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Periods of weed interference in maize crops cultivated in the first and second cycles

Períodos de interferência de plantas daninhas no milho de primeira e segunda safra

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Abstract

The interference of weeds in maize production may be reflected in grain yield losses that vary as a function of the density, stage and degree of aggressiveness of the species present. In the agricultural ecosystem, crops and weeds demand light, water, nutrients and space, which are frequently not available in sufficient quantities, leading to competition. The aim of this work was to determine the period of interference of weed plants, in particular of naked crabgrass (*Digitaria nuda*) on maize crop in the first and second harvest. The treatments were defined as increasing periods of coexistence and increasing control of weed community (7, 14, 21, 28, 35, 42, 49, and 56 days), two more controls, a control including one with weed control until the end of the culture cycle and another with coexistence until the harvest. For each period, were evaluated the stand of maize plants, length of ear, number of grains per row, number of rows per ear, cob, 100-grain weight, and grain productivity. The data obtained were subjected to analysis of variance using the F test, with average treatments compared using Tukey's test at 5% probability. Crop productivity was evaluated by means of regressions, the critical periods of interference were estimated. The critical timing of weed removal was 25 days for both harvests. The critical weed free period was 54 and 27 days for the first and second harvest respectively. For the conditions of the first and second harvest, the critical period of weed control was of 29 and 2 days respectively.
Key words: *Digitaria nuda*. Naked crabgrass. Competition. Phytosociology. Weed interference. *Zea mays*.

Resumo

A interferência de plantas daninhas no milho pode refletir em perdas na produtividade de grãos que variam em função da densidade, estágio e grau de agressividade das espécies presentes. No ecossistema agrícola, a cultura e planta daninha possuem demandas por luz, água, nutrientes e espaço, que na maioria das vezes, não estão disponíveis em quantidades suficientes, estabelecendo-se a competição. O objetivo desse trabalho foi determinar o período de interferência de plantas de plantas daninhas em especial do capim-colchão (*Digitaria nuda*) na cultura do milho na primeira e segunda safra. Os tratamentos foram divididos em períodos crescentes de convivência e de controle da comunidade infestante (7; 14; 21; 28; 35; 42; 49 e 56 dias), mais duas testemunhas, uma com controle até o fim do ciclo da cultura e outra com convivência até a colheita. Para cada período foram avaliadas o estande de plantas de milho, comprimento das espigas, número de grãos por fileiras, número de fileiras por espiga, massa de 100 grãos e produtividade de grãos. Os dados obtidos foram submetidos à análise de variância

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pelo teste F, sendo as médias dos tratamentos comparadas pelo teste Tukey a 5% de probabilidade. A produtividade da cultura foi avaliada por meio de regressões, onde foram estimados os períodos críticos de interferência. O período anterior à interferência foi de 25 dias para ambas as safras. O período total de prevenção da interferência foi de 54 e 27 dias para primeira e segunda safra respectivamente. Para as condições de primeira e segunda safra, o período crítico de prevenção a interferência foi de 29 e 2 dias respectivamente.

Palavras-chave. *Digitaria nuda*. Capim-colchão. Competição. Fitossociologia. Matointerferência. *Zea mays*.

Introduction

Maize is a major crop, both in Brazil and globally. The national maize output for the 2015/16 harvest is estimated as 81 million tons, of which first and second crops account for approximately 34.19% and 65.91% respectively. The average productivity for maize is approximately 5,048 kg.ha^{-1} and 5,108 kg.ha^{-1} (for the first and second crop, respectively) (IBGE, 2016).Despite the increase in productivity over the years, this could be greater if the maximum potential of the hybrids in the market was achieved.

Improper management of weeds in the annual crop production system leads to losses in productivity and to an increase in the cost of production for the subsequent crops. Weeds may harbor pests, act as disease hosts, release allelopathic substances, and compete with crops for water, light, and nutrients, in addition to interfering with crop processes such as harvest (FARIA et al., 2014; KERAMATI et al., 2008). For the maize crop, Kozlowski et al. (2009) and Carvalho et al. (2007) reported that the reduction in productivity due to interference caused by coexistence with weeds can vary from 13% to 87%, with an average of 15%.

It is known that these reductions in productivity vary according to the characteristics of the species and the environment; thus, the time of planting may influence the level of interference and, consequently, the optimal times for weed control. Knowledge of the level of interference of weeds at each planting time may assist in management decisions, avoiding unnecessary weed control strategies (PITELLI, 1985).

Digitaria nuda Schumach. and *Digitaria ciliaris* (Retz.) Koel, commonly known as naked crabgrass, are among the most common weeds in agricultural crops (LORENZI, 2000; DIAS et al., 2007). These are highly invasive plants, classified as problem weeds in 60 countries, which infest more than 30 crops of economic importance. In Brazil, they constitute a serious problem for many spring and summer crops, such as maize (VIEIRA et al., 2010; KISSMANN, 1997).

Considering the importance of the crop in this country, and the possibility of increasing the average productivity by appropriate management of the weed community we aimed to determine the critical timing of weed removal (CTWR), and critical weed free period (CWFP) for calculating the critical period of weed control (CPWC) for a weed community with a predominance of *D. nuda* in a first and second-crop cornfield.

Material and Methods

Experiments were set up and conducted in the experimental area of the Faculty of Agricultural Science, São Paulo State University "Júlio de Mesquita Filho" (UNESP), Botucatu campus, located at 22°07′56″S and 74°66′84″W average elevation 762 m, in a Cfa climate (Köppen), with hot, humid summers and cold, dry winters, with a distroferric red latosol characterized by: pH 5.3 (CaCl2); 12 g L^{-1} of OM; 10 mg L^{-1} of P (resin); V(%) of 56%; and 0.7, 22, 5, 22, 28, and 50 mmolc L^{-1} K+, Ca2+, Mg2+, H+Al3+, SB, and T, respectively. The pluvial precipitation accumulated in the period was 888.9 mm and 287.8 mm for first and second harvest, with average air temperature of 24.2°C and 19.20°C during the first and second crop cycles, respectively.

Soil preparation was carried out in a similar way for both planting times (one plowing operation and two harrowings). The maize hybrid used in both crops was Dow 8480, sown on October 28 for the first crop cycle and February 26 for the second crop cycle. This hybrid has an average productive potential of 9,300 kg ha^{-1}, with average plant height of 1.95 m and tolerance to Cercospora leaf spot and common rust, making it ideal for cultivation in a low tropic region (EMBRAPA, 2016). At the time of planting, the area was fertilized with 320 kg ha^{-1} of 4-14-8 (N-P-K) formulation, and at 25 days after the emergence of the seedlings with 60 kg ha^{-1} of N applied in cover as coverage. Both planting and coverage fertilizations were performed in accordance with the needs of culture indicated by Bulletin 100 (IAC, 1996).

The plots were 6.0 m long and 3.6 m wide, covering a total area of 21.6 m^2. Each plot consisted of four planting rows spaced 0.90 m apart, with eight seeds per meter. Three days after emergence of the plants, a thinning was performed, resulting in a stand of 60,000 plants per hectare. The two side rows were taken as borders, as were 0.5 m at each end of the plot.

The experiment used a randomized block design with four replicates in a 2 × 8 factorial with two controls. The treatments were divided into periods of coexistence and increasing control of weed community (7,14, 21, 28, 35, 42, 49, and 56 days), two more controls, one with weed control until the end of the crop cycle and another with coexistence until harvest. The period of coexistence was defined as beginning started when 70% of the maize plants had emerged.

At the end of each period of coexistence species identification and counting of weed plants was performed. In the control treatments, weeds were collected at the end of the crop cycle to determine their dry mass. For this evaluation, two frames, each enclosing an area of 0.25 m^2 were thrown randomly in each plot, and the samples so identified were collected, stored in paper bags, and subjected to drying in a forced-air furnace at 60±2°C until a constant weight was achieved and then the dry mass was determined.

Maize was harvested when the grain moisture reached 18%. The first harvest was performed 199 DAP (days after planting), and second harvest was performed 166 DAP. At harvest, 10 spikes were collected randomly from the useful area of the plot for measurements of spike length, number of grains per row, number of rows, 100-grain weight, as well as the percentage of surviving plants in the useful area (stand). All data were subjected to analysis of variance by the F test, and averages for each treatment compared using Tukey's test at 5% probability. Grain productivity was calculated after correcting the moisture of the grains harvested from the useful area to 12%.

The phytosociological indices of relative density, relative frequency, relative dominance, and relative importance of populations of weeds were calculated based on the formulas proposed by Mueller-Dombois and Ellemberg (1974). To determine the periods of interference, nonlinear regression analysis was performed, using productivity data separately within each mode of interference. Based on the regression equation, periods of weed interference were determined for the first and second maize crop cycles for the arbitrary tolerance level of 5% reduction in yield, expressed in kg ha^{-1}, from the yield of the treatment group that was free of weeds.

Results and Discussion

In the first harvest, 12 families and 14 species of weeds were identified in the experimental area. The families with the highest number of species were Asteraceae and Poaceae, with two species each (*Bidens pilosa* (L.), *Emilia fosbergii* (L.) Nicolson and *Cenchrus echinatus* (L.) and *Digitaria nuda*, respectively). According to Holm et al. (1977) 37% of the major weed species worldwide belong to these families. Also present were specimens of *Alternanthera tenella* Colla (Amaranthacea), *Raphanus sativus* (L.) (Brassicaceae), *Commelina benghalensis* (L.) (Commelinaceae), *Cyperus rotundus* (L.) (Cyperaceae), *Euphorbia heterophylla* (L.) (Euphorbiaceae), *Desmodium tortuosum* (Sw.) DC. (Fabaceae), *Sida glaziovii* (K.) Schum. (Malvaceae), *Phyllanthus tenellus* (Roxb.) (Phyllanthaceae), *Portulaca oleracea* (L.) (Portulaceaceae) and *Richardia brasiliensis* Gomes (Rubiaceae).

Table 1 shows the phytosociological indices obtained during periods of weed control and the control condition without weeding of all weeds identified within the experimental area at the end of the crop cycle. In the control condition without weeding, the species *D. nuda* predominated in the weed community, with a relative importance (RI) of 66.32%. The largest relative importance, for the remaining periods, was also of *D. nuda* plants, except at 42 days after plant emergence (DAE), when *A. tenella* had the largest RI (38.68%) followed by *D. nuda* at 33.91%. Even with the population variation observed during the first third of the crop cycle owing to the germination of ruderal species, *D. nuda* plants displayed greater RI, owing to higher density and higher accumulation of dry biomass, indicating that this weed species is more aggressive than the others.

For the coexistence periods (Table 2), seedling emergence had not yet occurred at 7 DAE. At 14 DAE, *D. nuda* displayed the highest relative density value, albeit with considerably reduced biomass production, due to which it displayed no value for relative dominance (R. Do.), while *R. brasiliensis* showed the highest figure. Despite displaying no R. Do. value, *D. nuda* had the largest RI. For the remaining periods, *D. nuda* had the highest RI in the community, with the highest plant density and accumulated biomass. In some cases, these figures were close to 100% (35 and 56 DAE for R. Do.), indicating near exclusivity of the species in crop interference.

When the dry mass of weeds in this study was analyzed, it was observed that a coexistence for short periods such as 14 DAE, was not sufficient to accumulate mass, despite a significant number of individuals. However, at 21 DAE its dry mass surpassed that of the other species present, with a considerable increase that was maintained until 56 DAE (Table 2). The best-adapted biotypes, or even plant species, are usually more competitive and are capable of increasing their proportion over time, eliminating those individuals that are less fit to occupy a given ecological niche, as was observed for *D. nuda* (CHRISTOFFOLETI et al., 1997).

For the first crop cycle, the weed control periods did not affect either the survival of maize plants or the 100-grain weight (Table 3). As for the number of grain rows in the ear, the lowest figures were observed in groups subjected to the shorter periods of weed control (7-14 DAE).

Coexistence of the crop with weeds during the whole crop cycle decreased the number of grains per row and the ear length (Table 3). Coexistence of weeds for different initial periods of the crop cycle did not affect the survival rate of maize plants, the number of grains per ear, or the 100-grain weight. However, the number of grains per row and the ear length were affected by coexistence of the crop with the weeds (Table 4).

The highest value for number of grains per row and ear length, was observed when the plots were subjected to weed control during the entire crop cycle for maize. On the other hand, lower values were attributed to the treatments with the larger periods of coexistence of the crop with the weed plants. The productivity of maize in the control condition without weeding for the entire cycle was 3.042 kg ha^{-1}. which is 60% lower than that observed in the weed-free control (Figure 1). Therefore, assuming a 5% loss relative to the weed-free control, the CTWR was 25 DAE, and the CWFP was 54 DAE, resulting in a CPWC of 29 days.

Table 1. Phytosociological indices, relative density (R. De.), relative frequency (R. Fr.), relative dominance (R. Do.) and relative importance (RI) for the weed populations making up the weed communities as a function of weed control periods (days after emergence, DAE) with the first maize crop cycle in Botucatu, SP, Brazil.

Species	R. De.	R. Fr.	R. Do.	RI
		No control[1]		
Digitaria nuda	86,92	21,05	90,98	66,32
Alternantheratenella	6,26	15,79	5,12	9,06
Sida glaziovii	3,08	21,05	1,36	8,50
Others	3,74	42,11	2,54	16,12
		0 – 7 DAE		
Digitaria nuda	78,57	20,00	78,59	59,05
Richardia brasiliensis	7,14	20,00	6,31	11,15
Sida glaziovii	6,84	20,00	6,62	11,15
Others	7,45	40,00	8,48	18,65
		0 – 14 DAE		
Digitaria nuda	75,94	26,67	92,45	65,02
Alternantheratenella	16,88	30,00	3,30	13,39
Sida glaziovii	3,13	20,00	1,51	8,21
Others	4,05	23,33	2,74	13,38
		0 – 21 DAE		
Digitaria nuda	69,32	26,67	65,69	53,86
Alternantheratenella	13,41	26,67	7,58	15,89
Sida glaziovii	4,09	20	5,95	10,01
Others	13,18	26,66	20,78	20,24
		0 – 28 DAE		
Digitaria nuda	66,10	36,36	78,06	60,18
Alternantheratenella	19,49	18,18	13,23	16,97
Richardia brasiliensis	5,93	9,09	5,83	6,95
Others	8,48	36,37	2,88	15,90
		0 – 35 DAE		
Digitaria nuda	67,41	36,36	88,33	64,03
Richardia brasiliensis	8,99	27,27	4,39	13,55
Alternantheratenella	13,49	9,09	5,77	9,45
Others	10,11	27,28	1,51	12,97
		0 – 42 DAE		
Alternantheratenella	38,89	30,00	47,16	38,68
Digitaria nuda	45,29	40,00	19,13	33,91
Sida glaziovii	3,70	20,00	23,79	15,83
Others	12,12	10,00	9,92	11,58
		0 – 49 DAE		
Digitaria nuda	80,00	42,86	77,66	66,84
Alternantheratenella	10,00	28,57	7,86	15,48
Richardia brasiliensis	5,00	14,29	14,02	11,10
Others	5,00	14,28	0,46	6,58

[1]Control with weed interference during the whole cycle.

Table 2. Phytosociological indices, relative density (R. De.), relative frequency (R. Fr.), relative dominance (R. Do.) and relative importance (RI) for the weed populations making up the weed communities as a function of weed coexistence periods (days after emergence, DAE) with the first maize crop cycle in Botucatu, SP, Brazil.

Species	R. De.	R. Fr.	R. Do.	IR
		0 – 14 DAE		
Digitaria nuda	86,40	25,00	-	37,13
Richardia brasiliensis	5,92	25,00	64,28	31,73
Sida glaziovii	6,64	25,00	28,57	20,07
Others	1,04	25,00	7,15	11,07
		0 – 21 DAE		
Digitaria nuda	83,90	25,00	90,87	66,59
Richardia brasiliensis	9,72	18,75	5,42	11,30
Sida glaziovii	4,57	25,00	2,74	10,77
Others	1,81	31,25	0,97	11,34
		0 – 28 DAE		
Digitaria nuda	86,14	25,00	83,63	64,92
Richardia brasiliensis	8,63	25,00	10,32	14,65
Sida glaziovii	4,51	25,00	5,35	11,62
Others	0,72	25,00	0,70	8,81
		0 – 35 DAE		
Digitaria nuda	92,46	25,00	97,76	71,74
Richardia brasiliensis	3,66	25,00	1,19	9,95
Sida glaziovii	2,01	18,75	0,49	7,08
Others	1,87	31,25	0,56	11,23
		0 – 42 DAE		
Digitaria nuda	76,62	19,05	87,53	61,07
Richardia brasiliensis	16,67	19,05	8,09	14,60
Sida glaziovii	5,23	19,05	3,53	9,27
Others	1,48	42,85	0,85	15,06
		0 – 49 DAE		
Digitaria nuda	79,61	16,67	87,02	61,10
Richardia brasiliensis	11,81	16,67	2,71	10,40
Alternantheratenella	5,80	16,67	6,99	9,82
Others	2,78	49,99	3,28	18,68
		0 – 56 DAE		
Digitaria nuda	89,23	21,05	95,87	68,72
Alternantheratenella	4,13	15,79	2,04	7,32
Sida glaziovii	2,57	15,79	0,40	6,36
Others	4,07	47,37	1,69	17,60

In the second crop cycle, 10 families and 14 species of weeds were identified in the experimental area-two families less than in the first crop cycle and the same number of species. The family with highest number of species was Asteraceae with five species (*Acanthospermum hispidum* (DC.), *B. pilosa*, *Conyza bonariensis* (L.), *E. fosbergii*, and *Galinsoga parviflora* Cav.). Also present were *A. tenella* (Amaranthacea), *C. rotundus* (Cyperaceae), *E. heterophylla* (Euphorbiaceae), *D. tortuosum* (Fabaceae), *S. glaziovii* (Malvaceae), *P. tenellus* (Phyllanthaceae), *D. nuda* (Poaceae), *P. oleracea* (Portulaceaceae), and *R. brasiliensis* (Rubiaceae). This species composition is in agreement with observations by other researchers for maize crops, for instance in the study by Duarte et al. (2007). Notably, the presence of more species of family Asteraceae is a common occurrence in Brazilian agricultural lands (OLIVEIRA; FREITAS, 2008; MACIEL et al., 2008).

Table 3. Effect of weed control periods on percentage of survival, number of rows per ear, number of grains per row, ear length, and 100-grain weight for the first crop in Botucatu, SP, Brazil.

Control periods	Survival (%)	Number of rows per ear	Number of grains per row	Ear length (cm)	100-grain weight (g)
No control[1]	92,71	14,52 abc	20,76 b	11,05 b	21,19
0 – 7	95,45	14,20 bc	28,00 ab	13,01 ab	26,06
0 – 14	96,12	14,10 c	30,63 a	13,67 ab	26,67
0 – 21	95,83	15,30 ab	31,77 a	14,40 a	27,89
0 –28	96,21	15,35 ab	31,82 a	14,53 a	28,36
0 – 35	98,48	15,12 abc	33,07 a	14,62 a	28,86
0 – 42	98,86	15,25 abc	32,75 a	14,67 a	28,46
0 – 49	97,11	15,35 ab	33,02 a	15,17 a	26,76
0 – 56	95,97	15,40 a	34,82 a	15,93 a	26,20
$F_{TREATMENT}$	1,16 ^{NS}	4,72 **	4,96 **	4,90 **	2,31 ^{NS}
Var. (%)[2]	3,50	3,20	12,20	9,00	11,40
LSD[3]	8,05	1,17	9,05	3,05	7,34

**Significant at 1%; ^{NS}Not significant; means followed by the same letter are not statistically different by the F test (p > 0.05).[1] Weed interference during the whole cycle, [2]Variance, [3]Low significative difference.

Table 4. Effect of weed coexistence periods on percentage of survival, number of rows per ear, number of grains per row, ear length, and 100-grain weight for the first crop in Botucatu, SP, Brazil.

Coexistence periods	Survival (%)	Number of rows per ear	Number of grains per row	Ear lenght (cm)	100-grain weight (g)
Control[1]	95,96	15,23	33,86 a	15,44 a	26,61
0 – 7	97,73	15,00	32,43 ab	14,60 ab	26,57
0 – 14	97,35	15,00	33,20 ab	14,65 ab	29,32
0 – 21	98,10	15,00	30,93 ab	14,17 ab	26,70
0 –28	95,83	14,45	31,63 ab	14,07 ab	26,68
0 – 35	94,70	14,32	30,12 ab	13,75 ab	26,13
0 – 42	95,07	14,26	29,20 ab	13,43 ab	28,06
0 – 49	95,60	14,40	27,37 ab	13,07 ab	26,37
0 – 56	94,31	14,47	24,30 b	12,20 b	24,12
$F_{TREATMENT}$	0,80 ^{NS}	2,88 ^{NS}	2,47 *	2,20 **	0,93 ^{NS}
Var. (%)[2]	3,16	2,90	12,70	9,20	9,60
LSD[3]	7,31	1,04	9,28	3,10	6,16

**Significant at 1%; ^{NS}Not significant; means followed by the same letter are not statistically different by the F test (P > 0.05).[1]Control of weed interference during the whole cycle, [2]Variance, [3]Low significative difference.

For the study of phytosociological indices during the weed control periods, the no-weeding control displayed higher figures for relative density, R. Do., relative frequency and consequently RI for *D. nuda* (Table 5). The higher importance of the species in the community lasted until 28 DAE of weed control. Only from 35 DAE, the importance of *D. nuda* was surpassed by that of *S. glaziovii*, owing to the reduction in the number of individuals of *D. nuda*. During this period, the number of species present decreased, as was also observed in conditions with weed control up to 28 DAE. After 35 DAE of weed control, no more weeds occurred, perhaps due to suppression by the maize plants, and also to the low humidity of the soil during the second crop cycle, imposing more restrictive conditions on the germination and growth of weeds. The high importance of *D. nuda* was mainly due to the high initial accumulation of biomass by the plants.

Figure 1. Graph of critical timing of weed removal (CTWR), critical weed free period (CWFP), and critical period of weed control (CPWC), assuming a 5% reduction in the productivity of maize crop, according to management criteria with weed control and weed coexistence in the first crop in Botucatu, SP, Brazil. Weed control: y = 3292.918 + (4288.295/(1+((x/21.3133)^-2.3541))) R^2 = 0.9706, Coexistence: y = 2896.486 + (4684.732/(1+((x/34.4562)^6.746))) R^2=0.9613

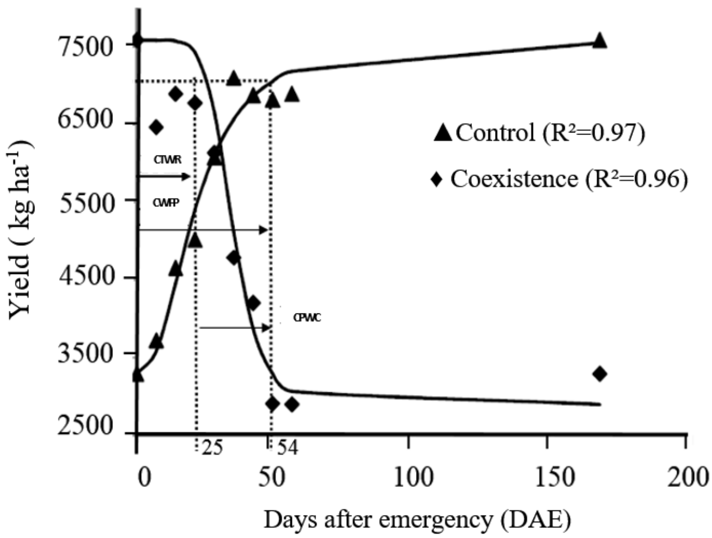


Table 6 shows the data for the phytosociological indices for the weeds studied during the crop coexistence periods. From 0-7 DAE, no RI figures were estimated, as the mass of the weeds, as well as that of other species, was insufficient for analysis. For all periods evaluated, *D. nuda* achieved higher RI than the other species, in terms of both number of individuals and biomass accumulation.

Regarding maize interference, in the second crop cycle, the no-weeding control caused reduction in the number of surviving plants. The no-weeding control also reduced the number of grains per row, ear length, and 100-grain weight. The number of rows per ear, however, was not affected (Table 7).

The maize crop was not affected by the different initial periods of coexistence with the weed plants. The other variables were affected by the increase in the period of coexistence of maize crop and weeds (Table 8). The presence of weeds in the second crop cycle led to a 54% reduction in final maize yield from that observed in the first crop cycle. Considering an acceptable loss of production of 5%, there were crop yield reductions from 25 DAE (CTWR). CWFP was estimated as 27 DAE, resulting in a CPWC of 2 days (Figure 2).

This short CPWC may be related to environmental conditions. Lower rainfall and temperatures may have favored the crop over the weed community and, as maize is a competitive plant, it grew, causing inter-row shading (BALBINOT JUNIOR; FLECK, 2004). Based on these results, we conclude that the data generated by first crop research do not correspond to those observed for the second crop (even with competition by the same specific community).

The weed community was very similar in both crop cycles, D. *nuda* being the most important species in both, which is in line with the increasing dominance of this species in weed communities observed in recent years (DIAS et al., 2007). The presence of these plants leads to a high utilization of environmental resources, as they can accumulate biomass for up to 73 days after emergence, which has led to drastic interference up to 40% in developing maize (SOUZA et al., 2012).

Table 5. Phytosociological indices, relative density (R. De.), relative frequency (R. Fr.), relative dominance (R. Do.) and relative importance (RI) for the weed populations making up the weed communities as a function of weed control periods (days after emergence, DAE) with the second maize crop cycle in Botucatu, SP, Brazil.

Species	R. De.	R. Fr.	R. Do.	RI
		No control[1]		
Digitaria nuda	71,39	22,22	82,30	58,64
Sida glaziovii	22,75	16,67	9,11	16,18
Alternantheratenella	0,74	11,11	6,43	6,09
Others	5,12	50,00	2,16	19,09
		0 – 7 DAE		
Digitaria nuda	72,60	40,00	91,97	68,19
Sida glaziovii	8,22	20,00	2,21	10,14
Galinsogaparviflora	9,59	10,00	2,06	7,22
Others	9,59	30,00	3,76	14,45
		0 – 14 DAE		
Digitaria nuda	58,33	30,77	92,00	60,37
Sida glaziovii	35,71	30,77	4,46	23,65
Richardia brasiliensis	3,57	23,08	2,95	9,87
Others	2,39	15,38	0,59	6,11
		0 – 21 DAE		
Digitaria nuda	70,10	50,00	75,14	65,08
Sida glaziovii	23,71	33,33	8,43	21,82
Richardia brasiliensis	6,19	16,67	16,43	13,10
		0 – 28 DAE		
Digitaria nuda	67,65	60,00	80,95	69,53
Sida glaziovii	32,35	40,00	19,05	30,47
		0 – 35 DAE		
Sida glaziovii	85,71	50,00	57,66	64,46
Digitaria nuda	6,12	16,67	41,04	21,28
Phyllanthustenellus	6,12	16,67	0,59	7,79
Others	2,05	16,66	0,71	6,47

[1]Control with weed interference during the whole cycle.

The production characteristics of maize, such as the number of rows per ear and ear length were affected by the different periods of weed control. Similar results have previously been reported (ZAGONEL et al., 2000; GALON et al., 2008). The 100-grain weight increased with increase in the period of coexistence of the crop with the weed plants; this might be a plant strategy to guarantee its reproduction under stress conditions. Notably, the presence of weeds in maize crops could also reduce the phenological development of plants and thus change the characteristics of the grain (SHEIBANY et al., 2009).

Table 6. Phytosociological indices, relative density (R. De.), relative frequency (R. Fr.), relative dominance (R. Do.) and relative importance (RI) for the weed populations making up the weed communities as a function of weed coexistence periods (days after emergence, DAE) with the second maize crop cycle in Botucatu, SP, Brazil.

Species	R. De.	R. Fr.	R. Do.	RI
		0 – 7 DAE		
Digitaria nuda	96,21	30,77	-	63,51
Sida glaziovii	1,70	30,77	-	16,24
Richardia brasiliensis	1,42	23,08	-	12,25
Others	0,67	15,38	-	8,00
		0 – 14 DAE		
Digitaria nuda	95,56	25,00	94,01	71,52
Sida glaziovii	1,86	25,00	2,86	9,91
Richardia brasiliensis	1,36	25,00	2,50	9,62
Others	1,22	25,00	0,63	8,95
		0 – 21 DAE		
Digitaria nuda	95,84	22,22	95,72	71,26
Richardia brasiliensis	1,90	22,22	2,05	8,72
Sida glaziovii	0,70	22,22	0,93	7,95
Others	1,56	33,34	1,30	12,07
		0 – 28 DAE		
Digitaria nuda	90,57	17,39	86,48	64,81
Portulaca oleracea	3,61	17,39	7,53	9,51
Richardia brasiliensis	2,31	17,39	2,07	7,26
Others	3,51	47,83	3,92	18,42
		0 – 35 DAE		
Digitaria nuda	96,12	21,05	95,24	70,80
Richardia brasiliensis	1,20	21,05	2,12	8,12
Sida glaziovii	1,87	15,79	1,58	6,41
Others	0,81	42,11	1,06	14,67
		0 – 42 DAE		
Digitaria nuda	92,46	16,67	94,47	67,87
Portulaca oleracea	3,13	16,67	2,72	7,51
Richardia brasiliensis	1,92	16,67	1,74	6,78
Others	2,49	49,99	1,07	17,84
		0 – 49 DAE		
Digitaria nuda	90,33	21,05	93,30	68,23
Richardia brasiliensis	5,27	21,05	4,53	10,28
Sida glaziovii	1,63	15,79	0,59	6,00
Others	2,77	42,11	1,58	15,49
		0 – 56 DAE		
Digitaria nuda	91,45	30,77	96,82	73,02
Richardia brasiliensis	2,08	23,08	1,26	8,81
Sida glaziovii	3,79	15,38	0,56	6,58
Others	2,68	30,77	1,36	11,59

Productivity in the first crop cycle was higher and more sensitive to competition than in the second cycle. The lower interference in the second cycle led to a shorter period requirement of weed control (2 days). The duration of the interference therefore depends on environmental conditions. The influence of environmental conditions on the duration of the interference period was also observed in other countries (MEMON et al., 2012).

Table 7. Effect of weed control periods on percentage of survival, number of rows per ear, number of grains per row, ear length, and 100-grain weight for the second crop in Botucatu, SP, Brazil.

Control periods	Survival (%)		Number of rows per ear		Number of grains per row		Ear length (cm)		100-grain weight (g)	
No control[1]	92,42	c	13,77		22,87	c	11,82	b	20,50	bcd
0 – 7	95,96	abc	14,70		27,72	ab	13,42	a	21,00	abcd
0 – 14	94,69	bc	14,65		27,00	b	13,40	a	21,35	abcd
0 – 21	99,24	a	14,60		27,92	ab	13,60	a	22,60	a
0 –28	99,22	a	14,50		28,27	ab	13,40	a	22,15	ab
0 – 35	99,24	a	14,50		28,20	ab	13,52	a	22,66	a
0 – 42	100,00	a	14,60		28,50	a	13,67	a	21,65	abc
0 – 49	98,99	ab	14,52		27,47	ab	13,40	a	21,68	ab
0 – 56	100,00	a	14,57		27,87	ab	13,97	a	21,96	ab
$F_{TREATMENT}$	8,84	**	1,46	NS	38,60	**	7,18	**	8,32	**
Var. (%)[2]	1,90		3,20		2,00		3,52		3,56	
LSD[3]	4,40		1,10		1,33		1,14		1,81	

**Significant at 1%; NSNot significant; means followed by the same letter are not statistically different by the F test (p > 0.05).[1] Weed interference during the whole cycle, [2]Variance, [3]Low significative difference.

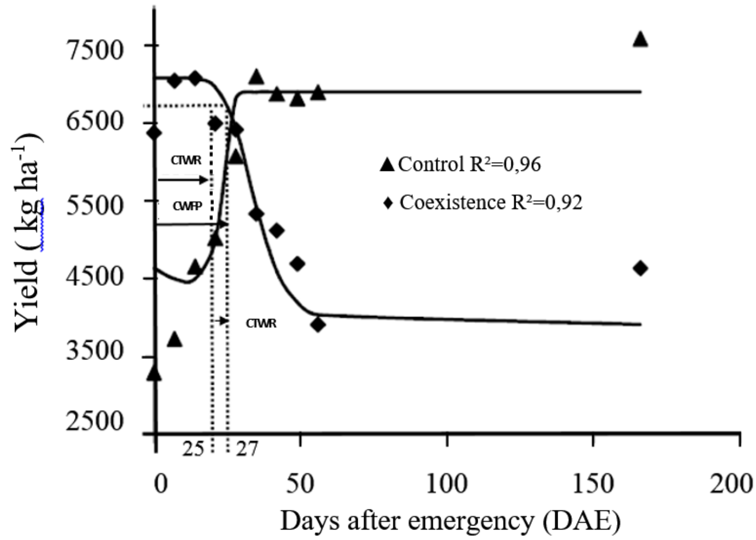
Table 8. Effect of weed control coexistence periods on percentage of survival, number of rows per ear, number of grains per row, ear length, and 100-grain weight for the second crop in Botucatu, SP, Brazil.

Coexistence periods	Survival (%)		Number of rows per ear		Number of grains per row		Ear lenght (cm)		100-grain weight (g)	
Control[1]	98,49		14,60	ab	27,22	ab	13,57	abc	20,24	e
0 – 7	100,00		15,00	a	28,37	a	14,30	a	21,51	de
0 – 14	98,98		14,40	ab	27,57	ab	14,27	a	23,15	abc
0 – 21	99,24		14,37	ab	27,22	ab	13,97	ab	23,69	ab
0 –28	98,98		14,17	ab	27,67	ab	14,10	a	23,97	a
0 – 35	98,48		14,25	ab	26,17	bc	13,00	bcd	22,12	cd
0 – 42	99,24		14,10	b	25,32	cd	12,82	cd	23,56	abc
0 – 49	99,24		14,07	b	23,92	de	12,22	d	23,42	abc
0 – 56	99,24		14,17	ab	22,62	e	12,22	cd	22,31	bcd
$F_{TREATMENT}$	0,41	NS	2,52	**	29,43	**	15,53	**	16,77	**
Var. (%)[2]	1,44		2,60		2,70		3,20		2,64	
LSD[3]	3,43		0,89		1,70		1,03		1,44	

**Significant at 1%; NSNot significant; means followed by the same letter are not statistically different by the F test (p > 0.05).[1] Weed interference during the whole cycle, [2]Variance, [3]Low significative difference.

Reduction in productivity was high in the presence of *D. nuda*, varying from 40-60%, an interference that was not observed for other species, underlining the importance of controlling this species in maize crops (FARIA et al., 2014).

Figure 2. Graph of critical timing of weed removal (CTWR), critical weed free period (CWFP), and critical period of weed control (CPWC), assuming a 5% reduction in the productivity of maize crop, according to management criteria with weed control and weed coexistence in the second crop in Botucatu, SP, Brazil. Weed control: y = 4496.09 + (2401.048/(1+((x/22.8461)^-16.0388))) R^2 = 0.9636, Coexistence: y = 3909.983 + (3165.467/(1+((x/34.4996)^6.5864))) R^2=0.9236.



Conclusion

In areas with high levels of *D. nuda*, infestation, whether the crop is planted in the first or the second crop cycle affects the weed control period, mainly owing to a change in the critical weed free period.

The CTWR is 25 days for both crop cycles. The CWFP is 54 and 27 days for the first and second crop cycles, respectively. The calculated CPWC is, therefore, 29 and 2 days for the first and second crop cycles, respectively.

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