Growth and Yield of Corn Grain and Green Ear in Competition With Weeds[1]

Crescimento e Rendimento de Espigas Verdes e de Grãos de Milho em Competição com Plantas Daninhas

SILVA, P.S.L.[2], DAMASCENO, A.P.A.B.[3], SILVA, K.M.B.[4], OLIVEIRA, O.F.[5] and QUEIROGA, R.C.F.[6]

ABSTRACT - Studies on plant growth are interesting because they provide explanations for the factors that influence yield in various crops. The objective of this work was to evaluate growth and yield in corn cultivar AG1051, when in competition with weeds. Cultivar AG 1051 was submitted to two groups of treatments: weed control, and sampling periods for dry biomass evaluation. The weed control treatments consisted of hoeing (two hoeings performed at 20 and 40 days after sowing) and no hoeing. Sampling periods consisted of collecting the above-ground part and roots of corn every fifteen days, until 105 days after sowing (DAS); the first sampling was performed 30 DAS. A completely randomized block design with ten replicates was used. For the characteristics evaluated in a single season, statistical analyses were carried out as a random block experiment. For the characteristics evaluated in several periods, statistical analyses were carried out as random blocks with split-plots (weed control assigned to plots). Fourteen weed species, unevenly distributed throughout the experimental area, were the most important. The growth observed for the above-ground part and root system of corn was 30% smaller in the non-hoed plots, compared to the hoed plots. Lack of weed control increased dry matter of the above-ground part of the weeds and reduced the number of unhusked and husked marketable green ears by 23% and 49%, respectively. Grain yield reduction caused by lack of weed control reached 38%.

Keywords: *Zea mays*, green corn, dry matter.

RESUMO - Apesar de trabalhosos, os estudos sobre o crescimento são de interesse porque fornecem explicações sobre os fatores que influenciam o rendimento das culturas. O objetivo do presente trabalho foi avaliar o crescimento e o rendimento de espigas verdes e de grãos do cultivar de milho AG 1051, em competição com plantas daninhas. Esse cultivar foi submetido a dois grupos de tratamento: controle de plantas daninhas e épocas de amostragem para avaliação da biomassa seca. Os tratamentos de controle das plantas daninhas foram com duas capinas (realizadas aos 20 e 40 dias após a semeadura) e sem capinas. As épocas de amostragem consistiram em coletas da parte aérea e das raízes do milho, realizadas de 15 em 15 dias, até 105 dias após a semeadura (DAS), sendo a primeira amostragem efetuada aos 30 DAS. Utilizou-se o delineamento de blocos completos casualizados, com dez repetições. Nas características avaliadas numa só época, as análises estatísticas foram feitas como um experimento de blocos ao acaso. Quanto às características avaliadas em várias épocas, as análises estatísticas foram feitas em blocos ao acaso com parcelas subdivididas (controle de plantas daninhas nas parcelas). Quatorze espécies de plantas daninhas, que se distribuíram desuniformemente na área experimental, foram as mais importantes. Os crescimentos da parte aérea e do sistema radicular do milho foram 30% menores em parcelas não capinadas do que nas capinadas. A falta de controle das plantas daninhas aumentou a matéria seca da sua parte aérea e reduziu em 23 e 49% os números de espigas verdes comercializáveis, empalhadas e despalhadas, respectivamente. A redução no rendimento de grãos devido à falta de controle das plantas daninhas foi de 38%.

Palavras-chave: *Zea mays*, milho verde, matéria seca.

[1] Recebido para publicação em 11.3.2009 e na forma revisada em 11.12.2009.

[2] Universidade Federal do Semi-Árido – UFERSA, Caixa Postal 137, 59625-900 Mossoró-RN, CNPq fellow, <paulosergio@ufersa.edu.br>; [3] Student, UFERSA, Caixa Postal 137, 59600-970 Mossoró-RN, CNPq fellow, <pauladamasceno1@hotmail.com>; [4] Universidade do Estado do Rio Grande do Norte – UERN, Caixa Postal 70, 59610-090 Mossoró-RN, <kmbsbarbosa@yahoo.com.br>; [5] UFERSA (retired professor), Caixa Postal 137, 59625-900 Mossoró-RN, <odaci@uol.com.br>; [6] Universidade Federal de Campina Grande – UFCG, Caixa Postal 10078, 58429-900 Campina Grande-PB, <robertoqueiroga@ccta.ufcg.edu.br>.

INTRODUCTION

Corn is cultivated by small farms and large companies in the 167 municipalities of the state of Rio Grande do Norte-RN, Brazil, to obtain green ears or dry grain (Gomes et al., 2007), occupying a planted area of 82.6 thousand hectares (CONAB, 2007). In commercial plantations, the mean grain yield is 545 kg ha^{-1} (CONAB, 2007), but no data are available on commercial green ear yield. Despite this crop's importance for the state, most growers are not concerned with weed control, which is only performed when time and labor are available. It is known, however, that weeds can reduce green ear and grain yield by up to 60% and 80%, respectively (Silva et al., 2004a, b).

Plant growth analysis is an explanatory, holistic, and integrative approach employed to interpret plant form and functioning (Hunt et al., 2002). Plant growth evaluation is usually labor-intensive: experimental plots must be larger when growth is measured by characteristics that require plant destruction to ensure extra border space; several samplings must be made throughout the plant cycle; a large number of samples must be dried at the same time for dry matter evaluations, etc. Many plant growth studies have been conducted in several crops, including corn. Corn growth evaluations have been carried out for parameters such as planting density (Sangoi et al., 2005), fertilizers (Wu et al., 2005), and competition with weeds (Lum et al., 2005; Carvalho et al., 2007). Despite being labor-intensive, growth studies provide explanations on aspects related to yield. For example, the relation between number of seeds per plant and growth rate was linear in soybean, reflecting reproductive plasticity, but curvilinear in corn and sunflower, reflecting morphogenetic restrictions to generate reproductive sinks (deposits) (Vega et al., 2001). Weeds decrease many physiological parameters in relation to corn growth (Cathcart & Swanton, 2004; Lum et al., 2005) and grain yield (Lum et al., 2005). No papers were found in the consulted literature on the relation between corn green ear growth and yield.

The objective of this work was to evaluate corn cultivar AG1051 growth and yield, when in competition with weeds.

MATERIAL AND METHODS

The experiment was conducted on Rafael Fernandes Experimental Farm (5º' latitude, 37º 20' WGr longitude and altitude of 18 m), located 20 km away from Mossoró-RN, from March to June 2005. The study was carried out under dry land conditions but received supplemental sprinkling irrigation when needed. The soil in the experimental area was classified as Eutrophic Red-Yellow Argisol, according to the Brazilian Soil Classification System (Embrapa, 1999), and as Ferric Lixisol, according to the Soil Map of the World (FAO, 1988). Soil tillage consisted of two harrowings and fertilization with 30 kg ha^{-1} N (ammonium sulfate), 60 kg ha^{-1} P_2O_5 (single superphosphate), and 30 kg ha^{-1} K_2O (potassium chloride). The fertilizers were applied in furrows located alongside and below the sowing furrows. The analysis of a sample taken from the experimental soil indicated: pH = 6.5; Ca^{2+} = 1.70 $cmol_c$ dm^{-3}; Mg^{2+} = 0.50 $cmol_c$ dm^{-3}; K^+ = 0.15 $cmol_c$ dm^{-3}; Na^+ = 0.03 $cmol_c$ dm^{-3}; Al^{3+} = 0.00 $cmol_c$ dm^{-3}; P = 35 mg dm^{-3}; Org. Mat = 12.0 g kg^{-1}.

Planting was carried out on 03.09.2005, using four cultivar AG 1051 seeds per pit. A 1.0 m spacing was used between rows, with pits on the same row spaced at 0.4 m. Thinning was performed 15 days after planting, leaving the two more vigorous plants in each pit. After thinning, the programmed sowing stand in the experiment was 50 thousand plants ha^{-1}. Two deltamethrin sprays (250 mL ha^{-1}) were performed at 7 and 14 days after planting, respectively, to control fall armyworm (*Spodoptera frugiperda*), the main pest attacking corn in the region. A side-dressing application with 30 kg ha^{-1} N (ammonium sulfate) was performed at 20 and 40 days after planting.

A completely randomized block design with ten replicates was used. Cultivar AG 1051 was submitted to two groups of treatment: weed control (two hoeings, performed at 20 and 40 days after sowing) or no weed control, and "sampling periods". For the characteristics evaluated in a single period, the statistical analyses were carried out as a simple randomized block experiment. For the characteristics evaluated in several periods, the statistical analyses were carried out as randomized blocks with split-plots. Each subplot consisted of three 6.0-m-long rows. The usable area was considered as that occupied by the 5.2 m in the central row. The treatments involving weed control or no weed control were applied in the plots. “Sampling treatments” were applied in the subplots. The sampling treatments consisted in collecting the above-ground part and root system of corn every 15 days, until 105 days after planting. The first sampling was performed 30 days after planting.

Length, width, and area of completely expanded leaves from three plants were evaluated in the first four samplings. Leaf area was measured using an automatic leaf area integrator, LICOR model 3100 (LI-COR, Inc. Lincoln). Evaluations in the six 15-day period samplings included fresh and dry matter of the above-ground part and root system of the corn plants. Root system was removed after an irrigation event, using a square shovel which was driven into the soil around the plant (at a depth of approximately 0.20 m), 0.20 m away from the stalk. Some root loss did occur, despite precautions to prevent it.

Four green corn harvests were performed, at intervals of two or three days; the first harvest was accomplished 68 days after planting, and the last, 75 days after planting. Green corn yield was evaluated based on total number and weight of unhusked green ears, and number and weight of both unhusked and husked marketable ears. The marketable unhusked ears were considered as those displaying a length equal to or above 22 cm, and without blemishes or evident markings of attack by diseases or pests. The marketable husked ears were considered as those with a length equal to or above 17 cm, showing health and grain set suitable for commercialization. After the last green ear harvest, length and diameter of all internodes from three plants were evaluated (using a digital caliper rule), as well as leaf and midrib thickness (measured with a digital caliper rule on the middle part of the leaf).

Ripe ears were harvested approximately 105 days after planting. Evaluations were made for number of ears ha^{-1} (based on ears harvested from the usable area), number of kernels ear^{-1} (from ten ears), 100-kernel weight (based on 10 samples), and grain yield (from ears harvested on the usable row). After the ripe ears were harvested, evaluations were made for weed composition and dry biomass of their above-ground part, as well as for corn height and ear height. The weeds were collected from a 1.0 m^2 area (four 0.25 m^2 subsamples, obtained with a 0.5 m x 0.5 m wooden frame laid randomly at four places in the usable area of each plot). The distance from ground level to the insertion point of the highest leaf was considered as plant height. Ear height was considered as the distance from ground level to the first ear’s insertion point. Both heights were measured in all usable plants of the subplot.

Soil tillage was performed with a tractor and sprays were applied with a back-pack sprayer; the other operations were accomplished by hand. Dry biomass was estimated by grinding samples weighing around 500 g, which were placed to dry in a forced air circulation oven adjusted to a temperature between 60 and 70 ^{o}C.

The data were submitted to analysis of variance using the SAEG software (Ribeiro Júnior, 2001), while the Table Curve software (Jandel Scientific, 1992) was used for the regression analyses. The data were submitted to the variance homogeneity test before the statistical analyses were conducted (Bartlett, 1937). Since weed counts have a tendency to follow the Poisson distribution, the corresponding data were transformed to square root before analysis of variance was conducted (Bartlett, 1947). A regression equation was selected based on the following criteria: biological explanation of the phenomenon observed, simplicity of the equation, significance of the coefficients at 5% probability by the Student’s *t* test, and coefficient of determination value.

RESULTS AND DISCUSSION

Fourteen weed species were the most important in the experimental area (Table 1). This small number of species is probably associated with intensive cropping (two crops per year, involving harrowings and fertilizations), with corn being grown in the experiment area for over ten years. The biomass of the above-ground part of weeds, as well as density and diversity of those plants are lower under conventional cultivation (tillage and high doses of chemical products), intermediate in reduced tillage systems, and higher in organic systems (Menalled et al., 2001). The weed population in a given area varies according to many factors, such as soil seed bank, soil, climate, crop, and agronomic practices. Although the population comprises different species, few of them are predominant, corresponding from 70% to 90% of the species total (Buhler, 1999). Some species (*Commelina benghalensis*) occurred in the entire experimental area, while others (*Acanthospernum lispidum*) had a restricted occurrence. In six of the ten blocks (1, 3, 4, 5, 7, and 10), the number of weed species in hoed plots was smaller than in non-hoed plots. The contrary occurred in two blocks (2 and 6), while in two other blocks, the number of species was the same in hoed and non-hoed plots. Dry matter of the above-ground part of weeds in hoed plots (371 g m^{-2}) was smaller than in non-hoed plots (819 g m^{-2}), with CV = 36%.

Table 1 - Distribution of weed species in experimental plots of corn grown with (two) hoeings or without hoeing

Block	Weed species	
	Plots	
10	No hoeing	With hoeing
	Alternanthera tenella Colla, *Cenchrus ciliaris* L. *Commelina benghalensis* L., *Cucumis anguria* L. *Digitaria sanguinalis* Scop., *Sida* sp.	*Alternanthera tenella* Colla, *Commelina benghalensis* L., *Digitaria sanguinalis* Scop.
9	No hoeing	With hoeing
	Alternanthera tenella Colla, *Cenchrus ciliaris* L. *Commelina benghalensis* L., *Cucumis anguria* L.	*Alternanthera tenella* Colla, *Cenchrus ciliaris* L. *Commelina benghalensis* L., *Cucumis anguria* L.
8	With hoeing	No hoeing
	Acanthospernum lispidum L.C., *Alternanthera tenella* Colla, *Commelina benghalensis* L., *Digitaria sanguinalis* Scop., *Ipomoea* sp.	*Commelina benghalensis* L., *Cucumis anguria* L., *Ipomoea asarifolia* (Dear.) Roem. Et Schult., *Panicum maximum* Jacq.
7	With hoeing	No hoeing
	Alternanthera tenella Colla, *Commelina benghalensis* L., *Digitaria sanguinalis* Scop.	*Alternanthera tenella* Colla, *Cenchrus ciliaris* L. *Commelina benghalensis* L., *Cucumis anguria* L.
6	No hoeing	With hoeing
	Cenchrus ciliaris L., *Commelina benghalensis* L., *Croton lobatus* L., *Cucumis anguria* L., *Ipomoea* sp.	*Alternanthera tenella* Colla, *Cenchrus ciliaris* L., *Commelina benghalensis* L., *Cucumis anguria* L., *Digitaria sanguinalis* Scop.
5	With hoeing	No hoeing
	Commelina benghalensis L., *Cucumis anguria* L., *Digitaria sanguinalis* Scop., *Phyllanthus amarus* Schumach et Thonn.	*Alternanthera tenella* Colla, *Cenchrus ciliaris* L., *Commelina benghalensis* L., *Dactyloctenium aegyptium* (L.) Beauv., *Panicum maximum* Jacq., *Phyllanthus amarus* Schumach et Thonn.
4	With hoeing	No hoeing
	Alternanthera tenella Colla, *Commelina benghalensis* L., *Digitaria sanguinalis* Scop.	*Alternanthera tenella* Colla, *Cenchrus ciliaris* L., *Commelina benghalensis* L., *Cucumis anguria* L., *Digitaria sanguinalis* Scop.
3	With hoeing	No hoeing
	Commelina benghalensis L., *Digitaria sanguinalis* Scop.	*Commelina benghalensis* L., *Cucumis anguria* L., *Digitaria sanguinalis* Scop., *Walteria indica* L.
2	No hoeing	With hoeing
	Commelina benghalensis L., *Digitaria sanguinalis* Scop., *Panicum maximum* Jacq.	*Commelina benghalensis* L., *Cucumis anguria* L., *Digitaria sanguinalis* Scop., *Phyllanthus amarus* Schumach et Thonn
1	No hoeing	With hoeing
	Cenchrus ciliaris L., *Commelina benghalensis* L., *Croton lobatus* L., *Dactyloctenium aegyptium* (L.) Beauv., *Panicum maximum* Jacq.	*Cenchrus ciliaris* L., *Commelina benghalensis* L., *Digitaria sanguinalis* Scop., *Phyllanthus amarus* Schumach et Thonn

Leaf width increases as a function of age were higher in hoed than in non-hoed plots, resulting in an effect of the age x weed control interaction (Table 2). As to leaf length, there was an effect of age (A) and weed control (C), but not of A x C interaction (Table 2). On average, corn leaves in hoed plots were longer than in non-hoed plots. Effect of treatments on mean plant leaf area was similar to leaf width results (Table 2), that is, there was an effect of the age x weed control interaction. Corn leaf area reductions (Aflakpui et al., 2002) caused by *Striga hermonthica*, a parasite species on corn, were also observed by other authors. Different authors (Ford & Pleasant, 1994) also verified a reduction in the number of corn leaves caused by weeds.

Competition with weeds reduced plant and ear height, mean internode diameter, and midrib thickness, although no effect was observed on internode length and leaf thickness (Table 3).Reduction in plant height must have been caused by reduction in number of internodes, since internode length was not influenced by weeds. Reduction in number of corn leaves caused by weeds (Ford & Pleasant, 1995) suggests this reduction in number of internodes.

Dry matter of the above-ground part and root system of corn increased less with plant age in plots without weed control, which resulted in an effect of the age x weed control interaction (Table 4). In both characteristics, reductions of the corn root system caused by

Table 2 - Mean leaf length, width, and area of corn cultivar AG 1051 grown with (two) hoeings or without hoeing at different plant ages

Plant age (days after planting, x)	Leaf width (cm) (y)		Leaf length (cm) (y)		Leaf area (cm^2 per plant) (y)	
	Two hoeings		Two hoeings		Two hoeings	
	Yes	No	Yes	No	Yes	No
30	3.38 a[2/]	3.13 a[2/]	45.4	43.2	615.6 a[2/]	404.3 a[2/]
45	6.29 a	4.97 b	74.2	66.5	2,026.4 a	1,161.4 b
60	7.60 a	6.62 b	76.7	66.6	4,705.5 a	2,678.1 b
75	7.87 a	6.91 b	76.6	67.5	4,795.8 a	2,974.1 b
Means	-		68.2 a[2/]		61.0 b	-
Coefficient of variation for plots, %	14.1		11.6		32.0	
Coefficient of variation for subplots, %	9.7		9.9		24.5	
Regression equation[1/]	$y = 8.81 - 490.58/x^2$	$y = 9.61 - 196.90/x$	$y = 55.08 + 32094.44/x^{1.5} - 185421.24/x^2$		$y^{-1/} = 0.00087 - 1.49864/x^{1.5} + 9.23571/x^2$	$y^{-1/} = 0.00261 - 0.47955/x + 2.67769/x^{1.5}$
LSD (Tukey test) for hoeing	0.4191		3.8		392.1	
R^2	0.99	0.96	0.96		0.99	0.99

[1/] All coefficients were significant at 5% probability by the t test.
[2/] Means followed by the same letter on the rows are not different at 5% probability, by the Tukey's test.

Table 3 - Mean values for plant height and ear height, internode length and diameter, and lamina and midrib thickness in corn cultivar AG 1051 grown with or without hoeing[1/]

Two hoeings	Plant height (cm)	Ear height (cm)	Mean internode length (cm)	Mean internode diameter (mm)	Leaf blade thickness (mm)	Midrib thickness (mm)
Yes	197 a	111 a	15.0 a	13.4 a	0.18 a	2.13 a
No	184 b	105 b	14.9 a	11.5 b	0.17 a	1.66 b
CV, %	4.0	5.2	2.4	3.6	6.6	15.6

[1/] Means followed by the same letter are not significantly different at 5% probability by the Tukey's test.

Table 4 - Mean values for dry matter of the above-ground part and root system of corn cultivar AG 1051 grown with or without hoeings at different plant ages

Plant age (days after seeding, x)	Dry matter of the above-ground part (kg ha^{-1}) (y)		Dry matter of the root system (kg ha^{-1}) (y)	
	Two hoeings		Two hoeings	
	Yes	No	Yes	No
30	359.2 a[2/]	211.7 a[2/]	45.5 a[2/]	27.3 a[2/]
45	1,179.1 a	769.3 b	192.5 a	93.9 b
60	4,106.8 a	2,758.9 b	738.0 a	378.9 b
75	6,732.5 a	4,528.0 b	739.6 a	418.5 b
90	10,423.0 a	6,167.7 b	850.8 a	656.8 b
105	11,040.8 a	7,901.6 b	793.4 a	555.2 b
Coefficient of variation for plots, %	21.0		32.6	
Coefficient of variation for subplots, %	20.5		27.9	
Regression equation[1/]	$\ln y = 2.80792 + 1.12812x - 0.00063x^2$	$y = -16779.30 + 2379.22x^{0.5} + 3532960.00/x^2$	$y = -653.68969 + 6.9288x^{1.5} - 0.50448x^2$	$\ln y = 6.74686 - 3216.5850/x^2$
LSD (Tukey) for hoeing	405.7		61.7	
R^2	0.99	0.99	0.93	0.92

[1/] All coefficients were significant at 5% probability by the t test.
[2/] Means followed by the same letter on the rows are not different at 5% probability, by the Tukey's test.

weeds were also observed by other authors (Thomas & Allison, 1975). There was a tendency of reduction of the corn root system in the last sampling, in both hoed and non-hoed plots. It is possible that such reduction was associated with root losses as the root system was removed. Already senescent roots might break more easily as they are removed.

With the exception of total number of green ears, lack of hoeing reduced all green corn production characteristics evaluated (Table 5). Such reductions varied from 22% in number of marketable unhusked green ears to 58% in marketable husked green ear weight. Other authors (Silva et al., 2004b; Silva et al., 2009) also verified green ear yield reduction as a result of corn competition with weeds.

Lack of weed control also reduced grain yield (Table 6) due to a reduction in the number of kernels ear^{-1}, since number of ears and 100-kernel weight were not influenced by hoeing (Table 5). Similar reductions in grain yield and its components have also been observed by other researchers (Duarte et al, 2002).

The weeds reduced most of the characteristics evaluated in the present study (Tables 2 to 6). Weeds decrease the yield of crops, by competing with them for water, nutrients, and light (Carruthers et al., 1998). Nutrient extraction by weeds has an impact on the availability of nutrients for the crop, thus affecting dry matter accumulation, as observed in this work (Table 4). In fact, absorption of N by weeds can vary from 32.4 kg ha^{-1} to 52.3 kg ha^{-1}, depending on the type of control to which they are submitted; in the case of P_2O_5, absorption varied from 4.3 kg ha^{-1} to 7.2 kg ha^{-1}, while K_2O absorption varied from 32.1 kg ha^{-1} to 38.9 kg ha^{-1} (Sreenivas & Satyanarayna, 1996). Nitrogen deficiency symptoms develop earlier in corn infested with weeds than in weed-free corn, which implies soil N depletion in corn grown in the presence of weeds (Rajcan & Swanton, 2001). In addition, corn yield reductions are smaller under higher than under lower nitrogen doses (Tollenaar et al., 1997). However, another aspect must be involved. The corn root system develops less in the presence of weeds (Thomas & Allison, 1975), as observed in the present work (Table 4). Consequently, a smaller corn root system due to the presence of weeds would be less efficient in absorbing nutrients.

When infested by weeds, corn crops develop water stress symptoms earlier than when weed-free (Young et al., 1984; Tollenaar et al.,

Table 5 - Green ear yield of corn cultivar AG 1051 grown with or without hoeings[1/]

Two hoeings	Total green ears ha^{-1}		Marketable unhusked green ears ha^{-1}		Marketable husked green ears ha^{-1}	
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)
Yes	49,230 a	14,872 a	47,885 a	14,674 a	37,500 a	7,964 a
No	49,145 a	10,248 b	42,094 b	9,452 b	19,444 b	3,357 b
CV, %	3.5	11.1	6.5	12.5	16.3	20.3

[1/] Means followed by the same letter are not significantly different at 5% probability by the Tukey's test.

Table 6 - Grain yield and its components in corn cultivar AG 1051 grown with or without hoeings[1/]

Two hoeings	Grain yield (kg ha^{-1})	Number of ears ha^{-1}	Number of kernels ear^{-1}	100-kernel weight (g)
Yes	6,533 a	49,225 a	454 a	32.8 a
No	4,081 b	46,303 a	319 b	30.9 a
CV, %	16.6	7.1	16.5	6.7

[1/] Means followed by the same letter are not significantly different at 5% probability by the Tukey's test.

1997). However, there are no differences between water contents in the soil's profile in corn with or without weeds (Young et al., 1984; Tollenaar et al., 1997). Actually, the water content in corn plots containing weeds was higher than in weed-free plots (Thomas & Allison, 1975). In the presence of weeds, the development of water stress symptoms may not be caused by water availability, but by a reduced ability of the root system to absorb water. Thus, although the experiment on which this work was based was irrigated, corn root system reduction by weeds (Table 4) would decrease its water-absorbing capacity. Water deficit induces stomata closure, stopping photosynthesis and reducing corn yield when in competition with weeds (Silva et al., 2004a). Another possibility is that weed root exudates would contain toxins that could inhibit root growth in corn (Rajcan & Swanton, 2001).

In the competition for light, two components are involved: the amount and quality of light. Direct competition between corn and weeds for incident photon flux density (PFD) is small since corn plants are taller than most weeds. This means that corn yield losses due to competition with weeds for incident PFD cannot be explained by reduced photosynthesis rates in lower leaves shaded by weeds. Such loss is more likely explained by a reduction in leaf area, as observed in this research (Table 2) as well as in other studies (Aflakpui et al., 2002). It has been verified (Tollenaar et al., 1997) that high competition by weeds reduced LAI in corn at the blooming stage by 15%. It is interesting to mention that a reduction in leaf area should reduce shading on weeds, making them more aggressive to corn, therefore generating a harmful cycle for the crop: the weeds reduce corn leaf area, and this reduction encourages weed growth, and so on.

Lower corn leaves receive light of a different quality than leaves receiving full sunlight. The light inside the canopy is rich in far-red (FR) radiation (730 to 740 nm). This is caused by the selective absorption of red light, R (660-670 nm) by the photosynthetic pigments and by the reflection of FR light by green leaves. This makes the FR/R ratio in the lower portion of the canopy higher than in the upper portion. Although weeds in general do not shade corn, there are indications that corn grown in the presence of weeds receives a higher FR/R ratio than a weed-free crop (Rajcan & Swanton, 2001).

It can be concluded that fourteen weed species, with a non-uniform distribution, occurred more frequently in the experimental area. The growth observed for the above-ground part and root system of corn was 30% smaller in non-hoed plots as compared to hoed plots. The lack of weed control increased dry matter of the above-ground part of weeds and reduced the number of unhusked and husked marketable green ears by 23% and 49%, respectively. The grain yield reduction caused by the lack of weed control reached 38%.

LITERATURE CITED

AFLAKPUI, G. K. S.; GREGORY, P. J.; FROUD-WILLIAMS, R. J. Growth and biomass partitioning of maize during vegetative growth in response to *Striga hermonthica* infection and nitrogen supply. **Exper. Agric.**, v 38, n. 3, p. 265-276, 2002.

BARTLETT, M. S. Some examples of statistical methods of research in agriculture and applied biology. **J. Roy Stat. Soc.**, v. 4, n. 1, p. 137-183, 1937.

BARTLETT, M. S. The use of transformations. **Biometrics**, v. 3, n. 1, p. 39-52, 1947.

BUHLER, D. D. Weed population responses to weed control practices. I. Seed bank, weed populations, and crop yields. **Weed Sci.**, v. 47, n. 4, p. 416-422, 1999.

CARRUTHERS, K. et al. Intercropping corn with soybean, lupin and forages: weed control by intercrops combined with interrow cultivation. **Eur. J. Agron.**, v. 8, n. 2/4, p. 225-238, 1998.

CARVALHO, L. B. et al. Estudo comparativo do acúmulo de massa seca e macronutrientes por plantas de milho var. BR-106 e *Brachiaria plantaginea*. **Planta Daninha**, v. 25, n. 2, p. 293-301, 2007.

CATHCART, R. J.; SWANTON, C. J. Nitrogen and green foxtail (*Setaria viridis*) competition effects on corn growth and development. **Weed Sci.**, v. 52, n. 6, p. 1039-1049, 2004.

COMPANHIA NACIONAL DE ABASTECIMENTO – CONAB. **SAFRA-Avaliação de Safra**. Brasília: Ministério da Agricultura e do Abastecimento, 2007.

DUARTE, N. F.; SILVA, J. B.; SOUZA, I. F. Competição de plantas daninhas com a cultura do milho no município de Ijaci, MG. **Ci. Agrotecnol.**, v. 26, n. 5, p. 983-992, 2002.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUARIA - EMBRAPA. Centro Nacional de Pesquisa do Solo. **Sistema brasileiro de classificação de solos**. Brasília: Serviço de Produção de Informação, 1999. 412 p.

FAO. **Soil map of the world; revised legend**. Rome: UNESCO, 1988. 119 p.

FORD, G. T.; PLEASANT, J. Competitive abilities of six corn (*Zea mays* L.) hybrids with four weed control practices. **Weed Technol.**, v. 8, n. 3, p. 124-128, 1995.

GOMES, J. K. O. et al. Effects of weed control through cowpea intercropping on maize morphology and yield. **Planta Daninha**, v. 25, n. 3, p. 433-441, 2007.

HUNT, R. et al. A modern tool for classical plant growth analysis. **Ann. Bot.**, v. 90, p. 485-488, 2002.

JANDEL. Jandel TBLCURVE. Table Curve 3.0. Curve fitting software**. Corte Madera, Jandel Scientific**, 1992.

LUM, A.F.; CHIKOYE, D.; ADESIYAN, S.O. Control of *Imperata cylindrical* (L.) Raeuschel (speargrass)with nicosulfuron and its effects on the growth, grain yield and food components of maize. **Crop Protec.** , v.24, p.41-47, 2005.

MENALLED, F. D.; GROSS, K. L.; HAMMOND, M. Weed aboveground and seedbank community responses to agricultural management systems. **Ecol. Appl.**, v. 11, n. 6, p. 1586-1601, 2001.

RAJCAN, I.; SWANTON, C. J. Understanding maize-weed competition: resource competition, light quality and the whole plant. **Field Crops Res.,** v. 71, n. 2, p. 139-150, 2001.

RIBEIRO JÚNIOR, J. I. **Análises estatísticas no SAEG**. Viçosa, MG: Universidade Federal de Viçosa, 2001. 301 p.

SANGOI, L. et al. Rendimento de grãos, produção e distribuição de massa seca de híbridos de milho em função do aumento da densidade de plantas. **R. Bras. Agroci.**, v. 11, n. 1, p. 25-31, 2005.

SILVA, A. A. et al. **Tecnologias de produção do milho**. Viçosa, MG: Universidade Federal de Viçosa, 2004a. p. 269-310.

SILVA, P. S. L.; SILVA, E. S.; MESQUITA, S. S. X. Weed control and green ear yield in maize. **Planta Daninha**, v. 22, n. 1, p. 137-144, 2004b.

SILVA, P. S. L. et al. Weed control via intercropping with gliricídia. II. Corn crop. **Planta Daninha**, v. 27, n. 1, p. 105-112, 2009.

SREENIVAS, G.; SATYANARAYANA, V. Nutrient removal by weeds and maize. **Indian J. Agron.**, v. 41, n. 1, p. 160-162, 1996.

THOMAS, P. E. L.; ALLISON, J. C. S. Competition between maize and *Rottboellia exaltata*. **J. Agric. Sci.**, v. 84, n. 1, p. 305-312, 1975.

TOLLENAAR, M.; AGUILERA, A.; NISSANKA, S. P. Grain yield is reduced more by weed interference in an old than in a new maize hybrid. **Agron. J.**, v. 89, n. 1, p. 239-246, 1997.

VEGA, C. R. C. et al. Seed number as a function of growth. A comparative study in soybean, sunflower, and maize. **Crop Sci.**, v. 41, p. 748-754, 2001.

WU, S. C. et al. Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. **Geoderma**, v. 125, n. 1, p. 155-166, 2005.

YOUNG, F. L.; WYSE, D. L.; JONES, R. J. Quackgrass (*Agropyron repens*) interference on corn (*Zea mays*). **Leed Sci.**, v. 32, p. 226-234, 1984.