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Doses of carnauba leaf residues and corn yield

Paulo SL Silva; Paulo IB Silva; Vianney R Oliveira; Kadson EF Silva; Alex L Monteiro
UFERSA, C. Postal 137, 59625-900 Mossoró-RN; paulosergio@ufersa.edu.br (bolsista CNPq); pauloigor@hotmail.com; vianney.reinaldo@hotmail.com; k-son@hotmail.com; alex_monteiro02@hotmail.com

ABSTRACT

Corn yield can be increased with the application of residues from perennial plant species. Many growers in Northeastern Brazil use carnauba (a palm tree native to that region) leaf residues to address deficiencies in soils that are poor in organic matter. The objective of this research was to evaluate the effects of application of carnauba leaf residue (crushed leaf blades applied two years after the harvest) doses on the green ear yield of two corn cultivars. Additionally, we also evaluated corn grain yield. Doses of leaf residues (0, 2, 4, 6, 8, and 10 t ha^{-1}) were applied in the sowing furrows of corn cultivars (AG 1051 and BR 106). A completely randomized block design with five replicates and split-plots was used (doses in plots). Increased doses of leaf residues resulted in higher total number of green ears and higher number and weight of marketable unhusked green ears (BR 106), and higher total green ear weight, marketable husked green ear weight, and grain yield (AG 1051 and BR 106). However, the application of carnauba leaf residues did not influence the total number of green ears, number of marketable unhusked ears, unhusked ear weight (AG 1051), and number of marketable husked ears (AG 1051 and BR 106). Cultivar BR 106 was superior to cultivar AG 1051 in total number of green ears and number of marketable unhusked green ears, while the opposite occurred for green ear weight and grain yield.

Keywords: *Copernicia prunifera*, *Zea mays*, green corn, grain yield, bagana, straw.

RESUMO

Doses de resíduos foliares de carnaubeira e rendimentos do milho

O rendimento do milho pode ser aumentado com a aplicação de doses de resíduos de espécies vegetais perenes. Muitos agricultores do Nordeste do Brasil utilizam resíduos de folhas da carnaubeira, uma palmeira nativa dessa região, para suprir as deficiências dos solos pobres em matéria orgânica. O objetivo do trabalho foi avaliar os efeitos da aplicação de doses de resíduos foliares da carnaubeira sobre o rendimento de espigas verdes de duas cultivares de milho. O estudo foi complementado pela avaliação também do rendimento de grãos. Doses de resíduos foliares (0, 2, 4, 6, 8 e 10 t ha^{-1}) foram aplicadas nos sulcos de semeadura de cultivares de milho (AG 1051 e BR 106). Utilizou-se o delineamento de blocos ao acaso com cinco repetições e parcelas subdivididas (doses nas parcelas). O aumento da dose de resíduos foliares aumentou o número total, o número e a massa de espigas verdes empalhadas comercializáveis (BR 106), as massas total e de espigas verdes despalhadas comercializáveis e o rendimento de grãos (AG 1051 e BR 106). Mas a aplicação de resíduos foliares da carnaubeira não influenciou os números total e de espigas empalhadas comercializáveis, massa de espigas empalhadas (AG 1051), e o número de espigas despalhadas comercializáveis (AG 1051 e BR 106). A cultivar BR 106 foi superior à cultivar AG 1051 nos números total e de espigas verdes empalhadas comercializáveis e o contrário ocorreu nas massas de espigas verdes e no rendimento de grãos.

Palavras-chave: *Copernicia prunifera*, *Zea mays*, milho verde, rendimento de grãos, bagana, palha.

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Carnauba (*Copernicia prunifera*) is a palm tree native to Northeastern Brazil, and can be found across all states in that region. Leaves are palmate with a waxy coating on both surfaces. The cuticular wax in plants serves as a protective agent against water loss, ultraviolet radiation, and attacks by pathogens and pests (Jetter & Kunst, 2008).

Carnauba wax, obtained from the waxy powder that coats the leaves, is important for many types of industries (Carvalho & Gomes, 2008) and also in the post-harvest conservation of several types of fruits (Mota *et al*., 2006). Brazil is the only country in the world that produces and exports carnauba wax; this has been considered the main economic activity in carnauba exploitation (Carvalho & Gomes, 2008). A ground leaf residue is produced from extraction of the waxy powder; upon residue decomposition, it is occasionally used as fertilizer by some growers.

There are several reasons that justify the importance of evaluating carnauba leaf residues as an organic fertilizer. First, growers that utilize carnauba residues report that crops respond to their application with higher yields, but no research reports on such response are available. Second, the residues are produced in a region whose soils are generally poor in organic matter, and where growers frequently cannot afford the resources to purchase fertilizers. Soil organic matter conservation is one of the most important limiting factors for sustainability development in semiarid regions (Stewart & Robinson, 1997). Third, attempts to use those residues for other purposes have been frustrating. For example, a reduction in the performance of ovines has been observed as the amount of carnauba leaf residues in the diet of those animals increased (Gomes *et al*., 2009).

There are other facts that justify evaluating the effects of carnauba leaf residues on corn, one of the most important crops in Northeastern Brazil. Due to the support extended to irrigated agriculture by the state and federal governments, irrigated corn areas have increased and currently corn is even exploited by large companies. During the off-season, there is a higher interest in irrigated corn, since the demand for green ears and grain is greater than the supply, with increased prices. During that period, from July to December, it is possible to obtain two cropping seasons. Intensive cultivation has negative impacts on the soil's physical, chemical, and biological properties (Biederbeck *et al.*, 1996, 1997; Bowman *et al.,* 1990). Since there is interest in the above-ground part of corn for cattle feeding, practically every plant is removed after each cropping season, leading to faster soil depletion. Finally, studies have shown that corn yield increases with the application of plant residues from other crops (Zingore *et al.*, 2003; Carvalho *et al.*, 2008).

The effects of plant residue application vary with the type of residue applied (Mucheru-Muma *et al.*, 2007; Carvalho *et al*., 2008), their combination with chemical fertilizers (Mucheru-Muma *et al*., 2007), deposition site in the soil (Wuest *et al.*, 2000), and dose applied (Oladeji *et al.*, 2006), among other factors. There are many studies (Tian *et al.*, 1993; Zingore *et al.*, 2003; Oladeji *et al.*, 2006;) on the use of plant residues from perennial species as organic fertilizers.

The objective of this work was to evaluate the effects of application of carnauba leaf residue doses on the green ear yields of two corn cultivars. The study additionally evaluated corn grain yield.

MATERIAL AND METHODS

The experiment was carried out at an experimental farm from the Universidade Federal Rural do Semi-Árido, located 20 km away from the municipal seat of Mossoró, Rio Grande do Norte state, Brazil (5°11'S, 37°20'W, 18 m elevation), during the period from August to November, 2006. The climate information data for the region were summarized by Carmo Filho & Oliveira (1989).

The experiment was sprinkler-irrigated. The water depth required for corn (5.6 mm) was calculated considering an effective depth of the root system of 0.40 m. Irrigation time was based on water retained by the soil at a tension of 0.04 Mpa. An irrigation shift of 1 day was established. The irrigations started after planting and were suspended one day before each harvest.

The analysis (Embrapa, 1999) of a soil sample from the experiment area, a Red Yellow Argisol (RYA) (Embrapa, 2006), indicated: pH (H_2O)= 6.5; Ca= 1.19 $cmol_c$ dm^{-3}; Mg= 0.97 $cmol_c$ dm^{-3}; K= 0.15 $cmol_c$ dm^{-3}; Na= 0.22 $cmol_c$ dm^{-3}; Al= 0.00 $cmol_c$ dm^{-3}; H + Al= 0.49 $cmol_c$ dm^{-3}; SB= 2.53 $cmol_c$ dm^{-3}; CEC= 3.02 $cmol_c$ dm^{-3}; t= 2.53 $cmol_c$ dm^{-3}; m= 0.00%, V= 83.8%; P= 2.0 mg dm^{-3}; organic C= 0.11%; Organic matter = 1.90 g kg^{-1}.

The soil was tilled by means of two harrowings. Plots were identified and received 30 kg N (ammonium sulfate), 60 kg P_2O_5 (single superphosphate), and 30 kg K_2O (potassium chloride) per hectare. Fertilizers were applied manually in furrows at a depth of approximately 20 cm. Six carnauba leaf residue doses (0, 2, 4, 6, 8, and 10 t ha^{-1}) were applied manually over the chemical fertilizers, and the furrows were later covered with soil using a hoe. The carnauba leaf blades were harvested, crushed, and two years later, shortly before the establishment of the experiment, were chemically analyzed. The analysis of the carnauba leaf residues indicated: N= 27.13 g kg^{-1}; P= 1.46 kg^{-1}; K= 5.41 kg^{-1}; Ca= 4.98 kg^{-1}; Mg= 2.88 kg^{-1}; B= 50.54 kg^{-1}; Fe= 47.78 mg kg^{-1}; Cu= 0.59 mg kg^{-1}; Mn= 2.07 mg kg^{-1}; Zn= 0.56 mg kg^{-1}; and Na= 1445.2 mg kg^{-1}. The carnauba in the region grows in soils rich in sodium which explains the high Na content in the leaf residues analyzed.

Planting was done manually on 07/29/2006, at a row spacing of 1.0x0.4 m, using four seeds/pit. A thinning operation was performed 20 days after planting, leaving the two more vigorous plants in each pit. Therefore, after thinning the experiment showed a population density equivalent to 50 thousand plants ha^{-1}. Two cultivars were evaluated: BR 106 and AG 1051. BR 106 is a free-pollination, medium-cycle, medium-sized, flint type, reddish-yellow variety. AG 1051 is a short-sized, super-early double hybrid corn cultivar with yellow dent grains.

Pest control was done by means of two deltamethrin sprays (250 mL ha^{-1}), performed at 7 and 14 days after planting. Weed control was accomplished by means of two hoeings, performed at 20 and 45 days after seeding. After each weeding operation, the experiment was fertilized with 30 kg N ha^{-1} (ammonium sulfate).

A completely randomized block design with five replicates and split-plots was adopted (fertilizer doses in plots). Each experimental unit consisted of four 6.0 m-long rows. The usable area was considered as the space occupied by the two central rows, with the elimination of plants from one pit at each end. One of the usable rows was selected to evaluate green ear yield, while the other was used to assess grain yield and its components.

Green ear harvesting was performed every two days (as the grain reached the "green corn" stage), during the period from 70 to 76 days after planting. The total number and weight of unhusked green ears and the number and weight of marketable green ears, either unhusked or husked were evaluated. Marketable unhusked ears were considered as those with a length above 22 cm and suitable appearance for commercialization (without blemishes or perforations by pests). Marketable husked ears were considered as those with a length above 17 cm that displayed grain set and health suitable for commercialization.

Ripe ears were harvested 105 days after sowing, when the grain showed a moisture content of approximately 20%. Next, the ears were husked and left to dry in the sun for approximately 72 hours, when they were threshed by hand. After weighing the grain, a 100 g sample was taken to estimate moisture content. Based on the moisture content thus determined, grain weight was corrected to a moisture content of 15.5%. The number of kernels per ear was estimated based on 20 ears, and 100-kernel weight was estimated based on five samples of 100 kernels.

The data were submitted to analysis of variance using SAEG, software developed by Universidade Federal de Viçosa (Ribeiro Júnior, 2001), while regression analyses were made with the software developed by Jandel (1992). The data were submitted to the variance homogeneity test prior to the statistical analyses (Bartlett, 1937). The regression equations were selected based on the following criteria: biological explanation of the phenomenon, simplicity of the equation, and testing of equation parameters by Student's t test at 5% probability.

RESULTS AND DISCUSSION

There were effects of cultivars (C), leaf residue doses (D), and the C x D interaction on the total number of green ears and on the number of marketable unhusked green ears. The residues did not influence those traits in cultivar AG 1051, but increased both traits in cultivar BR 106 (Figure 1). Leaf residue doses that provided maximum yield of total number of green ears and number of marketable unhusked green ears in the cultivar BR 106 were 8.17 t ha^{-1} and 8.1 t ha^{-1}, respectively (Figure 1). On average, cultivar BR 106 was superior to the other cultivar for both traits. With regard to number of marketable husked ears, no effects of cultivars or residue doses were observed (Means of 44277 and 44216 ears ha^{-1} for AG 1051 and BR 106 cultivars, respectively).

There were effects of cultivars (C) and residue doses (D) on total green ear weight. In both cultivars, increased leaf residue doses increased that trait (Figure 2). Leaf residue doses that provided maximum total weight of green ears, cultivars AG 1051 and BR 106, were 8.07 t ha^{-1} and 7.97 t ha^{-1}, respectively. There were effects of C, D, and the C x D interaction on marketable unhusked green ear weight (Figure 2), but weight only increased in cultivar BR 106, with optimal dose of 8.15 t ha^{-1}. There were also effects of C, D, and C x D on marketable husked ear weight (Figure 2). In both cultivars, increased leaf residue doses increased yield. Leaf residue doses that provided maximum weights of marketable husked green ears, cultivars AG 1051 and BR 106, were 8.42 t ha^{-1} and 8.22 t ha^{-1}, respectively. On average, cultivar AG 1051 was superior to cultivar BR 106 with respect to total ear weight (12,65 t ha^{-1} *vs.* 12,28 t ha^{-1}) and marketable, unhusked (12,49 t ha^{-1} *vs.* 11,53 t ha^{-1}) and husked (7,57 t ha^{-1} *vs.* 6,44 t ha^{-1}) ear weight.

There were effects of cultivars (C), residue doses (D), and the C x D interaction on the number of kernels ear^{-1} (Figure 3). The application of leaf residues did not influence this trait in cultivar BR 106, but increased the trait in the other cultivar. Only a cultivar effect was observed on 100-kernel weight. On average, 100-kernel weight

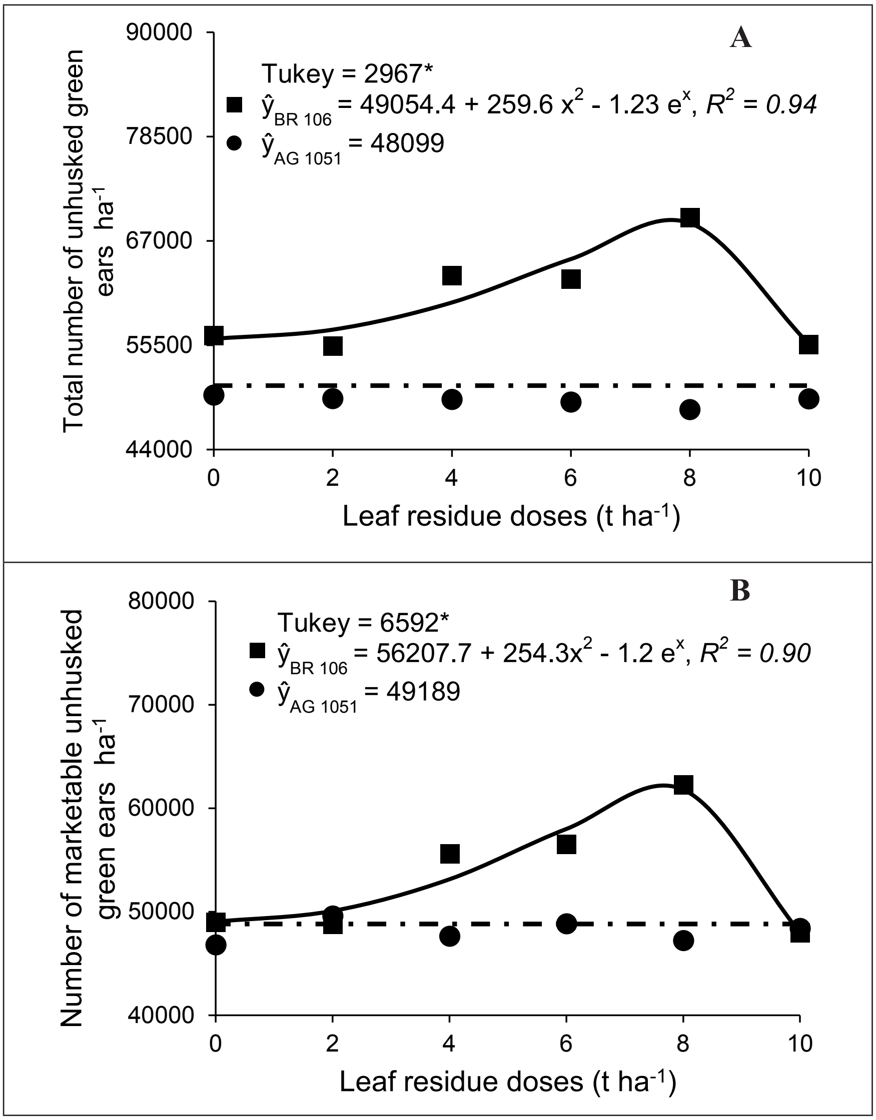

Figure 1. Mean total number of green ears (A) and number of marketable unhusked (B) green ears of corn cultivars in relation to the application of carnauba leaf residue doses [médias dos números total (A) e de espigas verdes comercializáveis empalhadas (B), de cultivares de milho, em resposta à aplicação de doses de resíduos foliares de carnaubeira]. Mossoró, UFERSA, 2006.
All parameters for all equations were significant at 5% probability by the t test (todos os parâmetros de todas as equações foram significativos a 5% de probabilidade, pelo teste t).
*Values to test cultivars in each residue dose, at 5% probability, by Tukey's test (valores para testar cultivares em cada dose de resíduo, a 5% de probabilidade, pelo teste de Tukey).

for AG 1051 and BR 106 cultivars were 32.0 g and 30.2 g, respectively. There were effects of C, D, and C x D on grain yield. In both cultivars grain yield increased as residue doses increased (Figure 3). Leaf residue doses that gave maximum grain yield in cultivars AG 1051 and BR 106, were 6.76 t ha^{-1} and 4.30 t ha^{-1}, respectively. On average, cultivar AG 1051 was superior (6,30 t ha^{-1}) to cultivar BR 106 (4,9 t ha^{-1}) for grain yield; such superiority occurred because AG 1051 was superior in number of kernels ear^{-1} (Figure 3) and 100-kernel weight, since cultivar BR 106 was better than cultivar AG 1051 for number of ears ha^{-1} (estimated by the total number of green ears ha^{-1} presented in Figure 1).

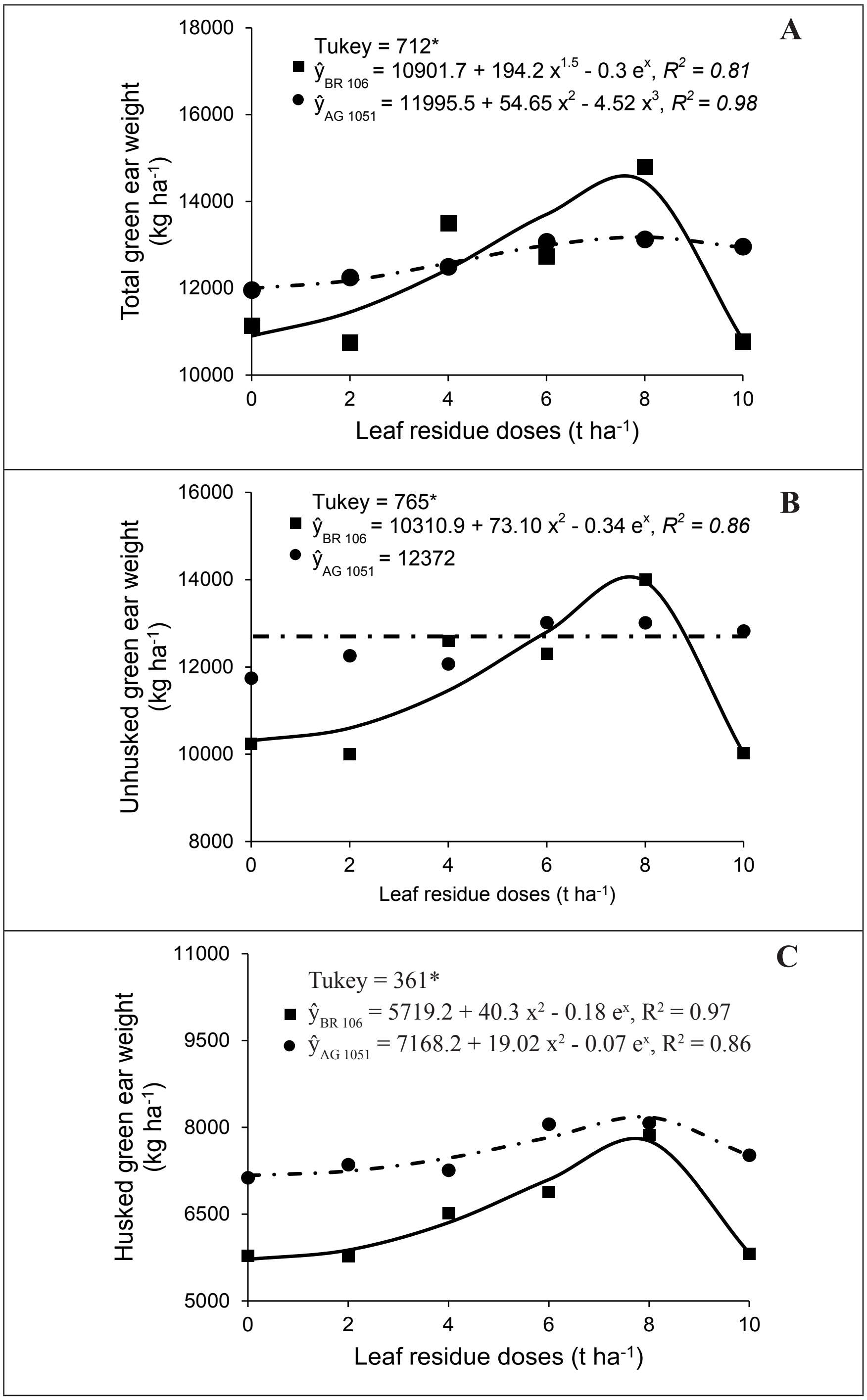

Figure 2. Mean total mass of green ears (A) and mass of marketable, unhusked (B) and husked (C) green ears of corn cultivars in relation to the application of carnauba leaf residue doses (médias das massas total (A) e de espigas verdes comercializáveis, empalhadas (B) e despalhadas (C), de cultivares de milho em resposta à aplicação de doses de resíduos foliares de carnaubeira). Mossoró, UFERSA, 2006.

All parameters for all equations were significant at 5% probability by the t test (todos os parâmetros de todas as equações foram significativos a 5% de probabilidade, pelo teste t).

In most of the evaluated traits (Figures 1 to 3) there were effects of the cultivars x leaf residue doses interaction, indicating a differential response of the cultivars to organic fertilization. For total green ear weight, marketable husked ear weight (Figure 2), and grain yield (Figure 3) such interaction was due to differences in the magnitude of the response. In other words, both cultivars responded to fertilization, but with different intensities. With respect to total number of green ears, number of marketable unhusked ears (Figure 1), marketable husked ear weight (Figure 2), and number of kernels ear^{-1} (Figure 3), the cultivars x residue doses interaction was due to the fact that cultivar AG 1051 did not respond to the residue doses, but cultivar BR 106 showed a positive response to the doses. These two types of interactions have been observed by other authors (Silva *et al.*, 2006) with applications of organic fertilizers, under similar environmental conditions, although with different cultivars.

Increased doses of leaf residues increased most traits utilized to assess corn yield, including total number of green ears, number and weight of marketable unhusked green ears (BR 106), total green ear weight, marketable husked green ear weight, and grain yield (AG 1051 and BR 106). Other authors (Mucheru-Muma *et al.*, 2007; Zingore *et al.*, 2003) also observed corn yield increases with the application of plant residues. The application of plant residues improves soil physical, chemical, and biological properties (Singh & Malhi, 2006; Banful & Hauser; 2011); this may contribute toward increased crop yields. The high sodium content in the leaf residues (Na= 1,44 g kg^{-1}) should not have been harmful to corn, since the experiment was conducted under irrigation and the

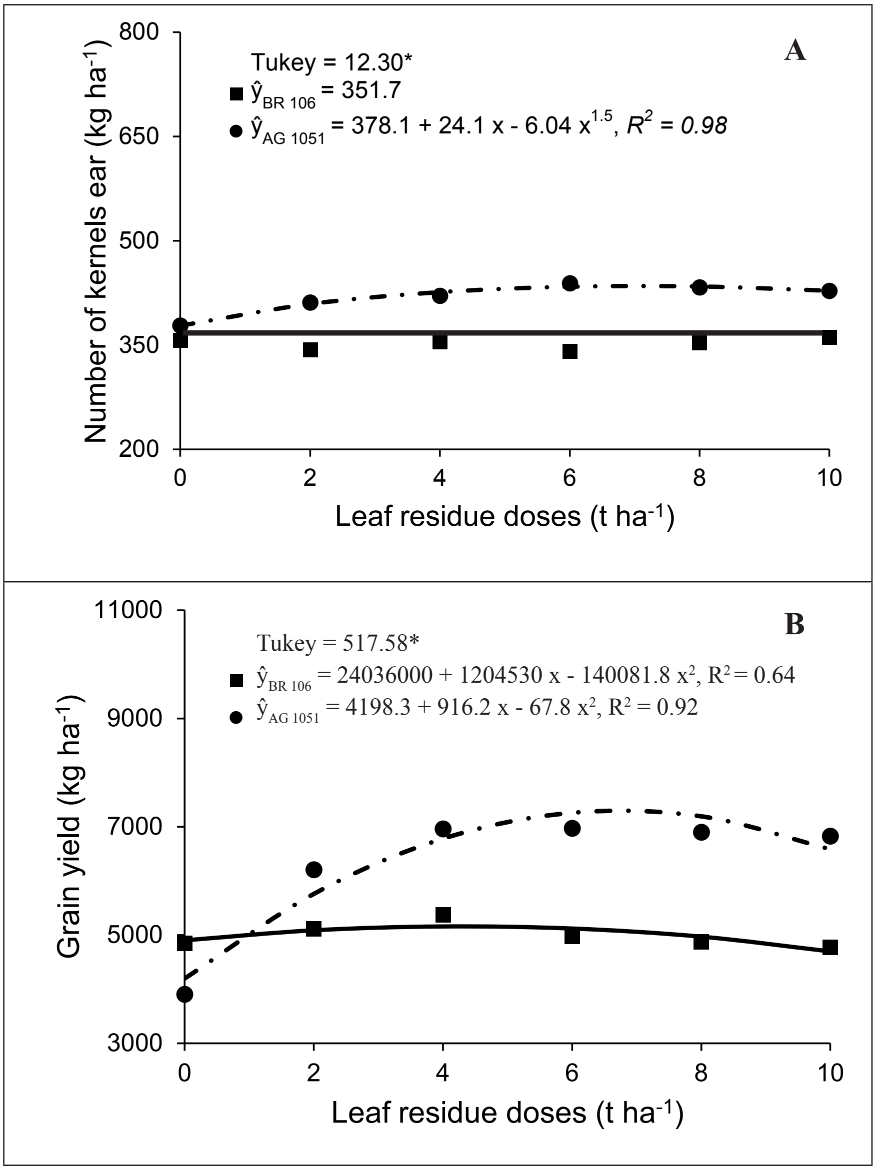

Figure 3. Mean number of kernels/ear (A) and mean grain yield (B) of corn cultivars in relation to the application of carnauba leaf residue doses [médias do número de grãos/espiga (A) e do rendimento de grãos (B), de cultivares de milho, em resposta à aplicação de doses de resíduos foliares de carnaubeira]. Mossoró, UFERSA, 2006.
All parameters for all equations were significant at 5% probability by the t test (todos os parâmetros de todas as equações foram significativos a 5% de probabilidade, pelo teste t).

fact that the soil of the experimental area is sandy. These conditions should have reduced the amount of sodium in the soil. Other information from the literature help to better explain the results obtained in this study. Because of the plant residues, the soil showed lower density and resistance to penetration and higher infiltration rate (Dalland *et al*., 1993). The residues also determined a significant increase in soil biological activity, in terms of C, N, and P of the microbial biomass and enzymatic activities (Yadav *et al*., 2011). In addition, as a response to the application of plant residues the soil showed higher levels of P, organic C, and cation exchange capacity (Hailu *et al*., 2000). The application of plant residues increased the absorption of several nutrients by corn, resulting in increased corn growth and yield (Tian *et al*., 1993). In this study, the application of residues may have contributed to maintain higher soil moisture contents, considering the high air temperatures (34.8 to 35.7°C) and insolation (310.1 to 320.7 h) that prevailed during the experimental period, although the study was conducted under irrigation. The mean cumulative rainfall infiltration was smallest in the soil without plant residues and increased in a curvilinear fashion as the amounts of residues applied increased (Baumhardt & Lascano, 1996).

However, the application of carnauba leaf residues did not influence the total number of green ears, the number of marketable unhusked ears, unhusked ear weight (AG 1051), and the number of marketable husked ears (AG 1051 and BR 106). In a few cases (Dam *et al*., 2005), a lack of corn response to the application of plant residues was also observed. Incidentally, some studies (Dam *et al*., 2005; Bahrani *et al*., 2007) have demonstrated that the application of plant residues may reduce crop yield, including corn yield (Bahrani *et al*., 2007). In this study, in traits where the cultivars under evaluation responded to the application of carnauba residues with increased yields (Figures 1 to 3), it was observed that higher residue doses determined yield reductions. One of the factors that may explain such corn yield reductions at higher carnauba residue doses, as observed in this study, could be a difficulty in obtaining plant establishment, at least in their initial growth stages. Since the residues were applied in furrows in the experiment on which this study was based, in order to provide fertilizer savings, the corn roots may have undergone some difficulty in becoming fixed and absorbing soil nutrients in plots that received higher amounts of the fertilizer. In support of this proposition, it has been verified that the effect of plant residues on plantlet development was dependent on where the material was placed in relation to the crop (Wuest *et al*., 2000). In addition to the direct physical effects of plant residues on the crops, there would also exist direct biological effects, such as competition for oxygen between microorganisms present in the residues and in the germinating seed. However, apparently the more commonly cited negative effects of plant residues on the crop where they are applied are of a chemical nature, via allelopathy (Wuest *et al*., 2000; Kong *et al*., 2006; Bahrani *et al*., 2007; Dudai *et al*., 2009).

It can be concluded that increased doses of leaf residues resulted in higher total number of green ears and higher number and weight of marketable unhusked green ears (BR 106), and higher total green ear weight, marketable husked green ear weight, and grain yield (AG 1051 and BR 106). However, the application of carnauba leaf residues did not influence the total number of green ears, number of marketable unhusked ears, unhusked ear weight (AG 1051), and number of marketable husked ears (AG 1051 and BR 106). Cultivar BR 106 was superior to cultivar AG 1051 in total number of green ears and number of marketable unhusked green ears, while the opposite occurred for green ear weight and grain yield.

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