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Weed interference periods on potato crop in Botucatu region, Brazil

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This study was carried out in Botucatu, State of São Paulo, Brazil in order to evaluate the interference periods of weeds on potato crop. The experimental design was a randomized complete blocks, with four replications, and treatments were arranged in two groups: 1) the crop was kept free from weeds through the periods of 7, 14, 21, 28 and 35 days after emergence, after each period weeds were allowed to grow; 2) the crop was kept weedy for the same periods of the first group, and afterwards the crop was kept weed-free besides a control maintained weed free and another maintained in coexistence with the weeds at 98 days (harvest). *Urochloa plantaginea, Cyperus esculentus, Raphanus raphanistrum, Sida rhombifolia,* and *Galinsoga parviflora* were the main weeds in the experimental area, being *U. plantaginea* the weed with the highest dry matter accumulation. Tuber size and yield were affected by interference of weed community. The total period of weed interference was 35, while the period previous of interference was 7; consequently, the critical period of weed interference was from 7 to 35 after crop emergence.

Key words: Competition, *Solanum tuberosum,* weed periods, weed management.

INTRODUCTION

The potato crop is exposed to a range of biotic and abiotic factors that affect its growth, development, and economic productivity. Considering these factors, weeds are very important and, according to Lutman (1992), compete by water, nutrients, and light, being the competition degree dependent on the type of weed community, species density and ability to compete for these environmental factors.

From all interference components, competition and allelopathy are the most significant processes, happening with high frequency (Velini, 1997). Furthermore, weeds can affect the quality of tubers (Vangessel and Renner, 1990; Monteiro et al., 2011), reducing their size, modifying their density, causing deformation, and thus hindering their commercialization. Interference degree usually is measured in relation to the crop yield and can be defined as the reduction in the percentage on economical crop yield caused by the interference of weed community. Interference degree among cultivated plants and weeds is dependent on factors related to the weed community (specific composition, density, and distribution), to the crop (genus, species or cultivars, spacing between plants and density of sowing), to the environment (weather, soil, crop management) and to the periods they are kept together (Pitelli, 1985). Losses between 12 and 86% due to competition with different weeds have been found in potato yield (Nelson and Thoreson, 1981; Tripathi et al., 1989; Muhammad, 1993; Liebman et al., 1996; Ciuberkis et al., 2007; Costa et al., 2008; Monteiro et al., 2011; Ahmadvand et al., 2009).

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Pitelli and Durigan (1984) established three periods in relation to time and duration of coexistence period with weeds: period previous of interference (PPI), total period of weed interference (TPWI) and critical period of weed interference (CPWI). During PPI, the crop can grow with weed community before interference; during TPWI the crop can control and avoid the growth of weeds; during CPWI, the most important period, weeds and crop compete more intensively for limiting resources, weed control is critical, and weed community development should not be allowed (Pitelli, 1985).

The present study aimed to determine the weed interference periods of potato crop (cultivar Atlantic), by means of determining total period of weed interference (TPWI), the period previous of interference (PPI), and the critical period of weed interference (CPWI).

MATERIALS AND METHODS

An experiment was carried out in the Lageado Experimental Field, at the Department of Crop Science, College of Agricultural Science, UNESP – São Paulo State University, Botucatu/SP, Brazil (22° 51' 09" S and 48' 25' 89" WGr.) with 740 m of altitude).

The tuber was planted in clay soil area, presenting the following properties: pH ($CaC1_2$) = 4.4; organic matter (g dm^{-3}) = 24; P (g dm^{-3}) = 14; H+Al, K, Ca, Mg, SB, CTC = 58, 5.0, 18, 6, 29, and 87 $mmol_c.dm^{-3}$, and V% = 33. The area was prepared by a moldboard plow, a heavy harrow, two leveling harrow, a rotative harrow, and a furrowing (20 cm depth) and the soil was fertilized and corrected according to Miranda-Filho (1996): 3.2 t ha^{-1} dolomitic limestone, 1.0 t ha^{-1} phosphorus, and 1.5 t ha^{-1} manure 8-28-16.

For planting, seed tubers of cultivars Atlantic were used and the plots were arranged in 4 rows of 5 m, spaced by 0.7 m, where seed tubers were placed at 0.25 m from each other. For evaluation, only two central rows in each plot were considered as useful area. Sprouting occurred in 19 after planting.

The experimental design was a randomized complete blocks, with four replications. The treatments were arranged in two groups: 1) the crop was kept free from weeds through the periods of 7, 14, 21, 28, and 35 days after emergence, after each period weeds were allowed to grow; 2) the crop was kept weedy for the same periods of the first group, and afterwards the crop was kept weed-free besides a control maintained weed free and another maintained in coexistence with the weeds at 98 days. All treatments were harvested at 98 days after planting. Weed control was performed through manual weeding.

Weed community was evaluated at the end of each coexistence period, when all weeds present in 0.5 m^2 of useful area of each plot which corresponded to two sub-samples of 0.25 m^2 were collected. Species were identified, quantified, and taken to the laboratory to be washed and oven dried at 70°C, until reaching constant weight. After that, dry matter mass from aerial parts of collected weeds was determined using 0.01 g precision scales.

Weed community phytosociological indices were determined by the following variables: absolute density, relative frequency, and index of importance value according to Mueller-Dombois and Ellenberg (1974).

Also, tubers were classified according to their sizes as follow: Type 1 > 54 mm; Type 2 > 48 to 54 mm, Type 3 > 41 to 47 mm, Type 4 > 34 to 40 mm, and Type 5 < 33 mm of diameter. After classification, tubers were weighed, and percentage of each tuber type was calculated.

Results of dry matter mass, absolute density, and tuber size were submitted to analysis of variance (ANOVA) and F test; the treatment means were compared by the t test at 5% of probability.

For determination of the critical period of interference prevention, yield data were obtained through the different coexistence and weed control periods, which were adjusted using the following model of non-linear regression:

$$y = a+b/[1+(x/c)^d]$$

Where: Y = yield tubers; x = days after crop emergence; a = minimum yield in the initial periods without weeds and the end of the trial to initial weed competition periods; b = differences between maximum and minimum yields; c = number of days which occurred 50% of reduction on maximum yield; d = slope of curve.

The limits of interference period were determined allowing maximum yield losses of 5% in relation to the yield obtained in plots that were kept free of weed competition during crop cycle.

RESULTS AND DISCUSSION

In Table 1, it can be noted that the weed community was composed by 15 weed species, with predominance of broad leaved (10 species). Among them, the family Asteraceae had the highest number of species (three species), while other families had only one species. Among the monocots, it was observed one species belonging to the Family Cyperaceae and four species to the family Poaceae, being the latter family, which presented the highest plant density, representing 27% of weed community. In other study of weed interference periods on potato, however in a different planting time, Costa et al. (2008) observed a different weed community. The weed community varied because it is influenced by seed germination and weather condition.

Urochloa plantaginea (Link) Hithc. was the specie that presented the highest dry biomass accumulation during the crop cycle (Table 2). Controlling weeds for 7 days reduced markedly the number of plants and the dry matter mass of *U. plantaginea*. Once the periods with no weed competition were increasing, the number and dry matter were decreasing, although without statistical difference among periods. Already for *Cyperus rotundus* L. and *Raphanus raphanistrum* L., a control for 14 days reduced both the density and dry matter accumulation in plant.

During the period of crop coexistence with weeds, from 14 to 28 days after crop emergence, it was observed that, the occurrence of a high frequency of *U. plantaginea* is therefore, the highest accumulation of dry matter mass observed at 35 days. Reduction of plant density and consequent increase in dry matter mass accumulation of weed community, during crop cycle were also verified by Martins (1994). Environment factors become restrictive, resulting in intraspecific competition with death of less capable individuals, followed by vigorous development of survivors.

In general, all species in the area have presented similar behavior, in which the control through 7 days caused a very significant reduction on weed dry matter mass accumulation, although density of *C. rotundus*, *Sida*

Table 1. Weed community of potato crop during the experimental period. Botucatu/SP, Brazil.

Family	Species	Common name	Code
Dicotiledoneae			
Brassicaceae	*Raphanus raphanistrum* L.	Wild Radish	RAPRA
Malvaceae	*Sida rhombifolia L.*	Country mallow	SIDRH
Asteraceae	*Galinsoga parviflora Cav.*	Gallant-soldier	GASPA
Asteraceae	*Bidens pilosa* L.	Hairy beggarticks	BIDPI
Asteraceae	*Emilia sonchifolia* (L.) DC.	Cupid's shaving	EMISO
Amaranthaceae	*Amaranthus deflexus* L.	Largefruit	AMADE
Rubiaceae	*Richardia brasiliensis* Gómez	Brazil puzley	RCHBR
Portulacaceae	*Portulaca oleracea* L.	Little hogweed	POROL
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	Morning glory	PHBPU
Oxalidaceae	*Oxalis latifolia Kunth*	Woodsorrel	OXALA
Monocotiledoneae			
Poaceae	*Urochloa plantaginea* (Link) Hithc.	Alessandergrass	URPL
Poaceae	*Panicum maximum* Jacq	Guinea grass	PANMA
Poaceae	*Eleusine indica* (L.) Gaert.	Indian goosegrass	ELEIN
Poaceae	*Digitaria horizontalis* Willd	Hay grass	DIGHO
Cyperaceae	*Cyperus esculentus* L.	Purple nutsedge	CYPES

Table 2. Effect of different periods of control or coexistence with weeds on density and dry matter accumulation of *Urochola plantaginea* (URPL), *Cyerus esculentus* (CYPES), *Raphanus raphanistrum* (RAPRA), and other weed species present in experimental area, Botucatu/SP, Brazil.

Treatment	URPL		CYPES		RAPRA	
	Density plants m^{-2}	Dry matter (g)	Density plants m^{-2}	Dry matter (g)	Density plants m^{-2}	Dry matter (g)
Weed free						
0-7[1]	15.5^{c}	8.1^{c}	20.5^{cde}	2.0^{cd}	11.5^{c}	2.3^{c}
0-14	9.0^{c}	1.6^{c}	8.5^{de}	1.0^{d}	8.0^{c}	0.4^{c}
0-21	3.5^{c}	0.35^{c}	10.0^{cde}	0.2^{d}	3.0^{c}	0.1^{c}
0-28	2.5^{c}	0.1^{c}	6.5^{e}	0.1^{d}	5.0^{c}	0.0^{c}
0-35	1.5^{c}	0.0^{c}	4.0^{e}	0.0^{d}	3.0^{c}	0.0^{c}
0-harvest	0.0^{c}	0.0^{c}	0.0^{e}	0.0^{d}	0.0^{c}	0.0^{c}
Weedy						
0-7	59.0^{a}	10.6^{c}	48.0^{ab}	8.1^{bc}	25.5^{abc}	5.8^{c}
0-14	34.5^{b}	19.6^{c}	36.5^{abc}	8.1^{bc}	42.0^{a}	16.6^{bc}
0-21	58.0^{a}	50.1^{b}	55.5^{a}	16.5^{a}	34.5^{ab}	32.0^{ab}
0-28	52.5^{a}	67.3^{b}	55.0^{a}	18.84^{a}	37.0^{ab}	47.9^{a}
0-35	44.0^{ab}	112.4^{a}	38.0^{abc}	12.94^{a}	15.0^{bc}	26.8^{b}
0-harvest	50.0^{ab}	99.3^{a}	31.5^{bcd}	14.98^{a}	13.5^{bc}	34.7^{ab}
F. treatment	17.32**	22.04**	6.31**	10.64**	2.59*	5.72**
F.block	1.01^{ns}	1.77^{ns}	4.28*	4.31*	1.55^{ns}	2.66*
C.V. (%)	42.4	57.0	62.3	64.5	110.2	103.4
L.S.D.	16.8	25.28	23.46	6.42	26.16	20.67

Averages followed by the same letter in column do not differ statistically by t test ($p \leq 0.05$); [1] days.

rhonbifolia L., *Galinsoga parviflora* Cav., and of other species group increased until 21 (Table 3).

Table 3. Effect of different periods of control or coexistence with weeds on density and dry matter accumulation of *Sida rhombifolia* (SIDRH), *Galinsoga parviflora* (GASPA), and other weed species present in experimental area, Botucatu/SP, Brazil.

Treatment	SIDRO		GASPA		Other species	
	Density plants m^{-2}	Dry matter (g)	Density plants m^{-2}	Dry matter (g)	Density plants m^{-2}	Dry matter (g)
Weed free						
0-7[1]	6.0^{de}	0.6^{b}	33.5^{abc}	3.4^{bcd}	13.0^{de}	1.0^{c}
0-14	9.0^{de}	0.3^{b}	27.0^{abc}	1.4^{d}	3.5^{e}	0.1^{c}
0-21	7.5^{de}	0.1^{b}	24.0^{abc}	0.2^{b}	16.5^{cde}	0.5^{c}
0-28	4.0^{e}	0.0^{b}	5.5^{bc}	0.0^{d}	5.0^{e}	0.0^{c}
0-35	3.0^{e}	0.0^{b}	4.5^{bc}	0.0^{d}	0.5^{e}	0.0^{c}
0-harvest	0.0^{e}	0.0^{b}	0.0^{c}	0.0^{d}	0.0^{e}	0.0^{c}
Weedy						
0-7	65.5^{bcd}	1.2^{b}	30.0^{abc}	1.6^{d}	38.0^{bcd}	2.9^{bc}
0-14	148.5^{a}	5.8^{b}	42.0^{a}	2.0^{cd}	83.5^{a}	8.2^{bc}
0-21	111.5^{ab}	5.5^{b}	52.0^{a}	8.3^{abcd}	42.0^{bcd}	6.3^{bc}
0-28	41.5^{cde}	2.0^{b}	35.0^{abc}	11.6^{abc}	45.5^{bc}	6.5^{bc}
0-35	73.5^{bc}	5.5^{b}	31.0^{abc}	17.1^{a}	49.5^{b}	20.0^{a}
0-harvest	114.5^{ab}	15.8^{a}	37.5^{ab}	13.0^{ab}	49.5^{b}	10.5^{b}
F. treatment	6.42**	3.22**	1.72^{ns}	3.07**	5.55**	3.49**
F. block	1.44**	0.82^{ns}	7.19**	5.33**	2.87*	1.29^{ns}
C.V. (%)	85.6	167.4	90.7	140.7	77.4	139.2
L.S.D.	60.03	7.41	35.03	9.88	32.17	9.37

Averages followed by the same letter in a column do not differ statistically by t test ($p \leq 0.05$); [1]days.

In the coexistence periods between crop and weed, it was observed that *R. raphanistrum* L., *S. rhombifolia,* and the group of less frequent species were in the highest plant density through 14 days; while the highest biomass accumulation was observed at 21 days for *R. raphanistrum* and at 35 days for the other species, except in the case of *S. rhombifolia*, which presented higher accumulation of dry biomass than the control treatment with coexistence with weeds during all crop cycle (Tables 2 and 3).

The highest density of *C. rotundus* plants was verified at 21 and 28 days, and the highest biomass accumulation at 21 days (Table 2). For *G. parviflora*, the highest density occurred at 14 and 21 days, and the highest dry matter accumulation was also observed at 21 days (Table 3). It was observed that biomass accumulation increased in the longest periods, while density was higher in the initial periods. Density of plants in the weed community is also dependent on the bank of seeds present in the soil and, according to environment factors, it can performe differently in relation to seed dormancy (Nogushi, 1983; Martins and Silva, 1994).

Regarding the relative density of weeds (Figure 1) and the density of each species in relation to the rest of them present in that area, the *G. parviflora* distinguished from the other species in all evaluated periods, except at 28 days. In the periods of coexistence between weed community and crop, *S. rhombifolia* plants presented the highest relative density. These results indicate that *G. parviflora* presented low competitiveness when compared with weed community in the area, once its infestation was low through the coexistence periods. Thus, initial periods of weed community control, even in the short ones, as 7 days, influenced *G. parviflora* plants survival rate.

For *S. rhombifolia*, it was observed that species should present aggressiveness that can help on survival, even by interspecific competition condition occurring in the experimental area. *S. rhombifolia* is common in areas where there is small perturbance of soil, as in no-till system, orchards, and pastures. Therefore, minimum soil movement is more suitable for its development.

Relative frequency data showed that all species presented similar results, except for *R. raphanistrum* and *C. rotundus* at 35 days, which reached the relative frequency mean of 27% (Figure 2). Also, the index of importance (Figure 3) showed that *G. parviflora* was the species with the highest value in the initial periods of control, while in the coexistence periods *S. rhombifolia* was the most important species. Costa et al. (2008) observed that *Commelina benghalensis* L. was the most important species in the initial periods of control and, *U. plantaginea* was in coexistence periods.

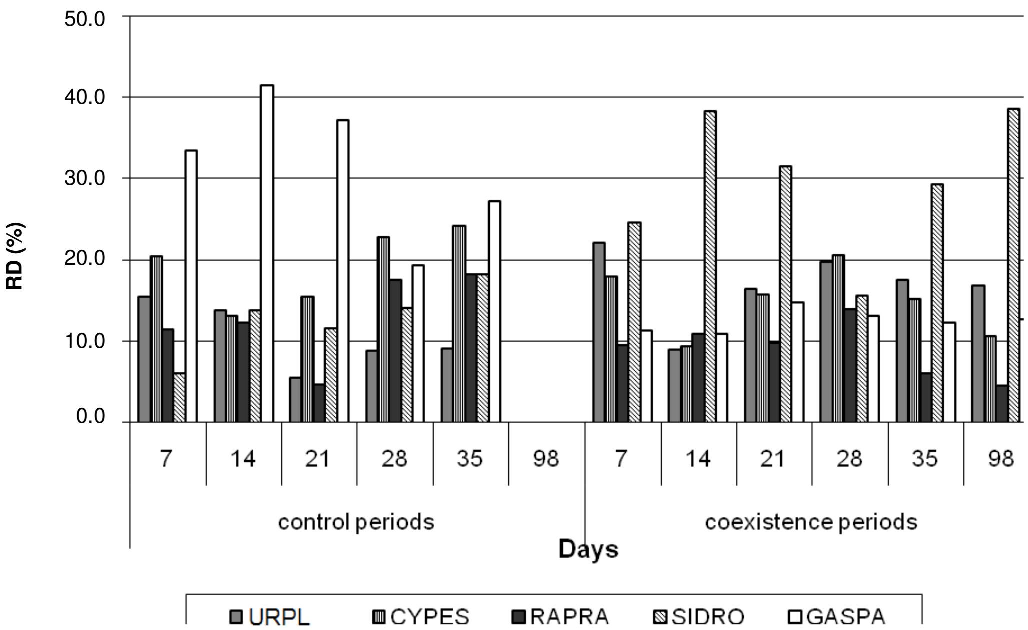

Figure 1. Relative density (RD) of *Uroclhoa plantaginea* (URPL), *Cyerus esculentus* (CYPES), *Raphanus raphanistrum* (RAPRA), *Sida rhombifolia* (SIDRH), *Galinsoga parviflora* (GASPA) present in experimental area, as a function of the number of days after potato emergence with control or coexistence with weeds, Botucatu/SP, Brazil.

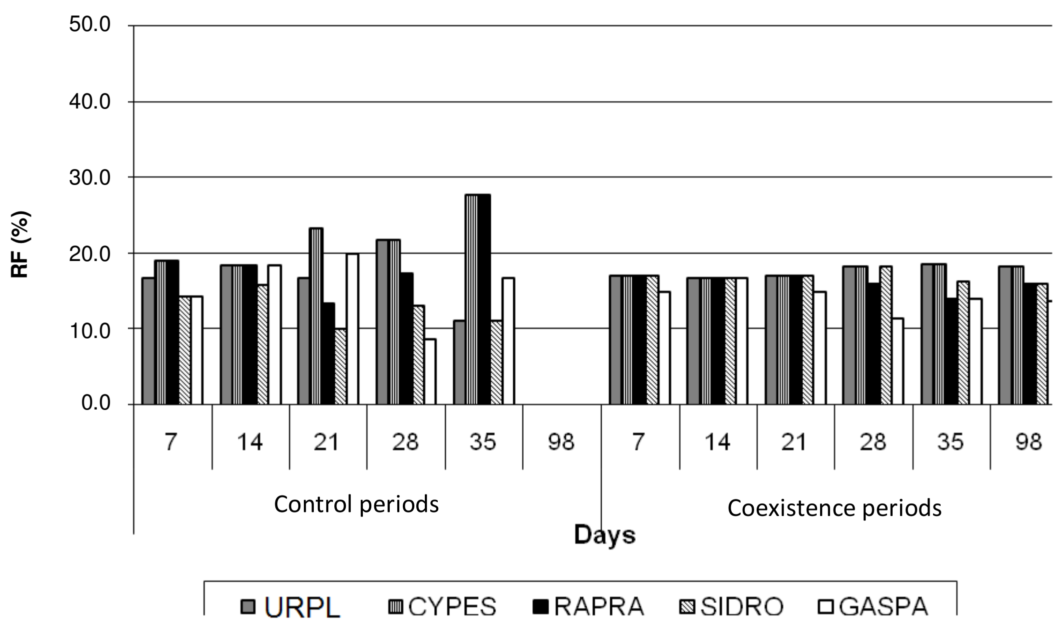

Figure 2. Relative frequency (RF) of *Urochloa plantaginea* (URPL), *Cyerus esculentus* (CYPES), *Raphanus raphanistrum* (RAPRA), *Sida rhombifolia* (SIDRH), *Galinsoga parviflora* (GASPA) present in experimental area, as a function of the number of days after potato emergence with control or coexistence with weeds, Botucatu/SP, Brazil.

In Table 4, it was verified that for tuber weight classification, to obtain potato of Type 1, or rather, with the highest diameter and weight, control for 35 was enough to assure the same percentage of potato of Type

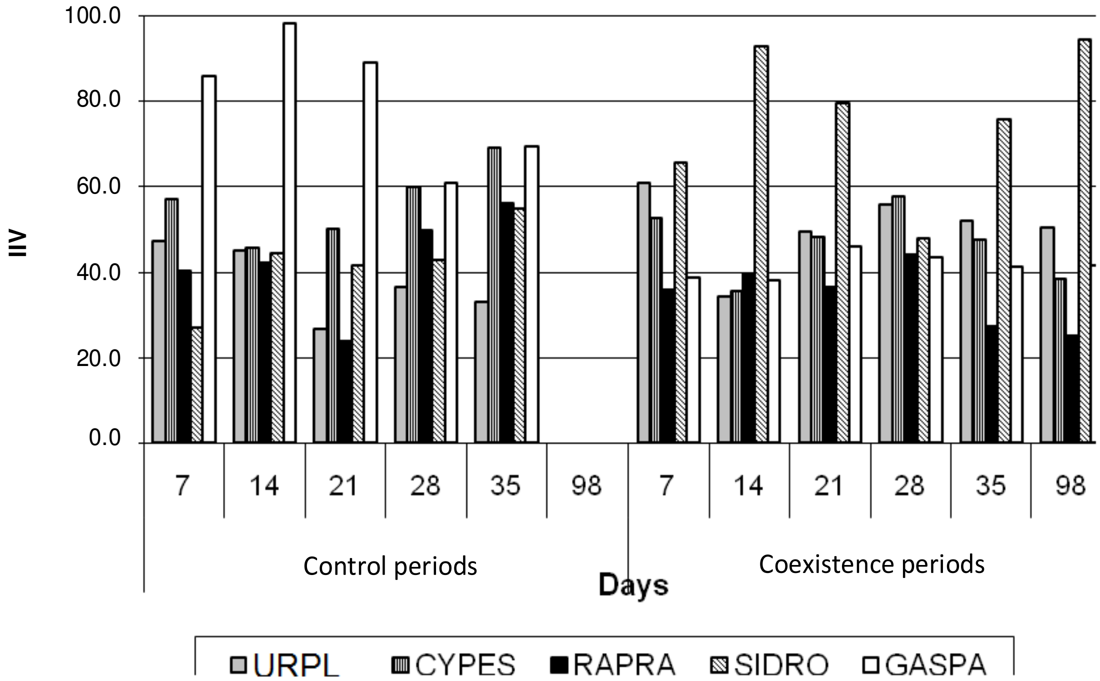

Figure 3. Index of importance value (IIV) of *Urochloa plantaginea* (URPL), *Cyerus esculentus* (CYPES), *Raphanus raphanistrum* (RAPRA), *Sida rhombifolia* (SIDRH), *Galinsoga parviflora* (GASPA) present in experimental area, as a function of the number of days after potato emergence with control or coexistence with weeds, Botucatu/SP, Brazil.

Table 4. Effect of different periods of control or coexistence with weeds on percentage of tuber classified in five different size types (diameter). Botucatu/SP, Brazil.

Treatment	Tuberclassification (%)				
	Type 1 >70 mm	**Type 2 >42≤70 mm**	**Type 3 >33≤42 mm**	**Type 4 >28≤33 mm**	**Type 5 ≤28 mm**
Weed free					
0-7[1]	18.3^{dc}	15.5^{dc}	29.5^{abc}	25.8^{bc}	10.9^{abc}
0-14	17.1^{cde}	16.5^{bcd}	31.6^{abc}	25.5^{bc}	8.1^{bc}
0-21	14.8^{def}	27.8^{ab}	28.9^{abc}	21.6^{bc}	6.9^{c}
0-28	21.2^{bcd}	21.3^{bc}	28.1^{abc}	21.1^{bc}	8.2^{bc}
0-35	34.3^{ab}	16.7^{bcd}	18.8^{c}	20.8^{bc}	9.5^{abc}
0-harvest	38.8^{a}	22.1^{bc}	18.8^{c}	14.3^{c}	6.1^{c}
Weedy					
0-7	29.2^{abc}	20.6^{bc}	20.6^{bc}	20.2^{bc}	9.5^{abc}
0-14	13.8^{def}	23.8^{bc}	32.3^{ab}	20.6^{bc}	9.5^{abc}
0-21	11.4^{def}	27.3^{abc}	27.5^{abc}	27.8^{abc}	5.9^{c}
0-28	4.1^{ef}	16.6^{bcd}	25..3^{abc}	40.2^{a}	13.8^{a}
0-35	2.9^{f}	37.3^{a}	19.1^{c}	30.8^{ab}	10.2^{abc}
0-harvest	9.9d^{ef}	7.7^{d}	36.6^{a}	32.6^{ab}	13.2^{ab}
F. treatment	5.20**	3.18**	1.81*	2.07*	1.86^{ns}
F.block	0.42**	2.48^{ns}	0.85^{ns}	0.84^{ns}	0.79^{ns}
C.V. (%)	54.9	39.9	33.3	38.6	39.5
L.S.D.	14.21	12.13	12.60	13.91	5.34

Averages followed by the same letter in a column do not differ statistically by t test ($p \leq 0.05$); [1]days.

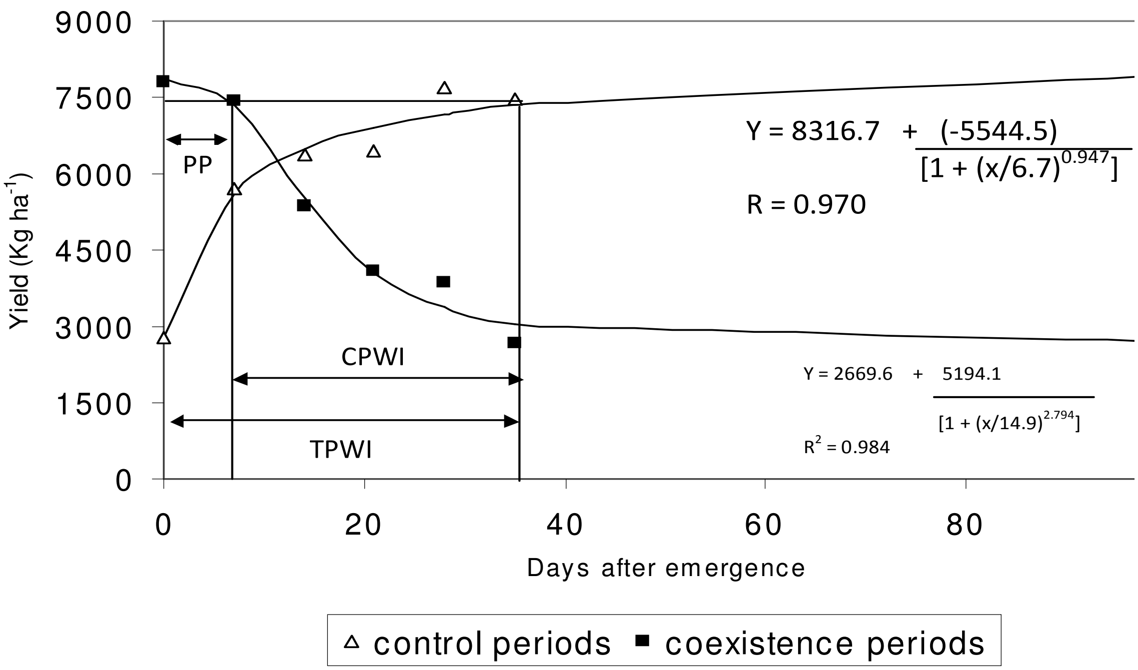

Figure 4. Yield of potato tubers as a function of coexistence and weed control periods in experimental area, Botucatu/SP, Brazil.

1 as the control treatment without weed competition. Percentage of Type 1 tubers was inferior to the control treatment when crop was under weed competition for a period of 14 days or more, however, about 25% of losses was observed in the 7-days weedy treatment. Although, not statistically differing from the control treatment, this loss can be considered important. In general, it was observed that the longer is the coexistence period, the higher is the percentage of tubers with inferior quality, with low weight and diameter. Vangessel and Renner (1990) and Monteiro et al. (2011) also found that the quantity and quality of marketable tubers was reduced when there was competition in potato crops against weeds.

Regarding tuber yield (Figure 4), it was observed that the coexistence with weeds during all crop cycle caused a reduction of 65% in relation to the control treatment without weed competition. It was verified, according to the terminology proposed by Pitelli and Durigan (1984) that (PPI) was of 7 days after sprouting, with 5% of yield reduction of potato crop, and (TPWI) was 35 days and, thus (CPWI) was from 7 to 35 (Figure 4). In fact, this shows that the control period between 7 and 35 resulted in yield as the control treatment. However, according to Jaiswal (1992) for the potato crop would be the critical period between 25 and 35 days after planting and Singh et al. (2005) found a period between 15 and 45 days. It should be noted that these differences are related to variety, planting date, differences in weeds, soil, and climatic conditions.

Treatments (control or coexistence periods) were started from sprouting, 19 days after seed tuber planting. That fact determined that an interval of only 7 had formed already the (PPI), because the interval of time between planting and sprouting was long enough for weed community to interfere on crop yield already by the first period studied.

In future studies, the beginning of treatment should be from planting of seed tubers, because the period until sprouting can be too long as observed, what could give advantage to the weed community in relation to the crop. It is also noteworthy that the time to sprouting depends on the cultivar, the temperature, the soil type, and others factors.

In summary, the present work determined that the total period of weed interference (TPWI) was 35, while the period previous of interference (PPI) was 7 and, consequently, the critical period of weed interference (CPWI) was from 7 to 35 after crop emergence.

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