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Weed interference on coffee fruit production during a four-year investigation after planting

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Aiming to investigate the effects of crescent weedy periods on the extension of the period before weed interference on coffee fruit production under two kinds of weed control, field trials were conducted in Arceburgo-MG, Brazil, during the period 2000 - 2004. Two groups of treatments were established according to the kind of weed control: (i) total area control and (ii) 0.5 m strip control at each side of planting line. Six periods of weed coexistence were established in both groups, at the beginning of the rainy season: 0, 30, 60, 90, 120 and 150 days. At the end of each period, weeds were monthly removed by glyphosate applications until coffee harvest. Main weeds found during investigation were *Alternanthera tenella*, *Amaranthus hybridus*, *Commelina benghalensis*, *Digitaria horizontalis*, *Digitaria insularis*, *Parthenium hysterophorus* and *Euphorbia heterophylla*. Weed density and dry matter varied among periods of coexistence and between kinds of control throughout the full time investigations, so that it was not possible to establish any correlation between their evaluations. Period before weed interference was higher in 2001/2002 than in 2002/2003 and 2003/2004, suggesting that the weed management adopted in 2000/2001 was not enough to prevent weed interference throughout the investigation, in both total and strip control.

Key words: *Coffea arabica*, competition, weed management, glyphosate, weedy periods.

INTRODUCTION

Coffee is one of the world's most popular beverages (Fujioka and Shibamoto, 2008). It is also the most important traded commodity in the world after oil (Naidu et al., 2008). Among coffee tree species, *Coffea arabica* L. shows the highest economic importance, producing the consumers' most appreciated coffee drink (Nascimento et al., 2006). In Brazil, coffee production is of economic as well as social importance; this country is the main world producer (Marana et al., 2008), where Minas Gerais State is responsible for 50% of the total Brazilian coffee production, also showing the most quailfied coffee industry (Silva et al., 2007).

Weeds cause quantitative and qualitative losses to agriculture products, such that these plants may be troublesome to coffee producers due to the interference on the tree growth and development, and on fruits yield (Ronchi and Silva, 2006; Alcântara et al., 2007; Dias et al., 2008; Marcolini et al., 2009). In coffee plantations, weeds may also affect the macronutrients uptake (Ronchi et al., 2007) and they can be alternative hosts of coffee strains of *Xylella fastidiosa* which causes coffee leaf scorch (CLS), a serious disease of *C. arabica* (Lopes et al., 2003).

Weeds may constrain crops directly by competition, allelopathy and harvest impediment, or indirectly by pests and pathogens hosting (Radosevich et al., 1997). The degree of weed interference is determined by factors linked to crops (cultivar, spacing and density), to weed community (composition, density and distribution), to environment (soil, climate and management) and to the period of weed interference (Bleasdale, 1960). The period that weeds coexist with crops, competing for limited environmental resources, is one of the most important factors affecting the degree of weed interference, so that crops are allowed to coexist with weeds for an

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early period without interference after planting, titled period before weed interference (Pitelli, 1985).

A few studies, found in literature, were performed focusing on weed interference on coffee plantations; thereby the objective of this study was to investigate the effects of crescent weedy periods on the extension of the period before weed interference on coffee fruit production under two kinds of weed control during four year-investigations after planting.

MATERIALS AND METHODS

The field trials were conducted at Fazenda Monte Alegre, Arceburgo-MG, Brazil, in sand clay loam soil, during the period 2000-2004. The local geographic coordinates were 21° 24' 26'' S latitude and 47° 00' 28'' W longitude. Before planting, the weeds were desiccated using glyphosate (1,440 g e.a./ha) and the soil tillage was performed by heavy disc harrow. Moreover, lime and fertilizers were applied in accordance to the soil analysis. Fertilizers applications were also performed during the years after planting. *Coffea arabica* seedlings cv. Rubi, containing five pairs of leaves, were planted in nine rows containing 48 plants in total on February, 2000. The spacing among rows was 2.5 m and that one among plants was 0.8 m. So, each experimental plot consists of three rows containing four plants, representing 12 plants per plot.

Two groups of treatments were established according to the kind of weed control: (i) total area control and (ii) 0.5 m strip control at each side of the bottom of the coffee plants. Moreover, six periods of weed coexistence were established in both groups, at the beginning of the rainy season: 0 (weedy check), 30, 60, 90, 120 and 150 (weed-free check) days. At the end of each period, weeds were monthly removed by glyphosate applications until the coffee harvest. This study consists of 12 treatments set up in a randomized block design with three replicates. At the end of each weedy period, two 0.25 m^2 samples of the weed community were collected from each side of plot central line (four samples in total), evaluating the number of plants and the dry matter accumulation that were submitted for F-test ($p = 0.05$). These data obtained were analyzed for both total and strip control, because there was not considered any effect of the kind of control on weed community due to the place where the weeds were collected.

The first investigation was performed from November, 2000 to April, 2001, evaluating just the weed community. The second investigation occurred from October, 2001 to February, 2002, while the third investigation was performed from December, 2002 to May, 2003 and the forth investigation occurred from November to April, 2004, evaluating both weeds and coffee production. In the periods when no evaluation was done, the weed control was performed by monthly applications of glyphosate. Pesticides and fungicides were also applied to prevent injuries on coffee plants during the full time investigations. The coffee fruits were harvested just at the end of each season of investigation, evaluating the dried fruits matter (11% of moisture). The fruit production was submitted for F-test ($p = 0.05$) and regression analysis according to the sigmoid Boltzmann model (Carvalho et al., 2008a, b), considering the interval of acceptance of 2, 5 and 10% of losses (Williams II, 2006).

RESULTS

The weeds found during the four-year investigation, in both total and strip control, were *Alternanthera tenella*, *Amaranthus hybridus*, *Acanthospermum hispidum*, *Bidens pilosa*, *Brachiaria decumbens*, *Brachiaria plantaginea*, *Commelina benghalensis*, *Cyperus esculentus*, *Cyperus rotundus*, *Digitaria insularis*, *Digitaria horizontalis*, *Eclipta alba*, *Eleusine indica*, *Emilia sonchifolia*, *Euphorbia heterophylla*, *Galinsoga parviflora*, *Ipomoea grandifolia*, *Leonorus sibiricus*, *Panicum maximum*, *Parthenium hysterophorus*, *Pennisetum purpureum*, *Portulaca oleracea* and *Sida rhombifolia*.

There was significant difference ($p < 0.05$) of weed density and weed dry mass in the periods of coexistence, for each season (Table 1). In general, weeds were more abundant at the beginning of the experimental stage; on the other hand, the tendency of weed dry mass accumulation varied a lot among the seasons.

Dry matter of coffee fruits was strongly reduced due to weed interference throughout the time (Figure 1). According to the adjusted regression equations, at the harvesting, in weed-free checks, coffee fruits production was 617.78 and 412.44 g/plant, in 2001/2002, 605.81 and 245.17 g/plant, in 2002/2003, and 572.53 and 371.80 g/plant, in 2003/2004, in total and strip control, respectively. On the other hand, in weedy checks, coffee fruits production was 94.65 and 22.87 g/plant, in 2001/2002, 44.40 and 39.62 g/plant, in 2002/2003, and 1.33 and 13.30 g/plant, in 2003/2004, in total and strip control, respectively. Thus, comparing the weedy and weed-free checks, coffee fruits production reduced by 85 and 94% in 2001/2002, 93 and 84% in 2002/2003, and 99 and 96% in 2003/2004, in total and strip control, respectively. Furthermore, the difference between the total and strip control weed-free checks was 33, 59 and 35% in the periods 2001/2002, 2002/2003 and 2003/2004, respectively.

The period before weed interference varied throughout the time in both total and strip weed control (Table 2). In 2000/2001, there was no coffee fruit production. Considering 2 to 10% of acceptable losses of fruit coffee production, we had the results: in 2001/2002, the period before weed interference could be established from 27 to 38 days in total control or from 42 to 53 days in strip control; in 2002/2003, this period could be established from 3 and 12 days in total control or it was less than 1 and 2 days in strip control; and in 2003/2004, this period could be established from 2 to 9 days in total control or from 3 to 20 days in strip control.

DISCUSSION

It is important to emphasize that, during the four-year investigations, weeds more frequently found in the rainy and warm season (Figure 2) were *A. tenella*, *D. horizontalis*, *P. hysterophorus* and *C. benghalensis*. After the second year of investigation, *D. insularis* was also frequently found while in the four years of investigation, *A. hybridus* and *E. heterophylla* were frequently found.

Table 1. General weed density (plants/m^2) and dry mass (g/m^2) ± standard error in coffee plantation, according to crescent periods of weed coexistence.

Days	Density	Dry mass
2000/2001#		
60	183 ± 45	518.6 ± 30.1
90	95 ± 25	962.6 ± 119.9
120	18 ± 3	1070.1 ± 178.9
150	47 ± 7	250.8 ± 40.5
2001/2002##		
30	105 ± 25	495.5 ± 30.1
60	37 ± 8	306.5 ± 41.9
90	27 ± 6	407.0 ± 94.8
120	35 ± 4	453.2 ± 83.0
2002/2003		
30	35 ± 5	467.8 ± 64.3
60	21 ± 4	643.8 ± 77.4
90	31 ± 9	293.1 ± 48.3
120	26 ± 4	599.5 ± 23.4
150	15 ± 4	440.8 ± 98.9
2003/2004		
30	38 ± 12	625.0 ± 71.0
60	36 ± 3	689.4 ± 140.3
90	18 ± 4	990.9 ± 166.6
120	34 ± 6	883.7 ± 204.6
150	13 ± 2	561.0 ± 66.6

Observation: For four seasons, F tests applied on periods of coexistence were significant to 5% for both weed density and dry mass, so that results were compared to standard error.
#At 30 days in 2000/2001, weeds were very small and did not have sufficient biomass to be weighted, so that there was not evaluation at this time.
There was not evaluation at 150 days in 2001/2002 because the coffee harvest was previously performed at 120 days.

Appearance of new weeds during the study might be explained by continuous weed management with glyphosate that could have created favorable conditions to some weeds making them dominants while controlling other ones. Moreover, species such as *C. benghalensis*, *D. insularis* and *E. heterophylla* could not be controlled efficiently with glyphosate. *C. benghalensis* plants are naturally tolerant to glyphosate (Culpepper et al., 2004) causing drastic charges in crop production practices, including reliance on glyphosate-based systems for weed control (Brecke et al., 2005; Spader and Vidal, 2000; Webster et al., 2005, 2006). Glyphosate applications can control *D. insularis* seedlings but the species may not be controlled efficiently by glyphosate after flowering (Machado et al., 2006; Timossi et al., 2006). It was found in many glyphosate-resistant *E. heterophylla* biotypes worldwide (Vila-Aiub et al., 2008; Powles, 2008), this means that species control using glyphosate can not be efficient.

Furthermore, in glyphosate-based systems, herbicide-non-controlled species are selected throughout the time, enabling the management of troublesome weeds (Webster et al., 2005, 2006), allowing variation on density, growth and development of the weed community. So this fact help us to evidence why it might not be established any correlation between the evolutions of weed density and weed dry matter (Table 1) throughout the time evaluations.

Coffee fruits production was not reduced significantly in total-controlled weed-free check throughout the time. On the other hand, a reduction of coffee production in strip-controlled one was observed mainly in 2002/2003 in relation to 2001/2002. It indicates that strip control was not efficient to prevent weed interference even in weed-free check. Marcolini et al. (2009) found that the distance between weeds and coffee plants influences on crop growth. Studying different strips of weed control in coffee plantation, Souza et al. (2006) concluded that the minimum strip necessary to prevent weed interference might be 1.00 m, while Dias et al. (2008) found the strip of 0.80 m. Thus, the strip weed control, adopted in this study, allowed weeds to keep the interference on the coffee plantation.

The reduction on crop production was always more than 80% when weeds coexisted with coffee trees during the full experimental stage, achieving almost 100% (Fig. 1). Reduction on coffee production depends on weed composition and density (Ronchi and Silva, 2006; Ronchi et al., 2007). Lemes et al. (2004) and Dias et al. (2008) observed more than 90% of losses, while Souza et al. (2006) verified 100% of losses. Ronchi et al. (2003) and Ronchi et al. (2007) also observed reductions on nutrient uptake for coffee trees under weed interference conditions, so that yield reductions may occur as a consequence of weed competition for these resources. Therefore, weeds may strongly influence the coffee fruit production if they coexist with coffee plantation throughout the time.

According to Blanco et al. (1982), the reproductive life of coffee trees may be affected if there is no weed control within appropriated time with yield losses of 77%. Moreover, Friessleben et al. (1991) reported that weed competition imposed to two-or three-year-old field grown *C. arabica* significantly reduced stem and crown diameter,

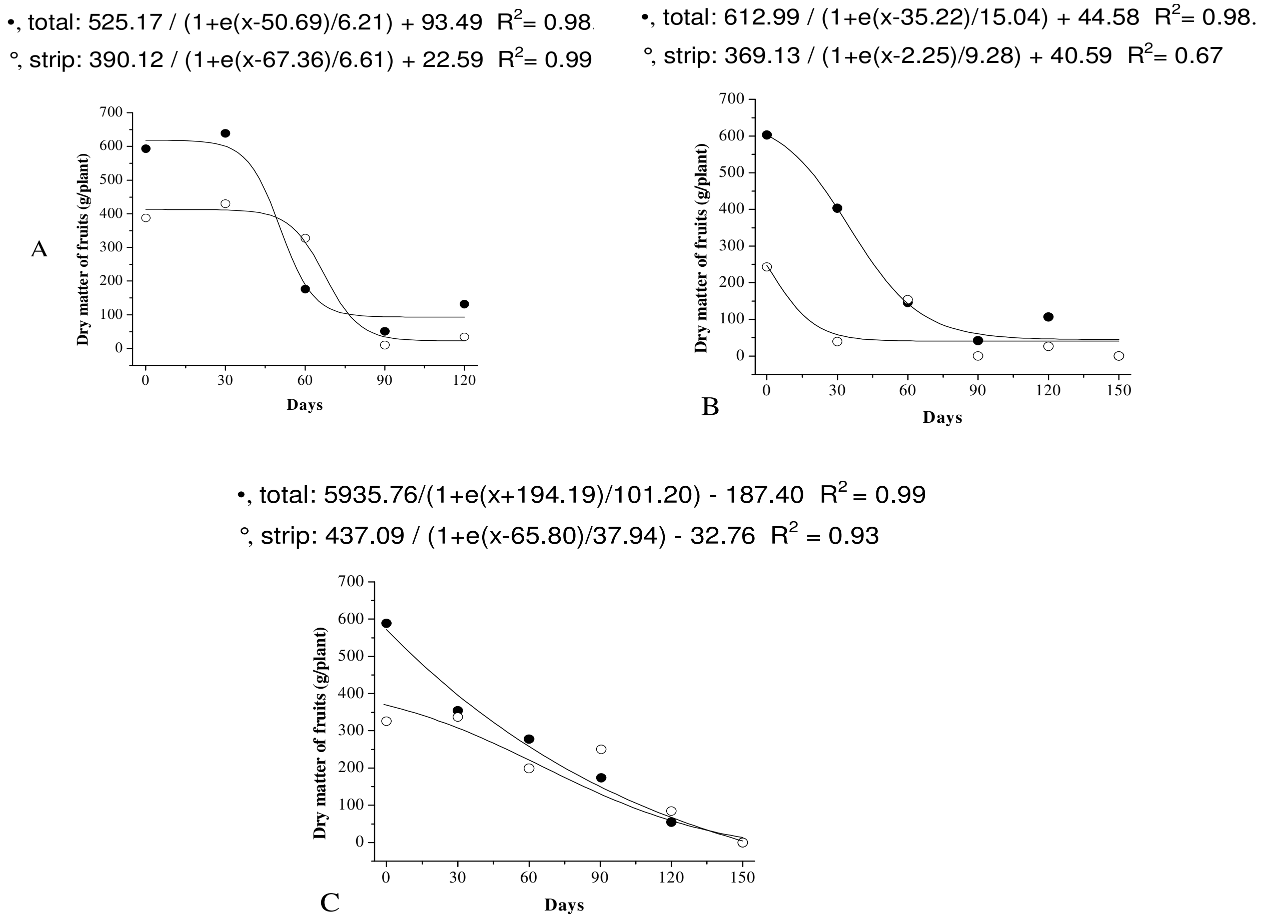

Figure 1. Dry matter of coffee fruits under crescent periods of weed coexistence and two kinds of weed control in 2001/2002 (A), 2002/2003 (B) and 2003/2004 (C). Obs. For three harvests, F tests applied on periods of coexistence in total and strip control, distinctly, were significant to 5%.

Table 2. Period before weed interference (days) on coffee plantation submitted to two kinds of weed control.

Year	Control	Acceptable loss		
		2%	5%	10%
2001/2002	Total	27	33	38
	Strip	42	49	53
2002/2003	Total	3	7	12
	Strip	< 1	1	2
2003/2004	Total	2	4	9
	Stri	3	9	20

diameter, plant height, number and length of plagiotropic branches and node formation on primary branches. Oliveira et al. (2002) reported that competition of *Commelina* spp. led to a reduction in leaf number, plant height and stem diameter of *C. arabica*, after this weed had been grown at several densities during 150 days following coffee transplanting into pots. Other adverse weed effects on coffee growth were brought about probably through competition mainly for nutrients, which reflexes on final production (Gallo et al., 1958; Njoroge, 1994) and light (Blanco et al., 1982; Castro and Garcia, 1996).

The balance of species interaction affects the period before weed interference. Such period was too much higher in 2001/2002 than in 2002/2003 and 2003/2004 (Table 2). Moreover, the period before weed interference was higher in strip control than in total control throughout the time in 2001/2002 and 2003/2004, while it was lower in strip control just in 2002/2003. During such period, crop-weeds resources allocation is too much low thereby

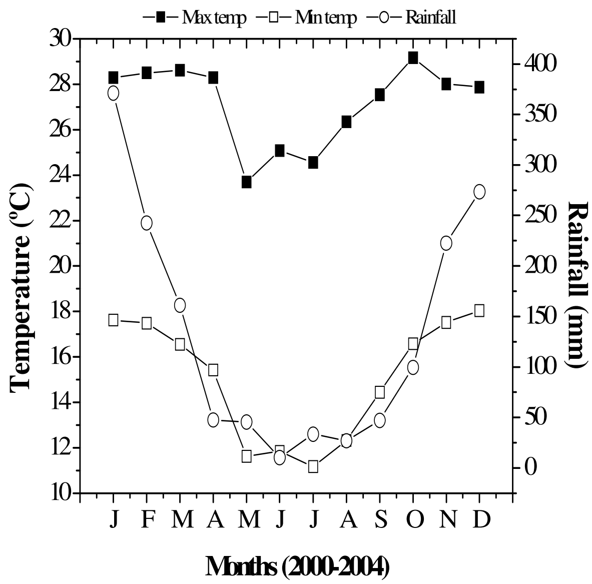

Figure 2. Average temperature trends (min and max) and rainfall index during the period 2000 - 2004.

it does not affect the soil resources availability, so that the end of this period indicates the time when the availability of essential resources to crops is overcame for weeds recruitment (Pitelli, 1985).

Regardless of this methodology is widely used to study effects of weedy periods on crop yields, a few works were found in literature on coffee plantations. In Brazil, Blanco et al. (1982) reported that the critical period of weed interference, whose initial stage indicates the final of the period before weed interference, comprised the rainy season, coinciding with crop fructification. In such season, weeds may quickly grow and produce a great amount of propagules, increasing their aggressiveness.

In India and Venezuela, in the same such season, Pereira and Jones (1954) and Moraima et al. (2000), respectively, observed that the critical period also occurred at the rainy season due to faster weed growth.

Lower values of the period before weed interference evidences that weeds are more competitive than crops earlier in the season (Carvalho and Guzzo, 2008; Carvalho et al., 2008a, b). Furthermore, the time and extension of the period before weed interference depend on weed community's aggressiveness (Pitelli, 1985). Thus, it suggests that the weed management adopted in 2000/2001 was not enough to prevent weed interference throughout the time, in both total and strip control. Therefore, the weed management by monthly glyphosate applications did not allow coffee plantation to be kept free of weed interference, so that the period before weed interference on coffee fruits production decreased throughout the time.

Conclusion

The period before weed interference tended to be reduced throughout the four-year investigation, suggesting that weeds became more competitive than coffee trees.

The 0.5 m strip control propitiated higher period before weed interference than total control in two of the three seasons, suggesting that coffee trees were more competitive when weeds were controlled in strip.

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