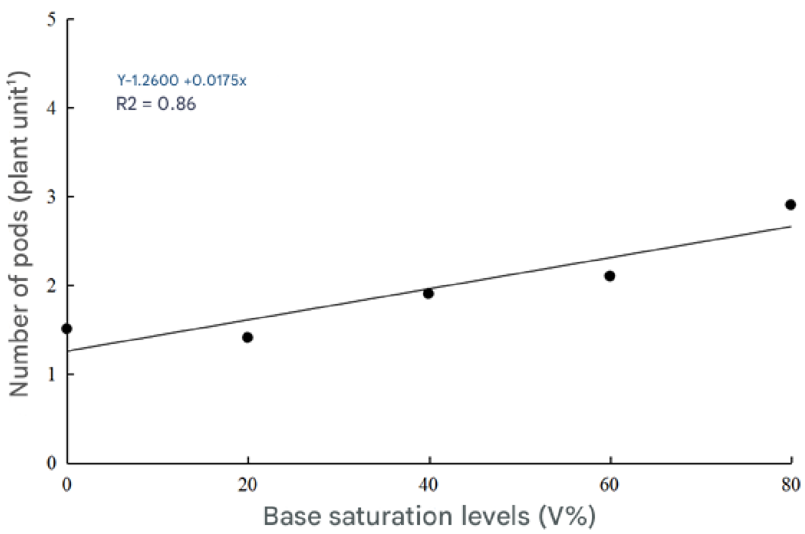
	F values						
Source of variation	**NV**	**MSF**	**MSV**	**MSC**	**MSPA**	**MSR**	**MST**
	Unit Plant-1	g/plant-1					
Limestone sources (FC)	2,37ns	0,85ns	0,02ns	1,83ns	1,07ns	4,18*	0,01ns
Base saturation (V%)	6,63*	4,25*	2,62ns	1,26ns	4,91*	2,96*	4,06*
HR x V% Interaction	1,26ns	1,03ns	2,70*	1,29ns	1,65ns	3,13*	1,17ns
CV (%)	37,49	22,24	34,88	31,44	20,86	39,85	20,43

*significant at the level of 5% probability; ns not significant.

Cowpea produced a greater quantity in the number of pods (LB) when it was subjected to 80% base saturation (2.9 plant-1 units), which means 93.3% of increase, when compared to the control treatment which provided 1.5 plant-1 units.

Although it is classified as a plant with good resistance capacity and tolerance to soil acidity, the responses of cowpea as a function of liming presented in this research were positive and similar to results observed in studies involving other annual crops such as corn (Costa, C. 2015), crambe (Mera, 2019) and common bean (Souza *et al.* 2011) and soybeans (Sampaio, 2021).

Figure 6. Number of pods (LB) of cowpea, cultivar BR3-Tracuateua, as a function of base saturation levels (V%).



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Therefore, it can be highlighted that the effect of liming on the soil increased base saturation, neutralized Al3+, reduced soil acidity, increased pH and calcium and magnesium concentrations and as a consequence enabled the absorption of nutrients in the soil solution and promoted higher performance in the production of pods of the crop under study (Figure 6).

However, it is worth noting that the significant effect on the number of pods may also be related to leaf area. Considering that the leaves are fundamental for photosynthesis and those of cowpea are of the simple and compound type formed by leaflets, Barbosa, Lima and Smiderle (2013) and Silva F. A. *et al.* (2019) found that the removal of cowpea leaflets caused a decrease in the production of the number of pods and explain that this is due to the importance of the leaf as responsible for photosynthesis and producing photoassimilates to serve the plant.

CONCLUSION

- Therefore, considering the conditions under which this work was carried out, it was found that cowpea responded positively to liming with calcitic and dolomitic limestone.
- Calcitic limestone altered the chemical attributes in the soil.
- It is recommended to adopt base saturation ranging between 60 and 80% to obtain better crop performances. There was no difference between the sources of lime for the evaluated variables of cowpea, except for root dry mass.

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