COMPETITIVE ABILITY OF CORN IN COEXISTENCE WITH GOOSEGRASS[1]

Habilidade Competitiva de Milho em Convivência com Capim-Pé-de-Galinha

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ABSTRACT - Competition between plants is one of the main interferences that occurs in agricultural systems and accounts for significant crop yield reductions. The aim of this study was to assess the competitive ability of corn in coexistence with the weed species *Eleusine indica*. The experiments were conducted in a greenhouse, in the growing season 2010/2011, and were arranged in a completely randomized design with four replications. The experimental units consisted of plastic pots with a volumetric capacity of 8 L. Treatments were arranged in a replacement series with five proportions of corn plants and weed: 100:0, 75:25, 50:50, 25:75, and 0:100, respectively, with a constant population of eight plants per pot, at the end of each treatment. The competitiveness analysis was conducted through diagrams applied to the replacement series experiment and competitiveness index, and the variables evaluated were root, shoot, and total dry mass, and plant height. When in equal proportions, corn showed competitive ability equivalent to goosegrass in relation to the variables shoot, root, and total dry mass. Goosegrass was more competitive than the crop in relation to plant height.

Keywords: competition, weed, *Eleusine indica, Zea mays.*

*RESUMO - A competição entre plantas é uma das principais interferências que ocorrem nos sistemas agrícolas, respondendo por reduções significativas no rendimento das culturas. O objetivo desta pesquisa foi avaliar a habilidade competitiva de milho em convivência com capim-pé-de-galinha (****Eleusine indica****). O experimento foi realizado em casa de vegetação, na estação de crescimento 2010/2011, em delineamento inteiramente casualizado com quatro repetições. As unidades experimentais consistiram de vasos plásticos com capacidade volumétrica de 8 L. Os tratamentos foram arranjados em série de substituição, com cinco proporções de plantas de milho e da planta daninha: 100:0, 75:25, 50:50, 25:75 e 0:100, respectivamente, com população final constante de oito plantas por vaso. A análise da competitividade foi realizada por meio de diagramas aplicados a experimentos substitutivos e índices de competitividade. As variáveis analisadas foram massa seca da parte aérea, da raiz e total e estatura de plantas. Quando em proporções iguais, o milho apresentou habilidade competitiva equivalente à do capim-pé-de-galinha em relação às variáveis massa seca da parte aérea, da raiz e total. O capim-pé-de-galinha foi mais competitivo que a cultura em relação à estatura de plantas.*

Palavras-chave: competição, planta daninha, *Eleusine indica, Zea mays.*

INTRODUCTION

Plant interactions cause negative, positive or neutral effects on the individuals involved (Booth et al., 2003). Competition is a form of negative interference in which individuals compete with each other on common resources such as water, nutrients, space and light, and it is a key process in plant populations or communities (Casper & Jackson, 1997; Berger et al., 2008).

Characteristics that are advantageous and that support the early growth of plants in the farming are crucial. Thus, the cultivar that

features higher competitive ability can manifest its suppression potential over competing plants (Lamego et al., 2005).

One of the main causes of crop yield reduction is the interference caused by weeds, especially in the early development of the crop - stage where there is a great competition for growth resources. Thus, models for studying the competition between plants were developed in different levels of complexity (Kropff, 1988).

The replacement series model is the most used to study the competition between plants as it allows assessing which species or biotypes are more competitive. It also determines if it is an intra or interspecific competition (Cousens, 1991). The interpretation of the experimental series replacement model includes the comparison between the observed and expected yields, where the expected yield is a linear function of the proportions of the mixed species. A straight line is drawn for each species, linking production based on monoculture to its zero yield point, which defines the expected income and represents competition on equal terms, that is, when interspecific competition is equivalent to intraspecific competition (Rejmánek et al. 1989).

In the replacement series model, the proportions of each mixed species vary, while the total density is kept constant. Thus, the assumption of replacement models is that the yield of mixtures may be determined by comparing yields with species in monocultures (Cousens, 1991).

According to Bianchi et al. (2006), in most cases, replacement experiments demonstrate that the crop is more competitive than weed species, since the effect of weeds in crops is not due to their higher competitive ability, but to the degree of infestation and high density where they are compared to cultivated plants. These authors, by using the experimental replacement series model, found that the ratio between soybean and turnip crops altered the competitive relationship between these species, but that the proportion between the different soybean cultivars didn't change this relationship, where turnip was more competitive than soybean cultivars. However, other studies showed higher competitive abilities for crops in relation to weed (Christoffoleti Victoria & Son, 1996; Hoffman

& Buhler, 2002; Moraes et al., 2009; Yamauti et al., 2011).

Eleusine indica (goosegrass) is a species that has raged in recent years and it may turn into a serious problem for corn crop yield and productivity in the near future. It belongs to the Poaceae family, found in most part of Brazil (Kissmann, 1997).

This species is considered one of the most important grass weeds and some authors classify it among the 18 worst weeds in the world (Radosevich et al., 1997; Ngim & Lee, 2000). There are reports of more than 60 countries and 50 crops suffering competition with this species. Its ability to establish itself in cultivated areas is a consequence of its intense seed production, next to 400,000 per plant, which can be transported by wind, increasing infestations (Kissmann, 1997).

Given the relative importance of goosegrass in the agricultural scenario, studies on the biology and the interference relationships of this species on different crops are fundamental.

The hypothesis of this study is that cultivated plants have higher competitive ability than the weeds, when they occur in equal proportions and under appropriate levels of resources. In this context, the aim was to investigate the competitive ability of corn crops in coexistence with goosegrass, through the replacement series method.

MATERIAL E METHODS

The experiment was conducted in a greenhouse in the growing season 2010/2011. The experimental units consisted of plastic pots with volumetric capacity of 8 L and height of 25 cm, filled with soil derived from the experimental area, classified as typical Dystrophic Red Latosol.

Due to the dormancy period of goosegrass seeds, a treatment to overcome this mechanism was firstly conducted, which consisted of mechanical scarification of the seeds with sandpaper (320 mesh) and posterior incubation in a BOD-type growth chamber. The temperature and light conditions were alternated to 16 hours at 20 °C (dark) and 8 hours at 30 ° C (light) for approximately four days (Dal Magro et al., 2010).

After germination, seeds were transferred to polystyrene foam trays containing 128 cells, filled with commercial substrate. At the seedling emergence, about 20 days, they were transplanted to the experimental units, coinciding with the emergence of corn seedlings, both seeded seven days before the final establishment of experimental units containing crop and weed at the same phenological stage.

The population density used for each experimental unit was obtained in accordance with the "Law of constant final yield" determined in previous trials (data not reported), where the population was eight plants per pot, equivalent to approximately 250 plants m^2. Treatments consisted of combinations of five proportions of corn and goosegrass, that is, 8:0, 6:2, 4:4, 2:6 and 0:8, which corresponded to the proportions of 100:0, 75:25, 50:50, 25:75 and 0:100, respectively. Treatments were arranged in a completely randomized design with four replications, the positions of pots being changed periodically, in order to obtain homogeneous experimental conditions.

At 42 days after corn emergence, all plants were collected, whose variables analyzed were plant height, measured from the distance of the base to the end of the last leaf, and shoot, root and total dry mass. To obtain dry mass, plants were divided into shoot and root and put to dry in a forced air circulation incubator at 60 ° C for a period of 72 hours. Then weighing was conducted; total dry mass corresponded to the sum of the shoot dry mass + root dry mass ratio in each proportion.

For analysis of the variables, we used the graphical analysis method or the conventional method for substitutive experiments (Roush et al. 1989; Cousens, 1991), which involves the construction of diagrams based on the relative productivity (PR) and total relative productivity (PRT), in proportions of 0, 25, 50, 75 and 100% of the crop and the weed.

The relative productivity of the variables was calculated by dividing the average of the mixture at the average of the monoculture, including in the calculation the average per plant of each species in each experimental unit. The PRT represented the sum of the relative productivity of the competitors in the respective proportions of plants (Hoffman & Buhler, 2002).

The formulas for calculating the relative and total productivities are given below, according to Hoffman & Buhler (2002): Pra = (p) (Amix / Amon); PRB = (1 - p) (Bmix / bmon); PRT = Pra + PRb, in which PRa = relative productivity of the species "a" (crop); PRb = relative productivity of the species "B" (weed), p = proportion of "a" in% divided by 100; Amix = value of the variable to be analyzed (e.g. dry mass) of "A" mixed; Amon = value of the variable to be analyzed of "A" in monoculture; Bmix = value of the variable to be analyzed of "B" mixed; Bmon = value of the variable to be considered of a "B" in monoculture, and PRT = total relative productivity.

The relative competitiveness indices (CR), relative clustering coefficients (K) and aggressiveness (A) were calculated in proportion of 50% of the crop and weed species. CR represents the comparative growth of the species A (corn) in relation to species B (goosegrass), K indicates the relative dominance of one species over another, and A indicates which species is more competitive. The joint interpretation of these values allows us to infer the degree of competition between species more safely (Cousens, 1991). Species A is more competitive than species B when CR<1, kA< Kb and A< 0. Species B is more competitive when CR < 1, kA < Kb and A < 0. The formulas of these indices are given below, according to Hoffman & Buhler (2002): CR = ((1 - p) / p) (PRa / PRb) kA = ((1 - p) / p) (PRa / (1 - PRa)) Kb = ((1 − p)/p) (PRb / (1 - PRb)), A = (PRa/2p) - (PRb / (2 (1 - p))).

For statistical analysis of the relative productivity, differences for PR values (DPR) obtained in proportions of 25, 50 and 75% of plants were primarily calculated in relation to the values belonging to the hypothetical straights in the following ratios: 0.25, 0.50 and 0.75. We used the T test at 5% of probability of error to test the differences relative to the DPR, PRT, CR, K and A indices in relation to hypothetical straights (Hoffman & Buhler, 2002), by using the statistical software SAS (Statistical Analysis System version 8.0).

The null hypothesis to test the differences between DPR and A estimated that the

averages were equal to zero ($H_0 = 0$); for PRT and CR, the averages were equal to unity ($H_0 = 1$), and for K index, that the average for differences between Ka and Kb were equal to zero [$H_0 = (kA - Kb) = 0$].

The variables were expressed as average values per plant, which were submitted to analysis of variance. If significants by F test ($p \leq 0.05$), the averages of treatments were compared by Dunnett's test ($p \leq 0.05$), considering monocultures as witnesses.

RESULTS AND DISCUSSION

The graphical analysis of replacement experiments of corn crops in coexistence with goosegrass showed that, in general, the values observed of relative productivity (PR) and total relative productivity (PRT) were close to those expected for all variables studied (Figures 1, 2, 3 and 4). PR on dry mass of corn shoots differed significantly from the hypothetical straight only in the proportion of 25/75, while for weed none significant differences in the proportion of plants were observed (Figure 1, Table 1). These results indicate that corn was damaged through the association with the weed and significantly reduced its productivity when exposed to higher densities of goosegrass. On the other hand, the weed species remained its productivity under the competitive effect of the crop, in all ratios studied. Thus, except for the proportion of 25/75 of corn crops and goosegrass, which differed significantly from the expected output, in other proportions, the ability of each species to interfere on the other was equivalent; each species contributed to the total mass of its direct proportion in the mixture (Radosevich et al. 1997).

For PRT, the yield obtained differed from the hypothetical straight only in the proportion of 25% of the crop and 75% of the competitor, which means that in this proportion species competed among themselves, where corn was damaged when in association with the weed. In the other proportions, the values were close to those expected, not differing significantly, indicating competition for the same environmental resources and that species maintained their productivity when combined (Figure 1 and Table 1).

The competitive ability of species in the environment depends on several factors, such as population density, time of emergence for each one, plant characteristics and competing species (Rizzardi et al., 2003; Bianchi et al., 2006). The higher the density of weeds, the greater the dispute for environmental resources and the greater the competition suffered by crop (Pitelli, 1985). Thus, the competitive effects between corn crops and goosegrass depends on the density of weeds in the crop and not exactly on the competitive effect of a single weed, as can be seen in Table 1.

Vangessel et al. (1995) have shown that, when the distribution of weeds in an area is uneven or non-uniform, there can be intraspecific competition effects in the area. Thus, it is important to understand the relationship between the density and the distribution of weeds, since they cause yield losses in crops. Furthermore, competition is influenced by the resources available in the environment. Leguizamón et al. (2011) observed that corn was more competitive than *Sorghum halepense* when environmental factors were not restrictive.

A study by Cury et al. (2012) showed that corn has reduced ability to accumulate nutrients when in competitionon. On the other
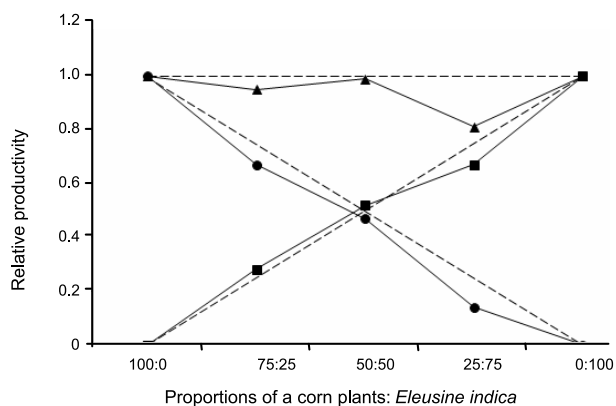
(●) Corn cultivar PR, (■) Competitor PR and (▲)PRT. Dashed lines represent the hypothetical relative productivity when there is no interference of one species over another.

Figure 1 - Relative productivity (PR) and total productivity (PRT) for dry mass of shoots of corn crops and *Eleusine indica*, depending on the proportion of plants.

Table 1 - Relative differences in productivity (DPR) for the variables shoot, root and total dry mass and plant height; and total relatice productivity (PRT), in proportions of 75/25, 50/50 and 25/75, of corn crops associated with grassgoose

	Plant Proportion (corn /goosegrass)		
	75/25	50/50	25/75
MSPA[1]			
DPR corn	-0.08 ($\pm$ 0.06) [ns]	-0.03 ($\pm$ 0.04) [ns]	-0.11 ($\pm$ 0.01) *
DPR goosegrass	0.03 ($\pm$ 0.03) [ns]	0.03 ($\pm$ 0.02) [ns]	-0.08 ($\pm$ 0.03) [ns]
PRT	0.95 ($\pm$ 0.08) [ns]	0.99 ($\pm$ 0.06) [ns]	0.81 ($\pm$ 0.02) *
MSR[2]			
DPR corn	-0.09 ($\pm$ 0.05) [ns]	0.03 ($\pm$ 0.02) [ns]	-0.01 ($\pm$ 0.03) [ns]
DPR goosegrass	-0.09 ($\pm$ 0.02) *	0.001 ($\pm$ 0.05) [ns]	0.02 ($\pm$ 0.08) [ns]
PRT	0.82 ($\pm$ 0.04) *	1.03 ($\pm$ 0.04) [ns]	1.01 ($\pm$ 0.06) [ns]
MST[3]			
DPR corn	-0.08 ($\pm$ 0.05) [ns]	-0.02 ($\pm$ 0.03) [ns]	-0.09 ($\pm$ 0.01) *
DPR goosegrass	0.002 ($\pm$ 0.03) [ns]	0.02 ($\pm$ 0.02) [ns]	-0.06 ($\pm$ 0.03) [ns]
PRT	0.92 ($\pm$ 0.07) [ns]	1.00 ($\pm$ 0.04) [ns]	0.85 ($\pm$ 0.01) *
EP[4]			
DPR corn	-0.03 ($\pm$ 0.03) [ns]	-0.04 ($\pm$ 0.01) *	-0.06 ($\pm$ 0.01) *
DPR goosegrass	0.04 ($\pm$ 0.03) [ns]	0.02 ($\pm$ 0.02) [ns]	-0.02 ($\pm$ 0.02) [ns]
PRT	1.01 ($\pm$ 0.04) [ns]	0.98 ($\pm$ 0.02) [ns]	0.92 ($\pm$ 0.02) *

[ns] not significant, * significant by t test ($p \leq 0.05$). Values in parentheses represent the standard error of the average. [1] MSPA: dry mass of the shoot; [2] MSR: dry mass of the root; [3] MST: total dry mass (root + shoot); [4] EP: plant height.

hand, weeds *Bidens pilosa*, *Cenchrus echinatus*, *Brachiaria brizantha*, *Commelina benghalensis*, *Brachiaria plantaginea* and *Euphorbia heterophylla*, content was severely reduced due to this interaction, indicating that the ability to accumulate nutrients does not represent a competitive advantage for these species.

Radosevich et al. (1997) point out that productivity losses resulting from competition among plants are more significant as more individuals are similar, reaching maximum stress within the same species, for in this case plants have the same ecological niche. Corn crops and goosegrass belong to the same botanical family; thus, they can compete for the same environmental resources, as for PRT (Figure 1), in which the values were close to unity. Goosegrass is among the most important grass weeds in the world, and its high competitive ability is due to the fact of not being picky about the climate and soil characteristics, being well adapted to various habitats (Kissmann, 1997).

In relation to root dry mass, the opposite happened to that seen for the variable shoot

dry mass, that is, weed significantly reduced their productivity when in the presence of higher densities of crop. The weed, in turn, kept its productivity in all ratios analyzed, and the values observed did not differ significantly from the expected values for this variable, indicating that corn is a good competitor against the root system and it explores efficiently soil resources. PRT differed significantly in the proportion of 75% of the crop and 25% of the competitor. The significant difference in this ratio is due mainly to the reduction in dry mass of roots of goosegrass under competitive effect of higher densities of the crop, where PRT is the sum of the yields of both species in the same proportion. In the other combinations, the competitive abilities of the two species were equivalent and PRT did not differ significantly, which means that competition occurred for the same environmental resources (Figure 2 and Table 1).

Corn cultivars had lower dry matter accumulation when in competition with six weed species, where leaves and stems were
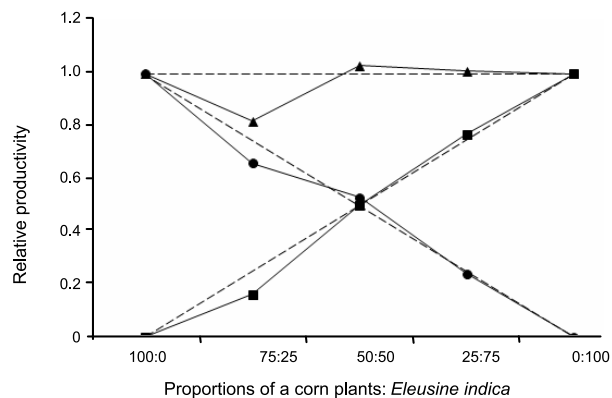
(●) Corn cultivar PR, (■) Competitor PR and (▲)PRT. Dashed lines represent the hypothetical relative productivity when there is no interference of one species over another.
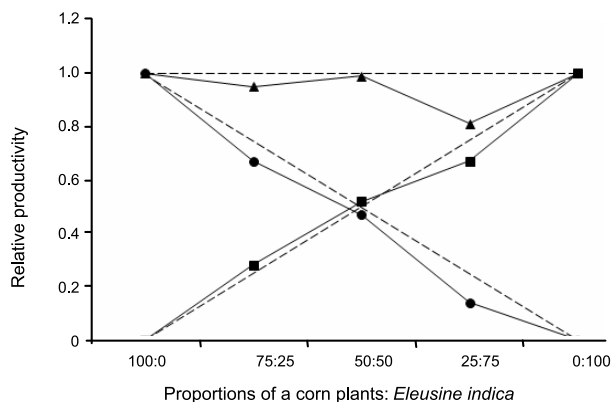
Figure 2 - Relative productivity (PR) and total productivity (PRT) for dry mass of root of corn crops and *Eleusine indica*, depending on the proportion of plants.

the organs most affected (Carvalho et al., 2011). However, for competing species, roots were the most damaged organs, and *Brachiaria brizantha* and *Commelina benghalensis* showed the greatest ability to compete with corn crop. The same authors also found that corn crops in competition with *B. brizantha* allocated root dry mass to the shoot, trying to shade the weeds and to reduce the availability of solar radiation for photosynthesis of weeds.

Cerrudo et al. (2012) observed that competition for weeds in early development of corn crop delayed leaf appearance. Thus, this was reflected in the inability to accumulate dry mass, causing rapid decline in the number and weight of grains.

Total dry mass, which is the sum of the dry mass of roots and shoots of the two species in each proportion of plants, can be seen in Figure 3. Generally, the weed kept its constant productivity in all combinations, while crop significantly reduced the dry matter when in greater weed density. Figure 3 shows similar results to that seen in Figure 1, which means that the dry mass of the shoot was more representative to the total dry mass of the plants, when compared to the dry mass of roots. Thus, for PRT and PR of corn, there was only a significant difference in the proportion 25/75 (Table 1).

The data on plant height indicate a reduction in the relative productivity of corn when in the presence of equal and superior proportions of the weed, since the values differed from the hypothetical straight (Figure 4 and Table 1). On the other hand, weed did not compete in any proportion. For PRT, there was a significant difference only in the proportion 25/75 (corn: goosegrass). In the

(●) Corn cultivar PR, (■) Competitor PR and (▲)PRT. Dashed lines represent the hypothetical relative productivity when there is no interference of one species over another.

Figure 3 - Relative productivity (PR) and total productivity (PRT) for the total mass (shoot + root) of corn crops and *Eleusine indica*, depending on the proportion of plants.
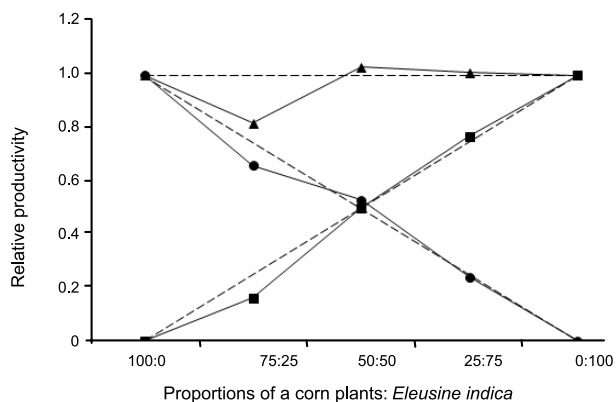
(●) Corn cultivar PR, (■) Competitor PR and (▲)PRT. Dashed lines represent the hypothetical relative productivity when there is no interference of one species over another.

Figure 4 - Relative productivity (PR) and total productivity (PRT) for height of corn crops and *Eleusine indica*, depending on the proportion of plants.

other combinations of plants, there were no competitive effects, and the abilities of species in competing were equivalent. In the line observed for PRT in the proportions in which there were no effects, values approached the unit and did not differ significantly, indicating competition for the same environmental resources.

The results of the replacement experiments between corn crops and goosegrass indicate that the height of corn reduced upon the occurrence of crop at densities equal or lesser to the weed (Figure 4). The reduction in plant height also led to a reduction in dry mass of the shoot, when corn was in competition with higher densities of weed (Figure 1).

Lamego et al. (2005) noticed that the shading on a plant is detected by the change in radiation red / far red. Thus, plants may allocate resources and invest in the growth of shoots and compromise their radical system. Rajcan & Swanton (2001) also emphasized the importance of changes in light quality in the interaction between species. These authors explain that the mutual shading of leaves reduces the density of photon flux photosynthetically active available, which results in reduction in photosynthetic rates.

High densities of plants, such as those found in the proportion of 25% of corn and 75% of goosegrass, may alter the amount of radiation that reaches the base of the corn stem, where is located the growing point, during the vegetative and early reproductive stage (Sangoi et al., 2010). Thus, plants become etiolated.

Pereira et al. (2011) found that the increase in plant density of brachiaria plants (*Urochloa decumbens*) caused significant reduction in height and diameter, as well as in the dry mass of eucalyptus plants (*Corymbia citriodora*).

From the results of Table 2 it can be seen that there was no dominance between species in relation to the dry mass of the shoot and root when both were in the same proportions. However, in equal proportions, plant height was significantly altered, and for this variable weed was more competitive, with CR <1 Km <Kc and A < 0.

Studies on soybean plants in coexistence with *Brachiaria plantaginea* showed that the association between the two species was antagonistic, which damaged the growth of both species in association, with prevalence of intraspecific competition. However, the CR, K and A competitive indices for the coexistence of these species did not differ in any proportion, because none species is more competitive than the other when in the same proportion of individuals (Agostinetto et al., 2009).

The analysis of corn response to the interference of goosegrass in different proportions of plants indicated that for shoot and total dry mass and height, corn plants have reduced productivity compared to monoculture when the weed density was greater than corn (ratio 25/75), which means that interspecific competition was more important than intraspecific competition (Table 3). Thus, it is infered that corn prefers a plant of the same species in the surroundings than a goosegrass plant. These results differ from those found by Christoffoleti & Victoria Filho (1996), who found that corn benefited from the presence of a *caruru* plant in its side to the other of corn.

Table 2 - Competitiveness indices of corn and goosegrass, expressed by relative competitiveness (CR), relative clustering coefficients (K) and aggressiveness (A)

Variables	CR	$K_{m = corn}$	$K_{c = goosegrass}$	A
MSPA[1]	0.89 (± 0.06) [ns]	0.91 (± 0.13) [ns]	1.12 (± 0.09) [ns]	-0.06 (± 0.03) [ns]
MSR[2]	1.10 (± 0.13) [ns]	1.14 (± 0.07) [ns]	1.06 (± 0.19) [ns]	0.03 (± 0.06) [ns]
MST[3]	0.93 (± 0.07) [ns]	0.94 (± 0.12) [ns]	1.08 (± 0.07) [ns]	-0.04 (± 0.04) [ns]
EP[4]	0.88 (± 0.03) *	0.84 (± 0.03) *	1.10 (± 0.07) *	-0.07 (± 0.01) *

[ns] not significant, * significant by t test ($p \leq 0.05$). Values in parentheses represent the standard error of the average. [1] MSPA: dry mass of the shoot; [2] MSR: dry mass of the root; [3] MST: total dry mass (root + shoot); [4] EP: plant height.

Tabela 3 - Corn response to interference with goosegrass, at 42 days after emergence

	Plant Proportion (corn/goosegrass)					
Variables	100/0 (T)	75/25	50/50	25/75	0/100 (T)	CV (%)
MSPA[1/]						
Corn	4.43	3.94	4.16	2.57 *	-	17.42
Goosegrass	-	2.37	2.2	1.86	2.09	16.52
MSR[2/]						
Corn	0.89	0.78	0.94	0.86	-	20.13
Goosegrass	-	0.45	0.7	0.72	0.7	20.37
MST[3/]						
Corn	5.32	4.73	5.11	3.43 *	-	13.76
Goosegrass	-	2.83	2.91	2.59	2.8	13.82
EP[4/]						
Corn	93.53	89.23	85.69	70.77 *	-	6.06
Goosegrass	-	55.61	49.41	45.84	47.15	11.69

Average differs from control (T) by Dunnett's test ($p \leq 0.05$). CV = coefficient of variation. [1/] MSPA: dry mass of shoot; [2/] MSR: dry mass of root; [3/] MST: total dry mass (root + shoot); [4/] EP: plant height.

On the other hand, weed did not differ significantly on values   per plant, on any variable analyzed. For the variable dry mass of the root, corn and goosegrass productivity had not significantly changed in this study, compared to that of monocultures (Table 3).

According to the results of this research, corn presents competitive ability equivalent to goosegrass in relation to shoot, root and total dry mass, and goosegrass shows greater competitive ability in relation to plant height when both are in equal proportions in the mixture. It is important to consider that experiments were conducted in greenhouse and that in the field, results can be differentiated because of external environmental factors and conditions, which can act on the competitive process of the species.

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