Factors Affecting *Constrictotermes cyphergaster* (Isoptera: Termitidae) Nesting on *Caryocar brasiliense* Trees in the Brazilian Savanna

by

G.L.D. Leite[1*], R.V.S. Veloso[2], J.C. Zanuncio[2], S.M. Alves[1], C.A.D. Amorim[1] & ~~O.F.F. Souza[1]~~ O. DeSouza[2]

ABSTRACT

The savanna (cerrado) region of Brazil presents great diversity of plants as hosts to insects such as the arboreal termite *Constrictotermes cyphergaster* (Silvestri) (Isoptera: ~~Termididae~~ Termitidae). *Caryocar brasiliense* Camb. (Caryocaraceae) is used by *C. cyphergaster* to build its nests in the Brazilian savanna. This tree species is widely distributed in the Brazilian savanna and its fruit is used to produce food, cosmetic ingredients, and lubricants. The size of the tree canopy and position of its branches, and chemical and physical soil attributes may affect the distribution of termite colonies and this work evaluated the effect of such factors on colonies of *C. cyphergaster* on *C. brasiliense* in two areas of savanna and four of pasture. The number of nests of *C. cyphergaster*/tree was higher in the four areas of pasture than in those of the savanna. In addition, *C. cyphergaster* nests was higher on *C. brasiliense* trees with more than four meters of crown height, two meters of crown width and more than 15 cm diameter of the trunk at breast height. The number of nests of *C. cyphergaster* was higher in the north and west faces and on bifurcations of the *C. brasiliense* canopy. No nests of *C. cyphergaster* were observed on the southeast side of *C. brasiliense* trees and few were observed on the south and east sides of the canopy of this plant. The optimum values for *C. cyphergaster* nesting were: pH (~5.5), phosphorus-remaining (~30 $mg.L^{-1}$), aluminum (~0.85 $cmol_c.dm^{-3}$), capacity of cationic exchange (~1.8 $cmol_c.dm^{-3}$), aluminum saturation

[1]Insetário G.W.G. Moraes, Instituto de Ciências Agrárias, Universidade Federal de Minas Gerais, Av. Universitária, n.1000, B. Universitário, Cx. Postal 135, CEP: 39404-006, Montes Claros, Minas Gerais State, Brasil, e-mail: gldleite@ig.com.br; carlosdelbem@hotmail.com, sergioagro2005@yahoo.com.br

[2]Departamento de Biologia Animal, Universidade Federal de Viçosa. 36571-000, Viçosa, Minas Gerais State, Brasil, ronnievond@yahoo.com, zanuncio@ufv.br, og.souza@ufv.br

*Author for correspondence

(~50%), soil base saturation (~16.5 %), organic matter (~6 dag.kg^{-1}) and trees + grove of trees (~20/ha). The abundance of *C. cyphergaster* nests on *C. brasiliense* trees was favored by plants with trunk diameters over 15 cm, with nests preferentially built on sides sheltered from predominant winds and more exposed to sunshine, combined with higher levels of organic material and clay in the soil. These factors are fundamentals for the colonization success of *C. cyphergaster*.

Key Words: Termites, ecology, soil, cerrado, cardinal point, wind.

INTRODUCTION

The Brazilian savanna (cerrado) ecosystem has a great diversity of plants that are host to insects such as the arboreal termite *Constrictotermes cyphergaster* (Silvestri) (Isoptera: Termididae) (Cunha *et al.* 2003; Sena *et al.* 2003; Lima-Ribeiro *et al.* 2006). The foraging activity of *C. cyphergaster* occurs during the night on the host plant although rarely this activity also happens in the soil and on other plants (Cunha 2000; Moura *et al.* 2006a, 2006b). Nests of *C. cyphergaster* were more common on healthy *Caryocar brasiliense* Camb. (Caryocaraceae) plants (Lima-Ribeiro *et al.* 2006). This termite does not damage their host plants because they feed on humus and use clay from the soil to build their nests (Cunha 2000). This plant is widely distributed in the Brazilian savanna and its fruit are used as food, cosmetics, lubricants and in the pharmacology industry (Araújo 1995; Passos *et al.* 2003), making it the main income source of many human communities.

Termites are important in forest and savanna areas in tropical region as they recycle nutrients and increase soil structure (Curtis & Waller 1998; Konaté *et al.* 1999; Yamada *et al.* 2006). However, this contribution may be reduced by human activities which may affect factors such as quantity and quality of food resources for termite colonies (Hedlund & Henderson 1999; Davies *et al.* 2003). Larger trees, especially those with wider canopies, favor nesting of arboreal termites since they provide higher amounts of food and more stable environments (Jones & Gathorne-Hardy 1995; Roininen *et al.* 1996; Cunha 2000; Gonçalves *et al.* 2005; Gonçalves *et al.* 2006). The diameter and inclination of the trunk, ramifications, tree height and soil type influence the colonization, establishment, form and size of *C. cyphergaster* colonies on plants of the savanna (Lima-Ribeiro *et al.* 2006). Interactions with ants can affect the distribution and abundance of termite nests on tree crowns (Leponce *et al.* 1999; Quinet *et al.* 2005). Additionally, chemical and physical features of the soil may accelerate litter decomposition and population dynamics of this termite (Cunha 2000; Lima-Ribeiro *et al.* 2006). These factors have been studied in herbivorous insects (Fernandes 1990; Richardson *et al.* 1999; Fernandes *et al.* 2000; Auslander *et al.* 2003; Unsicker & Mody 2005). However, the distribution of nests of *C. cyphergaster* in the canopy of *C. brasiliense* trees is not known, although nest location appears to significantly influence internal conditions for development of this species (Korb & Linsenmair 1999; Lima-Ribeiro *et al.* 2006).

The objective of this work was to study the effect of tree canopy size and position of its branches, and chemical and physical features of the soil under *C. brasiliense* trees on the arboreal *C. cyphergaster* termite in two areas of savanna and four of pasture in the municipalities of Montes Claros and Ibiracatu, Minas Gerais State, Brazil.

MATERIAL AND METHODS

This study was performed in the Municipalities of Montes Claros and Ibiracatu, state of Minas Gerais State, Brazil from January to June 2007 in two areas of savanna vegetation *stricto sensu* and four areas with pastures (originally savanna vegetation) with climate tropical Aw according to the classification of Köppen with dry winter and rainy summer. The geographical coordinates, altitude, soil type, physiochemical characteristics of the soil, floristic density, height and width of the crown were quantified in the areas studied (Tables 1 and 2).

The number of colonies of *C. cyphergaster* on tree trunks and branches and their orientation (cardinal point and on plant bifurcation) was evaluated monthly at each *C. brasiliense* tree. The experimental parcels were represented by six areas with a total of 360 trees (60 trees of *C. brasiliense* per area sampled; Tables 1 - 3). In each area, we walked (~1600 m) in the middle of the area in a straight line, and every 27 meters, randomly, we evaluated a *C. brasiliense* tree. We calculated height and width of canopy and trunk diameters of the breast height (DBH) using a tape measure. Every 300 meters, during walking, we evaluated the floristic diversity in an area of 1000 square meters, counting the number of trees/groves and shrubs. To determine the number of herbs

Table 1. Coordinates and altitude of the areas, number of *Constrictotermes cyphergaster* nests/tree, data of density/ha, height (m) and width (m) of the crown and diameter at breast height (cm) of *Caryocar brasiliense* trees/ha, soil covered per plant (%), number of bush (<0.50 m high), small trees (0.50 – 2.0 m high) and trees (> 2.0 m high) in an area of 10 meters around *C. brasiliense* plants in six areas of the Municipalities of Montes Claros and Ibiracatu, State of Minas Gerais, Brazil.

	Montes Claros				Ibiracatu	
Parameters evaluated*	Savanna	Pasture 1	Pasture 2	Pasture 3	Savanna	Pasture
Longitude	43º 55' 7.3" W	43º 57' 31.4" W	43º 53' 21.6" W	43º 53' 27.4" W	44º 09' 38.2" W	44º 10' 25.8" W
Latitude	16º 44' 55.6"S	16º 46' 16.1"S	16º 53' 45.2"S	16º 53' 42.1"S	15º 42' 29.5"S	15º 41' 35.5"S
Altitude	943 m	940m	999m	1009m	817m	806m
Number of *C. Cyphergaster* nests	0.05 B	0.24 A	0.30 A	0.33 A	0.15 B	0.05 B
Density of *C. brasiliense*/hectare	17.00 B	42.30 A	36.50 A	45.80 A	53.16 A	33.00 A
Height of the crown of *C. brasiliense*	4.07 B	6.89 A	4.04 B	5.06 B	6.31 A	6.86 A
Width of the crown of *C. brasiliense*	2.87 C	6.87 A	4.73 B	5.89 B	6.08 A	7.11 A
Diameter at breast height of *C. brasiliense*	17.53 B	28.45 A	21.95 B	18.57 B	27.26 A	26.63 A
Soil covering (%)	44.87 C	84.19 A	30.83 C	53.33 B	11.67 D	99.33 A
Bush	5.78 C	0.19 E	11.67 B	10.33 B	3.33 D	30.00 A
Small trees	23.51 C	4.76 D	38.00 C	79.00 B	121.33 A	1.33 D
Bigger trees	8.76 B	2.76 C	6.50 B	14.00 B	40.33 A	1.00 C

*Means followed by the same letter per line do not differ between them by the Scott-Knott test at 5% probability.

Table 2. Data of the physical and chemical analyses of the soil in six areas of the Municipalities of Montes Claros and Ibiracatu, State of Minas Gerais, Brazil.

	Montes Claros				Ibiracatu	
Parameters of the soil*	Savanna	Pasture 1	Pasture 2	Pasture 3	Savanna	Pasture
pH in water	4.85 C	4.87 C	5.40 A	5.17 B	5.50 A	5.60 A
Phosphorus-Mehlich 1 ($mg.dm^{-3}$)	0.80 C	0.59 C	1.33 C	4.30 A	1.00 C	2.63 B
Phosphorus-remaining ($mg.L^{-1}$)	40.76 A	17.64 D	28.30 C	30.53 C	35.17 B	40.07 A
Potassium ($mg.dm^{-3}$)	28.25 B	62.92 A	7.33 C	24.00 B	17.00 C	26.33 B
Calcium ($cmol_c.dm^{-3}$)	0.20 B	0.71 A	0.47 A	0.30 B	0.40 B	0.50 A
Magnesium ($cmol_c.dm^{-3}$)	0.10 B	0.37 A	0.23 A	0.17 B	0.23 A	0.30 A
Aluminum ($cmol_c.dm^{-3}$)	0.68 B	1.06 A	0.59 B	0.68 B	0.38 C	0.39 C
H + Al ($cmol_c.dm^{-3}$)	5.19 B	10.93 A	2.93 C	3.19 C	2.00 C	1.96 C
Summ of bases ($cmol_c.dm^{-3}$)	0.37 C	1.23 A	0.72 C	0.53 C	0.68 C	0.87 B
t ($cmol_c.dm^{-3}$)**	1.05 B	2.30 A	1.31 B	1.21 B	1.06 B	1.26 B
m (%)**	63.58 A	47.75 B	52.67 B	58.00 A	36.67 C	32.33 C
T ($cmol_c.dm^{-3}$)**	5.56 B	12.17 A	3.65 C	3.72 C	2.68 C	2.82 C
V (%)**	6.66 D	11.08 D	17.33 C	13.67 C	25.33 B	31.33 A
Organic matter ($dag.kg^{-1}$)	1.11 B	8.77 A	2.33 B	2.94 B	2.20 B	2.46 B
Gross sand ($dag.kg^{-1}$)***	20.92 D	5.75 E	26.27 C	36.33 B	32.67 B	48.33 A
Fine sand ($dag.kg^{-1}$)	53.92 A	30.33 C	57.73 A	49.67 A	54.67 A	40.33 B
Silt ($dag.kg^{-1}$)	10.83 B	24.83 A	7.33 C	6.67 C	7.33 C	7.33 C
Clay ($dag.kg^{-1}$)	14.33 B	39.00 A	8.67 C	7.33 C	5.33 D	4.00 D
Texture	Sandy	Loamier	Sandy	Sandy	Sandy	Sandy
Soil classification	dystrophic Yellow Red Latosoil	dystrophic Red Yellow Latosoil	dystrophic Red Yellow Latosoil	dystrophic Red Yellow Latosoil	dystrophic Yellow Red Latosoil	dystrophic Red Yellow Latosoil

*Means followed by the same letter per line do not differ between them by the test of Scott-Knott at 1% probability.
** t= capacity of cationic exchange, m= aluminium saturation in the capacity of cationic exchange; T= cation exchange capacity at natural pH 7.0; V= percentage of soil base saturation of the capacity of cationic exchange a pH 7.0.***gross sand (2 –0.2mm), fine sand (0.2 – 0.02mm), silt (0.02 – 0.002mm), clay (< 0.002mm).

and percentage of cover of soil we used a square (60 x 60 cm), sampling six points in each of the six areas of 1000 square meters. The activity of termite colonies was evaluated by cutting the lateral parts (three cuts, one on each side and a frontal one) of the termite mounds. The termite colonies were classified as alive (with soldiers and workers on its surface), or dead (no visible soldiers or workers).

A total of 36 soil samples (0-20 cm deep) were collected (six samples per area) and their physical and chemical characteristics were evaluated in the Laboratory of Soil Analysis of the NCA/UFMG, according to the methodology of Embrapa (1997). These samples were collected under the canopy projection of the *C. brasiliense* trees. Data were transformed to $\sqrt{x + 0.5}$ and submitted to analysis of variance (ANOVA) ($P < 0.05$), the Scott-Knott test ($P < 0.05$) (Scott-Knott 1974) and regression analysis ($P < 0.05$).

RESULTS

The number of *C. cyphergaster* nests per *C. brasiliense* was higher in areas of pasture in Montes Claros, Minas Gerais State, Brazil. There were no differences in the number of nests in the savanna of the Municipality of Montes Claros and in the savanna and pasture in the Municipality of Ibiracatu (Table 1). The number of nests of *C. cyphergaster* was higher on *C. brasiliense* trees with more than four meters height and two meters width of crown and over 15 cm of trunk diameter (Table 3). These measures presented positive correlations because larger height and width of tree crown was found in *C. brasiliense* with bigger trunks (Fig. 1). The lower density of *C. brasiliense* was found in the savanna of Montes Claros where only, 5.76% of the trees evaluated had diameters over 15 cm.

Most *C. cyphergaster* nests were observed on the west face of *C. brasiliense* trees in the savanna and in pasture 1 in Montes Claros (Fig. 2), in the north face in pasture 2 and on bifurcations in pasture 3 of this Municipality (Fig. 2). The number of *C. cyphergaster* nests was higher in the savanna and pasture on the north side and on branch bifurcations on the northwest side, respectively, in the Municipality of Ibiracatu (Fig. 2). In general, the number of nests of this termite was higher on the north and west sides and on bifurcations. No *C. cyphergaster* nests were found on the southeast side of *C. brasiliense* trees and few were observed on the south and east sides of the tree canopy (Fig. 2).

Table 3. Number of *Constrictotermes cyphergaster* nets as function of height, width and diameter of the trunk at breast height of *Caryocar brasiliense* trees and frequency (%) of these trees per category in six areas of the Municipalities of Montes Claros and Ibiracatu, State of Minas Gerais, Brazil.

	Category per height of the crown of *Caryocar brasiliense* (m)				
	0.40 – 0.99	1.00 – 1.99	2.00 – 3.99	4.00 – 6.99	> 7.00
Nets of *C. cyphergaster*/ *C. brasiliense* (mean)	0.00 B	0.04 B	0.10 B	0.28 A	0.28 A
	Frequency of *C. brasiliense*				
Savanna (Montes Claros)	6.17	16.46	27.98	37.45	11.93
Pasture 1 (Montes Claros)	0.00	4.76	0.00	47.62	47.62
Pasture 2 (Montes Claros)	0.00	0.00	45.00	50.00	5.00
Pasture 3 (Montes Claros)	0.00	14.82	14.82	38.89	31.48
Savanna (Ibiracatu)	0.00	0.00	26.32	36.84	36.84
Pasture (Ibiracatu)	0.00	15.00	15.00	15.00	55.00

	Category per width of the crown of *Caryocar brasiliense* (m)					
	0.20 – 0.99	1.00 – 1.99	2.00 – 3.99	4.00 – 5.99	6.00 – 7.99	> 8.00
Nests of *C. cyphergaster*/ *C. brasiliense* (mean)	0.00 B	0.06 B	0.21 A	0.22 A	0.36 A	0.33 A
	Frequency of *C. brasiliense*					
Savanna (Montes Claros)	13.58	22.63	58.03	5.76	0.00	0.00
Pasture 1 (Montes Claros)	4.76	4.76	4.76	14.29	19.05	52.38
Pasture 2 (Montes Claros)	0.00	5.00	20.00	50.00	25.00	0.00
Pasture 3 (Montes Claros)	0.00	7.41	20.37	18.52	18.52	35.19
Savanna (Ibiracatu)	0.00	5.26	26.32	15.79	15.79	36.84
Pasture (Ibiracatu)	0.00	15.00	10.00	5.00	30.00	40.00

	Category per diameter of the trunk at breast height of *Caryocar brasiliense* (cm)					
	1.00 – 7.99	8.00 – 9.99	10.0 – 14.9	15.0 – 19.9	20.0 – 39.9	> 40.0
Nests of *C. cyphergaster*/ *C. brasiliense* (mean)	0.02 C	0.19 B	0.23 B	0.28 A	0.34 A	0.31 A
	Frequency of *C. brasiliense*					
Savanna (Montes Claros)	35.39	26.34	32.51	5.76	0.00	0.00
Pasture 1 (Montes Claros)	4.76	0.00	0.00	14.29	66.67	14.29
Pasture 2 (Montes Claros)	0.00	5.00	35.00	25.00	30.00	5.00
Pasture 3 (Montes Claros)	16.67	7.41	9.26	18.52	46.30	1.85
Savanna (Ibiracatu)	5.26	5.26	10.53	21.05	42.11	15.79
Pasture (Ibiracatu)	25.00	0.00	5.00	0.00	60.00	10.00

*Means followed by the same letter per line do not differ between them by the Scott-Knott test at 5% probability.

The soil properties associated with higher abundance of *C. cyphergaster* nests were: pH= 5.5, phosphorus-remaining 30 mg.L^{-1}, aluminum 0.85 cmol$_c$.dm^{-3}, capacity of cationic exchange 1.8 cmol$_c$.dm^{-3}, aluminum saturation 50%, soil base saturation 16.5 %, and organic matter 6 dag.kg^{-1} (Fig. 3). The lower values of pH were observed in the savanna and pasture areas in Montes Claros; the higher values of phosphorus-remaining in the savanna of Montes Claros and in the pasture of Ibiracatu; the higher quantity of aluminum, capacity of cationic exchange and organic matter in the pasture in Montes Claros; and the percentage of soil base saturation in the pasture in Ibiracatu (Table 2).

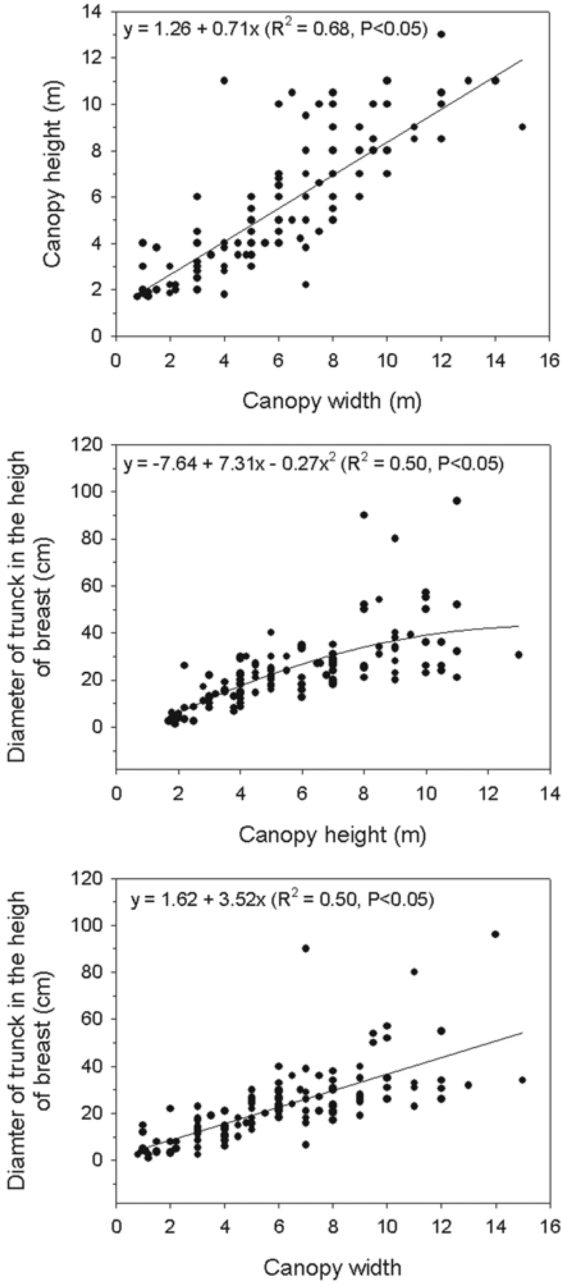

Fig. 1. Effect of canopy width and canopy height on the diameter of the trunk at breast height of *Caryocar brasiliense*.

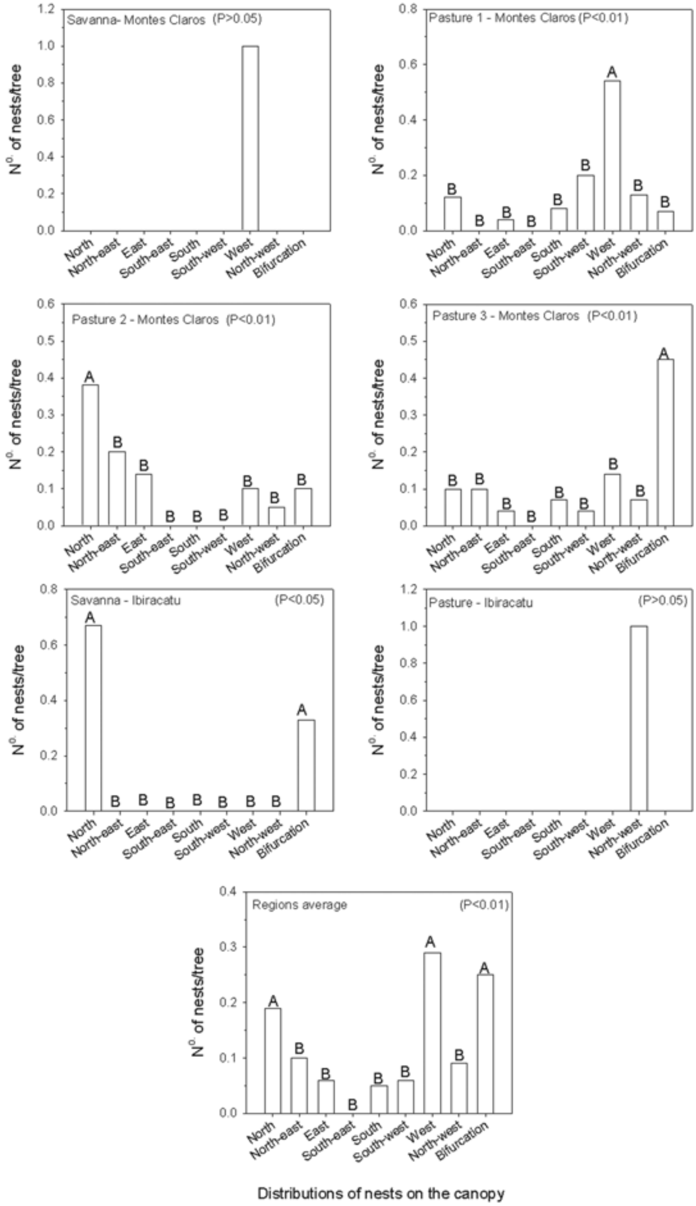

Fig. 2. Position of *Constrictotermes cyphergaster* nests on the canopy of *Caryocar brasiliense* trees as function of cardinal points and on bifurcations in six areas of the Municipalities of Montes Claros and Ibiracatu, Minas Gerais State, Brazil. Averages followed by the same letter do not differ, amongst themselves, by the test of Scott-Knott.

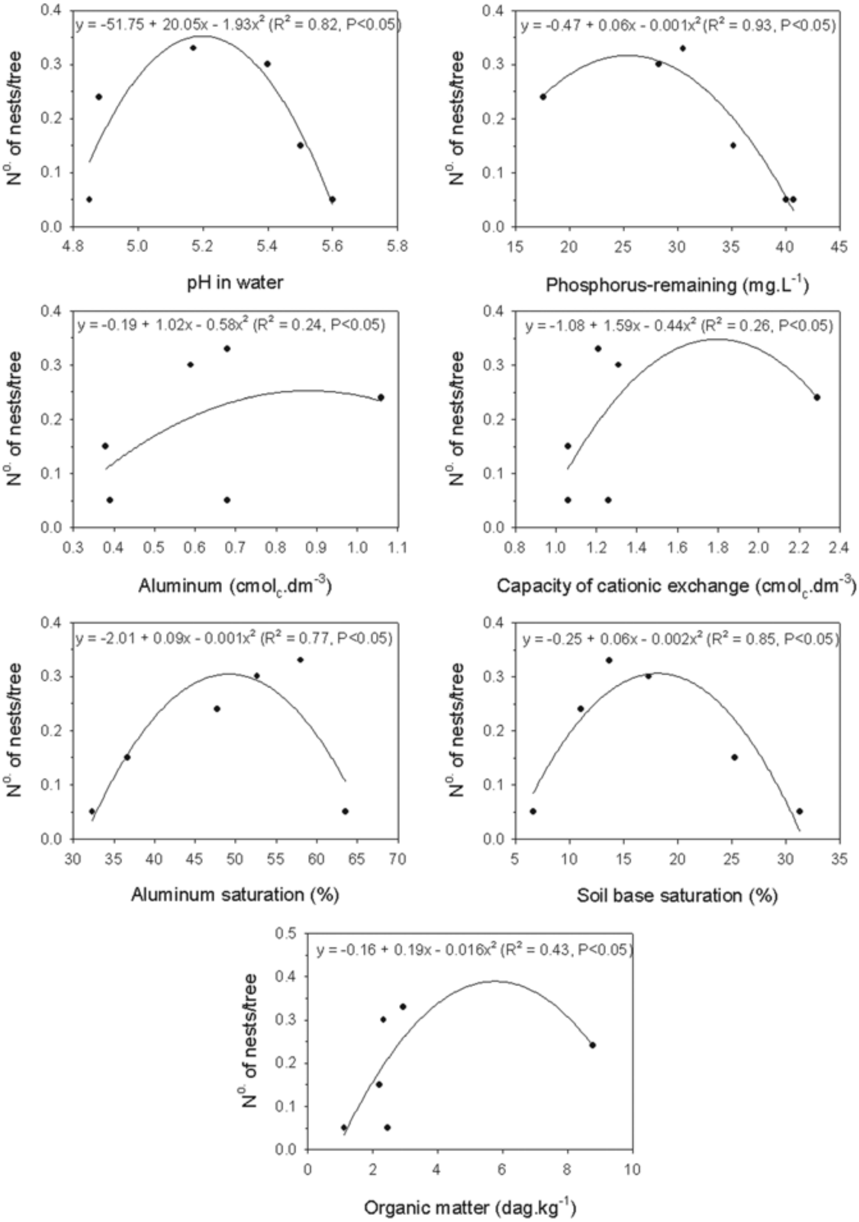

Fig. 3. Effect of pH, phosphorus-remaining (mg.L^{-1}), aluminum ($cmol_c.dm^{-3}$), capacity of cationic exchange ($cmol_c.dm^{-3}$), aluminum saturation (%), soil base saturation (%), and organic matter (dag.kg^{-1}) on the number of *Constrictotermes cyphergaster* nests on *Caryocar brasiliense*.

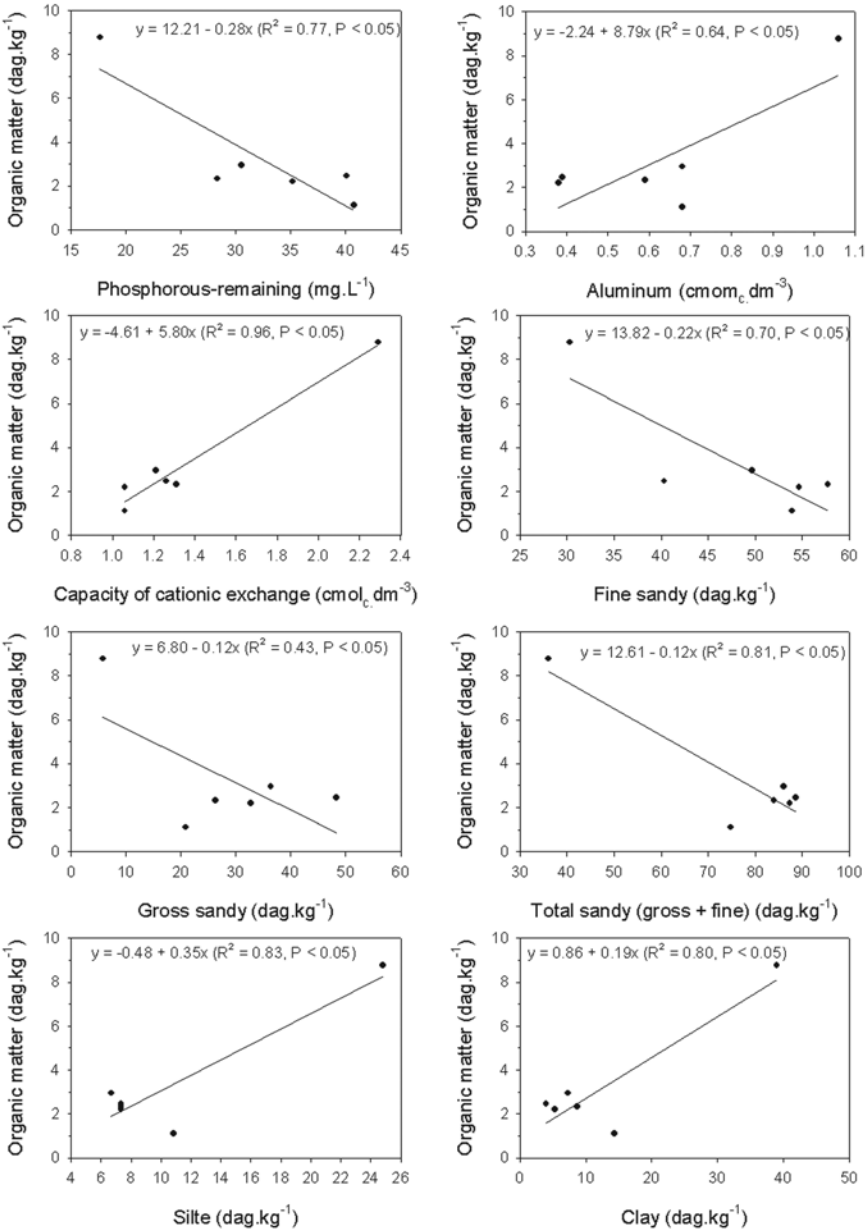

Fig. 4. Effect of phosphorus-remaining (mg.L^{-1}), aluminum (cmol$_c$.dm^{-3}), capacity of cationic exchange (cmol$_c$.dm^{-3}), fine sandy (dag.kg^{-1}), gross sandy (dag.kg^{-1}), total sandy (dag.kg^{-1}), silte (dag.kg^{-1}) and clay (dag.kg^{-1}) on organic matter (dag.kg^{-1}) of the soil.

An increase on phosphorus-remaining, gross sand, fine sand and total sand was associated with low levels of organic matter (Fig. 4). On the other hand, increases in the aluminum level, capacity of cationic exchange, silt and clay increased the level of organic matter (Fig. 4).

DISCUSSION

The lower density of *C. cyphergaster* nets on *C. brasiliense* trees with lower height, crown width and diameter of the trunk agrees with similar results for this termite (Cunha 2000; Lima-Ribeiro *et al.* 2006). Nests of *C. cyphergaster* were reported on savanna trees with trunks from 17 to 116 cm total circumference but with larger preference (72%) for plants with trunks between 30 and 60 cm circumference (Cunha 2000). The *stricto sensu* Brazilian savanna is characterized by the predominance of an herbaceous-shrubby stratum with few arboreal species (Almeida *et al.* 1998) and reduced numbers of them with trunk circumferences between 30 and 60 cm (Almeida *et al.* 1998). Trees with larger size have a greater stability and availability of places to construct the nests and they be more easily located by winged arboreal termites besides having larger deposition of leaves on the soil to produce the organic matter (Jones & Gathorne-Hardy 1995; Gonçalves *et al.* 2005). These trees present larger number of leaves and, thus have a microclimate with larger water availability under their crown to maintain termite colonies (Lima-Ribeiro *et al.* 2006).

The lower preference of *C. cyphergaster* to build nests on the northeast and east sides of *C. brasiliense* trees can be due to wind direction in the north region of Minas Gerais which is mostly northeast (Leite *et al.* 2006). This may result in colder temperatures in the winter and a higher desiccant effect on these sides of the tree. This shows that wind direction can explain the larger number of *C. cyphergaster* nests on *C. brasiliense* trees on the west side where they are sheltered from wind currents.

Greater exposure to sunshine on the north face results in higher temperatures and lower sunshine on the south side results in lower temperatures in this side in the Southern Hemisphere (Auslander *et al.* 2003). The exposure to the sun and, therefore, higher temperatures, may explain the frequent occurrence of *C. cyphergaster* nests on the north side and its low occurrence on the south side of the canopy of *C. brasiliense* trees. On the other hand, the lack of nests of this termite on the southeast side of tree canopy may be due to the sum of impacts of lower sunshine incidence in the south side and the impact of wind on the east side. For this reason, the southeast side was least favorable to the development of *C. cyphergaster* colonies.

A great number of *C. cyphergaster* nests presented pear format but with irregularities on trunks with sloping stems or bifurcations (Cunha 2000). Termite nests constitute a closed and isolated environment with a different microclimate, including temperature, humidity and internal conditions, compared to the surrounding area (Korb & Linsenmair 1999; Lima-Ribeiro *et al.* 2006). Trees with larger number of leaves and, consequently, estomates, generate a microclimate with larger availability of water under their canopy and make a larger quantity of humidity available for the termite to maintain their colonies (Lima-Ribeiro *et al.* 2006).

The level of organic matter in the soil presented negative correlation with the percentage of sand. These characteristics had correlation with abundance of *C. cyphergaster* nests. Areas with larger percentage of sand and lower levels of organic matter had smaller density of nests of this termite. The soil organic matter collected in the vicinity of the host plant is used by *C. cyphergaster* to build and to repair their nests (Cunha 2000; Lima-Ribeiro *et al.* 2006; Moura *et al.* 2006b; Brossard *et al.* 2007). The low amount of organic matter and the largest proportion of total sand in the soils of the savanna of Montes Claros and in the pasture of Ibiracatu can deter the of establishment of *C. cyphergaster* nests. This is due to the fact that the organic matter is decomposed by the soil biota and these areas are sandy, which facilitates water percolation of the organic matter into deeper layers of the soil, making it unavailable to the termites. This can explain the negative correlation between the level of sand with the organic matter and the positive correlation with organic matter and the finer soil particles (silt and clay).

The municipality of Montes Claros and Ibiracatu have similar climatic classifications and *C. brasiliense* is not a plant species preferred by predators and/or competitors of *C. cyphergaster* (Lima-Ribeiro *et al.* 2006). For this reason the main factors that affect the nesting of this termite species on *C. brasiliense* trees with trunk diameters over 15 cm are larger availability of organic matter and clay in the soil to construct and to repair nests. The orientation of colonies of this termite on trunks and on branches of trees seems to be important to maintain ideal conditions of temperature, humidity, etc for the development of the colonies. This confirms the fact this termite prefers to build its nests on tree sides not exposed to currents of predominant winds in the area and of higher exposure to sunshine. The better characteristics of the soil for nesting of *C. cyphergaster* are likely due to the preferable changes among the chemical properties by microbial activity in the soil, but this needs to be further studied.

ACKNOWLEDGMENTS

To the Brazilian agencies "Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)" "Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)", and "Secretaria de Ciência e Tecnologia do Estado de Minas Gerais", Prefeitura de Ibiracatu" and "EMATER" of Ibiracatu.

REFERENCES

Almeida, S.P., C.E.B. Proença, S.M. Sano & J.F. Ribeiro 1998. Cerrado: Espécies vegetais úteis. EMBRAPA – CPAC, Planaltina, Brazil: 464.

Araújo, F.D. 1995. A review of *Caryocar brasiliense* (Caryocaraceae) – an economically valuable species of the central Brazilian cerrados. Economic Botany 9(1): 40-48.

Auslander, M., E. Nevo & M. Imbar 2003. The effects of slope orientation on plant grown, developmental instability and susceptibility to herbivores. Journal Arid Environnment 55(3): 405-416.

Brossard, M., D. López-Hernández, M. Lepage & J.C. Leprun 2007. Nutrient storage in soils and nests of mound-building *Trinervitermes* termites in Central Burkina Faso: consequences for soil fertility. Biology and Fertility of Soils 43(4): 437–447

Cunha, H.F. 2000. Estudo de colônias de *Constrictormes cyphergaster* (Isoptera, Termitidae: Nasutitermitinae) no Parque Estadual da Serra de Caldas Novas, Go. Instituto de Ciências Biológicas, Goiânia, Brazil: 51.

Cunha, H.F., D.A. Costa, K.D. Santo, L.O. Silva & D. Brandão 2003. Relationship between *Constrictotermes cyphergaster* and inquiline termites in the Cerrado (Isoptera: Termitidae). Sociobiology 42(2): 761-770.

Curtis, A.D. & D.A. Waller 1998. Seasonal patterns of nitrogen fixation in termites. Functional Ecology 12(5): 803-807.

Davies, R.G., P. Eggletonu, D.T. Jones, J.F. Gathorne-Hardy & L.M. Herández 2003. Evolution of termite functional diversity: analysis and synthesis of local ecological and regional influences on local species richness. Journal of Biogeography 30(6): 847–877.

Empresa Brasileira de Pesquisa Agropecuária 1997. Centro Nacional de Pesquisa de Solos. Manual de Métodos de Análises de Solos (2.ed.). EMBRAPA, Rio de Janeiro, Brazil:212.

Fernandes, G.W. 1990. Hypersensitivity: a neglected plant resistance mechanism against insect herbivores. Environmental Entomology 19(5): 1173-1182.

Fernandes, G.W., T.G. Cornelissen, R.M.S. Isaias & T.A.F. Lara 2000. Plants fight gall formation: hypersensitivity. Ciência e Cultura 52(1): 49-54.

Gonçalves, T.T., O. De Souza, R. Reis Jr & S.P. Ribeiro 2005. Effect of tree size and growth form on the presence and activity of arboreal termites (Isoptera: Termitidae) in the Atlantic Rain Forest. Sociobiology 46(2): 421-431.

Hedlund, J.C. & G. Henderson 1999. Effect of available food size on search tunnel formation by the *Formosan subterranean* termite (Isoptera: Rhinotermitidae). Journal of Economic Entomology 92(3): 610-616.

Jones, D. & F. Gathorne-Hardy 1995. Foraging activity of the processional termite *Hospitalitermes hospitalis* (Termitidae: Nasutitermitinae) in the rain forest of Brunei, north-west Borneo. Insectes Sociaux 42(4): 359-369.

Korb, J. & K.E. Linsenmair 2002. Evaluation of predation risk in the collectively foraging termite *Macrotermes bellicosus*. Insectes Sociaux 49(3): 264-269.

Konaté, S., X. Le Roux, D. Tessier & M. Lepage 1999. Influence of large termitaria on soil characteristics, soil water regime, and tree leaf shedding pattern in a West African savanna. Plant and Soil 206(1): 47–60,

Leite, G.L.D., R.V.S. Veloso, J.C. Zanuncio, L.A. Fernandes & C.I.M. Almeida 2006. Phenology of *Caryocar brasiliense* in the Brazilian Cerrado Region. Forest Ecology and Management 236(2-3): 286-294

Leponce, M., Y. Roisin & J.M. Pasteels 1999. Community interactions between ants and arboreal-nesting termites in New Guinea coconut plantations. Insectes Sociaux 46(2): 126–130.

Lima-Ribeiro, M.S., M.P. Pinto, S.S. Costa, J.C. Nabout, T.F.L.V.B. Rangel, T.L. Melo & I.O. Moura 2006. Associação de *Constrictotermes cyphergaster* Silvestri (Isoptera: Termitidae) com espécies arbóreas do cerrado brasileiro. Neotropical Entomology 35(1): 49-55.

Moura, F.M.S., A. Vasconcellos, V.F.P. Araújo & A.G. Bandeira 2006a. Seasonality in foraging behaviour of *Constrictotermes cyphergaster* (Termitidae, Nasutitermitinae) in the caatinga of Northeastern Brazil. Insectes Sociaux 53(4): 472 – 479.

Moura, F.M.S., A. Vasconcellos, V.F.P. Araújo & A.G. Bandeira 2006b. Feeding Habit of *Constrictotermes cyphergaster* (Isoptera, Termitidae) in an area of caatinga, Northeast Brazil. Sociobiology 48(1): 21-26.

Passos, X.S., A.C.M. Castro, J.S. Pires, A.C.F. Garcia, F.C. Campos, O.F.L. Fernandes, J.R. Paula, H.D. Ferreira, S.C. Santos, P.H. Ferri & M.D.R. Silva 2003. Composition and antifungal activity of the essential oils of *Caryocar brasiliense*. Pharmaceutical Biology 41(5): 319-324.

Quinet, Y., N. Tekule & J.C. Biseau 2005. Behavioural interactions between *Crematogaster brevispinosa rochai* Forel (Hymenoptera: Formicidae) and two *Nasutitermes* species (Isoptera: Termitidae). Journal of Insect Behavior 18(1): 1-17.

Richardson, B.J., F.F. Azarbayjani, B. Shelley & S.Y.L.V.I.A. Richardson 1999. Arboreal arthropod biodiversity in woodlands: Effect of collection procedures and geographic distance on estimates of diversity found on two species of *Melaleuca.* Austral Ecology 24(5): 544–554.

Roininen, H., P.W. Price & J. Tahvanainen 1996. Bottom-up and top-down influences in the trophic system of a willow, a galling sawfly, parasitoids and inquilines. Oikos 77(1): 44-50.

Scott J.A. & M.A. Knott 1974. A cluster analysis method for grouping means in the analysis of variance. Biometrics 30(3): 507-512.

Sena, J.M., A. Vasconcellos, M.A.B. Gusmão & A.G. Bandeira 2003. Assemblage of termites in a fragment of cerrado on the coast of Paraiba State, northeast Brazil (Isoptera). Sociobiology 42(2): 753-760.

Unsicker, S.B. & K. Mody 2005. Influence of tree species and compass bearing on insect folivory of nine common tree species in the West African savannah. Journal of Tropical Ecology 21(2): 227-231.

Yamada, A., T. Inoue, D. Wiwatwitaya, M. Ohkuma, T. Kudo & A. Sugimoto 2006. Nitrogen Fixation by Termites in Tropical Forests, Thailand. Ecosystems 9(1): 75–83