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The effects of the coexistence of weed communities on table beet yield during early crop development

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ABSTRACT. The objective was to evaluate the effects of initial weedy periods on the weed community and on the productivity of direct seeded and transplanted table beet cropping systems. A field trial was conducted at São Paulo State University, Brazil, in a randomized complete block design using a 2 x 13 factorial scheme. Direct seeding and seedling transplanting methods were evaluated within thirteen increasing weekly weedy periods. Weed relative importance was calculated and weed density and weed dry matter accumulation data were analyzed by nonlinear regression as well as beet yield and stand, which were submitted to analysis of variance. *Amaranthus viridis*, *Coronopus didymus*, *Cyperus rotundus*, *Digitaria nuda*, *Galinsoga parviflora* and *Nicandra physaloides* were the most important weeds found, with special reference to *C. didymus*. Weed dry matter accumulation was greater in the direct seeded crop, although weed density was higher in the transplanted crop. Transplanted beet yield was greater than of direct seeded beet in the weed-free treatment during the whole crop cycle. Crop-weed coexistence could remain for four and seven weeks after seeding/transplanting in direct seeded and in transplanted beet, respectively, before reducing yield economically. Thus, direct seeded crop was more susceptible to weed interference than the transplanted one.

Key words: *Beta vulgaris*, weeds, interference, direct seeding, seedling transplanting.

RESUMO. Efeitos de convivência da comunidade de plantas daninhas na produção de beterraba durante o desenvolvimento inicial da cultura. Objetivando avaliar efeitos de períodos de infestação inicial na comunidade infestante e na produtividade da beterraba em sistema de semeadura direta e transplantio, conduziu-se um experimento em delineamento de blocos casualizados, esquema fatorial 2 x 13. Métodos de semeadura direta e transplante de mudas foram avaliados dentro de 13 períodos semanais crescentes de infestação. Importância relativa, densidade e matéria seca acumulada pelas plantas daninhas foram analisadas por regressão não-linear, assim como produtividade e estande da cultura de beterraba, que foram submetidos à análise de variância. *Amaranthus viridis*, *Coronopus didymus*, *Cyperus rotundus*, *Digitaria nuda*, *Galinsoga parviflora* e *Nicandra physaloides* foram as plantas daninhas mais importantes, destacando-se *C. didymus*. O acúmulo de matéria seca das plantas daninhas foi maior na cultura em semeadura direta, embora a densidade de plantas daninhas tenha sido mais alta em sistema de transplantio. A produtividade da beterraba transplantada foi maior que a da semeadura direta no tratamento livre de plantas daninhas. A convivência das plantas daninhas com a cultura pode permanecer por quatro e sete semanas depois da semeadura/transplantio, respectivamente, antes de reduzir a produtividade. A cultura em sistema de semeadura direta foi mais susceptível à interferência das plantas daninhas que a cultura sob sistema de transplantio.

Palavras-chave: *Beta vulgaris*, plantas daninhas, interferência, semeadura direta, transplante de mudas.

Introduction

Table beet crop (*Beta vulgaris*) has gained importance during the last ten years in Brazil. However, beet root production is negatively influenced by weed community in coexistence, affecting crop yield, growth and development. Period of crop-weed coexistence is probably the main factor that influences the degree of interference among them.

There is a period in which weeds may be in coexistence with the crop without any negative influence, since weed interference is not yet established (PITELLI, 1985). The knowledge of this period is essential in order to establish weed control strategies (MESCHEDE et al., 2004).

There are a few ways to increase the initial period without weed interference (PITELLI, 1985).

Cultural crop management is the best approach to control weeds, providing competitive advantage to crops at the expense of weed communities. As a result, the period without interference is enhanced.

Production systems in table beet crop are either in direct seed or transplanted from a nursery to the production area. However, the transplanting method may provide faster beet plant growth and better crop stand, and so it may be used as a tool for weed control (SILVA et al., 1999).

The objective of this research was to evaluate the effects of increasing initial weedy periods on weed community and on direct seeded and transplanted table beet productivity.

Material and methods

A field trial was carried out at College of Agriculture and Veterinarian Sciences of São Paulo State University, in Jaboticabal, São Paulo State, Brazil, at 21°15'22"S and 48°18'58"W. The experiment was conducted from early July to early October 2006, in a Typical Oxisol, clay-textured (LRe), originated from Basalts of São Bento Group, *Serra Geral* formation (CUNHA et al., 2005).

The soil attributes were: pH = 5.6 in 0.01 M $CaCl_2$; organic C = 25 g dm^{-3}; P (resin) = 87 mg dm^{-3}; 4, 43, 16, and 25 $mmol_c$ dm^{-3} of K^+, Ca^{2+}, Mg^{2+}, and $H+Al^{3+}$, respectively; base saturation = 72%; CEC = 88%; sand, silt, and clay of 19, 31, 50%, respectively.

Lime with relative power of total neutralization equal to 120% was applied at 590 kg ha^{-1}, at 20 days before planting. N-P-K fertilization was applied at 240 kg ha^{-1} in a formulation 4-30-16, in addition to 12, 24, and 12 kg ha^{-1} of ammonium sulfate, simple super-phosphate and borax, respectively. Supplementary mineral fertilization was applied at 90 and 36 kg ha^{-1} of urea and potassium chloride, respectively. This application was shared into three equal amounts over 15, 30 and 45 days after planting. Lime and fertilizers were applied manually over the ground and their incorporation into soil was done firstly by disc harrow just before crop planting. Supplementary mineral fertilizers were incorporated by irrigation water.

The experiment was set up in a randomized complete block design, on a 2 x 13 factorial scheme with three replicates. Two planting methods and thirteen weedy periods (including a weed-free treatment) were evaluated. The treatments were determined by increasing week of initial weedy after planting date, considering both direct sowing and transplanting methods until harvesting.

The planting date was July 4th for both planting methods. 'Tall Top Early Wonder' table beet cultivar was direct seeded and transplanted into beds with four rows in a band up to 0.25 m wide and in a density of 40 plant m^{-2}. The experimental plots measured 1.20 m length and 1.00 m width, but it was considered the center of the plot, 1.00 m^2, for evaluation. After the seeding/transplanting and throughout the season, the experiment was irrigated by sprinkler system.

At each increased week after planting (WAP), except the first, a sample of 0.5 x 0.5 m of the weed community was harvested for biomass measuring and the rest of the plot was kept weed-free by hand-weeding, according to the treatments.

Sampled weed community was separated into species, counting number of individuals per species and determining dry matter accumulation per species after being dried in an air convention oven at 60°C for 96 hours. The density and dry matter data were estimated for plant and gram per square meter, respectively, and they were submitted to regression analysis.

Additionally, the relative importance of the weed species within the weed community was calculated according to the methodology used by Carvalho et al. (2008a and b).

The beet roots were harvested at 13 WAP, when 90% of the roots in the weed-free treatment showed transversal diameter equal or greater than 5 cm. Roots were harvested in the two center rows of the plots. After harvesting, the roots were counted to estimate the beet stand and were also weighted to determine the crop yield. Then, root yield data were estimated for ton per hectare and subjected to sigmoid regression analysis. The stand and root yield data were converted to square to be also analyzed by F and Tukey tests ($p < 0.05$).

In addition, table beet root yield losses were estimated based on regression equation reached by the sigmoid model. This makes it possible to determine the time frame of the initial period without weed interference and to evaluate the percentage of losses as a function of the initial weedy period.

Results and discussion

The weed community was composed mainly by *Amaranthus viridis* (AMAVI), *Coronopus didymus* (COPDI), *Cyperus rotundus* (CYPRO), *Digitaria nuda* (DIGNU), *Galinsoga parviflora* (GASPA) and *Nicandra physaloides* (NICPH), although other species were observed as well. These species were present in almost all samples, showing high frequency. The main species have also been frequent weeds infesting vegetable crops (ZANATTA et al., 2006), among them *A. viridis*, *C. didymus* and *G. parviflora* had already been reported as important weeds in table beet crop (DEUBER et al., 2004; HORTA et al., 2004). It may be due probably to the most common autumn-winter growing season of these annual broadleaved weeds.

The main species might be identified as ruderal weeds because they showed early emergence, short life cycle, quick and profuse diaspore production and great resources allocation in reproductive structures (RADOSEVICH et al., 2007). For these reasons, ruderal plants are able to colonize quickly the ground and compete efficiently with crops. Horticultural agroecosystems are suitable to ruderal weed growing due to intense soil exploitation, great soil movement, high fertilization rates, low water unavailability and no-uniformity of area occupation (RADOSEVICH et al., 2007). These characteristics allow weeds become greater issue in vegetable crops than field crops, whether not properly managed.

C. didymus was the most relatively important weed in both direct seeded and transplanted table beet crops (Table 1). However, this species was more important in direct seeded than in transplanted crops, showing greater density and dry matter accumulation. *C. didymus* is a small and typical winter plant (KISSMANN; GROTH, 1999), which was not able to grow after July during three-year investigations at 21°18'14"S and 48°26'44"W (Monte Alto – neighboring city of Jaboticabal) (PITELLI, 1985). Therefore, early soil shading provided by transplanted beet (HORTA et al., 2004) may quickly suppress *C. didymus* growth, which is not able to cross beet canopy to be in contact with light, restraining photosynthetic rate. That may be why this species was more important in direct seeded crop.

Table 1. Sums of relative importance (RI), density (De) and dry matter accumulation (DMA) of weed species grown in coexistence with table beet throughout the growing season.

Weed Species	Direct Seeded			Transplanted		
	RI* %	De Plants	DMA grams	RI* %	De plants	DMA grams
COPDI	494.20	3,065.34	958.91	323.85	2,662.65	216.67
NICPH	188.91	434.66	1,486.91	229.34	522.66	2,126.57
AMAVI	106.34	412.01	57.71	148.91	1,106.67	103.21
GASPA	100.79	410.66	105.53	136.10	485.33	492.04
CYPRO	81.36	190.68	13.35	106.67	438.67	24.28
DIGNU	70.71	167.99	14.92	100.33	493.33	31.77
Others	161.23	352.00	200.49	154.80	466.65	83.13

*RI was calculated according to Carvalho et al. (2008a and b).

Two flushes of weed emergence in both direct seeded and transplanted table beet crops occurred around 4-5th and 7-8th WAP, respectively (Figure 1). The main weeds emerged at the first flush and other less important weeds emerged at the second flush, in both planting methods.

No-uniformity in germination flush is a characteristic of pioneer plants, also designed ruderals (RADOSEVICH et al., 2007). Weeds that emerge early in the season are more capable of becoming dominant (RADOSEVICH et al., 2007) and the most effective to colonize and to infest agroecosystems, providing higher interference.

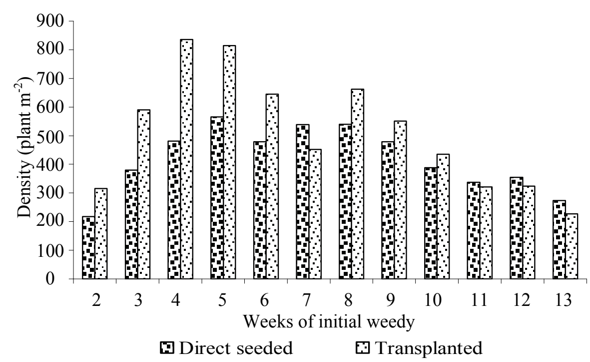

Figure 1. Density of weed community on direct seeded and transplanted table beet crop submitted to increasing week of initial coexistence with the crop.

The weed density was reducing constantly after 9th WAP in both direct seeded and transplanted table beet crops (Figure 1), but the dry matter was greatly accumulated over this period (Figure 2). So, intra- and inter-specific competition was increased when the density and the development of the weed community was augmented; as a result, the tallest and the most developed plants became dominant, suppressing and even killing the smaller and the less developed ones (RADOSEVICH et al., 2007).

Transplanted beet reduced weed dry matter accumulation a little more than direct seeded beet, although weed density was higher. On the other hand, the weed density late in the season was low due to plant competition in both planting methods.

Horta et al. (2004) observed greater suppression of the weed community by transplanted beet in relation to direct seeded one and they affirmed that this behavior might be attributed to faster growth and soil surface shading reached by transplanted crop.

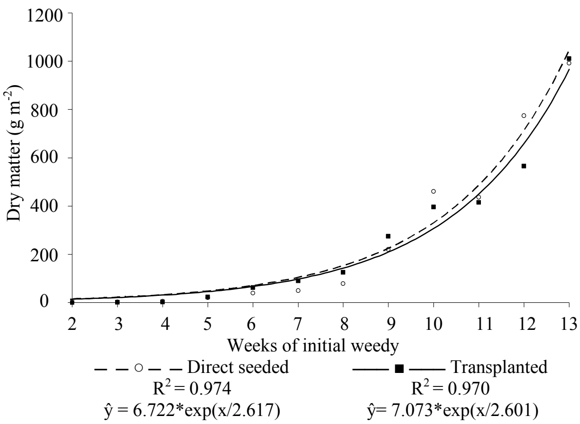

Figure 2. Dry matter accumulation of weed community on direct seeded and transplanted table beet crop submitted to increasing week of initial weedy.

Table beet root yield was greater in transplanted than in direct seeded crop when weeds were hand-weeded throughout the growing season, despite the beet stand had been similar (Table 2). It showed that stand was not the issue, in this case, and transplanted beet was more productive than direct seeded beet. On the other hand, Horta et al. (2004) verified that their yields were significantly similar, as was beet stand. Horta et al. (2001) and Guimarães et al. (2002) observed that transplanting method did not significantly increase beet yield. So, in theory, Filgueira (2005) affirmed that greater beet roots can be produced when beet crop is transplanted, so that it could explain the results of this investigation.

Table 2. Root yield (ton ha^{-1}) and stand (%) of table beet submitted to increasing week of initial weed coexistence with the crop (WIW).

WIW	Yield		Stand	
	DS[1]	TR[2]	DS[1]	TR[2]
0	37.99 b	44.92 a	95.00 a	98.33 a
2	35.80 a	35.82 a(-)	91.67 a	85.00 a
3	32.86 a	35.57 a(-)	88.33 a	85.00 a
4	28.66 b(-)	40.93 a	90.00 a	90.00 a
5	29.50 b(-)	42.04 a	86.67 a	95.00 a
6	26.01 b(-)	36.41 a(-)	88.33 a	86.67 a
7	27.52 b(-)	39.91 a	81.67 a	85.00 a
8	12.36 b(-)	32.02 a(-)	70.00 b(-)	86.67 a
9	11.82 b(-)	19.78 a(-)	70.00 a(-)	78.33 a
10	1.62 b(-)	17.06 a(-)	38.33 b(-)	75.00 a(-)
11	0.82 b(-)	21.14 a(-)	36.67 b(-)	73.33 a(-)
12	1.83 b(-)	13.57 a(-)	38.33 b(-)	66.67 a(-)
13	1.76 b(-)	15.39 a(-)	35.00 b(-)	71.67 a(-)

[1]direct sowing; [2]transplanting; *Means followed by the same letter between columns are not different by Tukey test ($p < 0.05$); Means followed by (-) are different to weed-free treatment (0 WIW) by Tukey test ($p < 0.05$)

The root yield the beet stand were strongly reduced by weeds and a drastic reduction occurred after the 8th WAP (Table 2 and Table 3), mainly in direct seeded table beet. Coincidently, a second flush of weed emergence (Figure 1) and a fast dry mass accumulation (Figure 2) happened around this period. Weed interference becomes high when beet stand is reduced (DAWSON, 1977) to the extent that the success in vegetable crop production and the optimum yields may be accomplished only when maximum stand establishment is achieved (GRASSBAUGH; BENETT, 1998). This is probably the reason why high yield losses were observed when table beet was direct seeded (Table 3).

Table 3. Estimative of root yield (RY) and root yield loss (RYL) of table beet crop submitted to increasing week of weed initial coexistance (WIW), based on regression equations.

WIW	Direct Seeded		Transplanted	
	RY ton ha^{-1}	RYL %	RY ton ha^{-1}	RYL %
0	34.69	0.00	39.46	0.00
2	34.35	0.99	39.46	0.00
3	33.86	2.40	39.46	0.00
4	32.86	5.27	39.46	0.00
5	30.93	10.86	39.46	0.00
6	27.47	20.83	39.41	0.13
7	22.15	36.15	38.75	1.80
8	15.62	54.98	32.23	18.32
9	9.47	72.69	19.67	50.15
10	4.99	85.62	16.97	56.98
11	2.28	93.42	16.76	57.52
12	0.84	97.59	16.75	57.56
13	0.11	99.68	16.75	57.56

Direct seeded table beet was highly susceptible to weed interference, especially when weeds occurred throughout the growing season, reducing crop yield by almost 100% (Table 3). Weed interference reduced beet root yield more than 80% (HEWSON; ROBERTS, 1973; SCHWEIZER, 1981; SCOTT et al., 1979), attaining 100% yield losses (HORTA et al., 2004; KAVALIAUSKAITĖ; BOBINAS, 2006), when direct seeded crop and weeds coexisted until harvesting. On the other hand, transplanted beet yield was less reduced, around 57% (Table 3). However, Horta et al. (2004) observed over 90% of transplanted beet yield reduction. In their investigation, these authors verified high weed infestation and great weed community dry matter accumulation just before 3rd WAP, while it occurred only after 8th WAP in this investigation. Therefore, weeds growing quickly early in the season may suppress crop intensively, restraining plant growing even in transplanted table beet.

Crop-weeds coexistence in transplanted beet was allowed for more prolonged period since planting than in direct seeded crop before weed interference might be established, providing yield reduction (Figure 3), corroborating the results from Horta et al. (2004). Although the weed density had been higher in transplanted than in direct seeded beet (Figure 1) and the weed dry matter accumulation had been almost the same in both (Figure 2), the transplanted crop restrained properly the weed interference. This might be a result of the earlier soil surface shading attained by transplanted crop, providing greater initial period without interference than direct seeded crop (Figure 3).

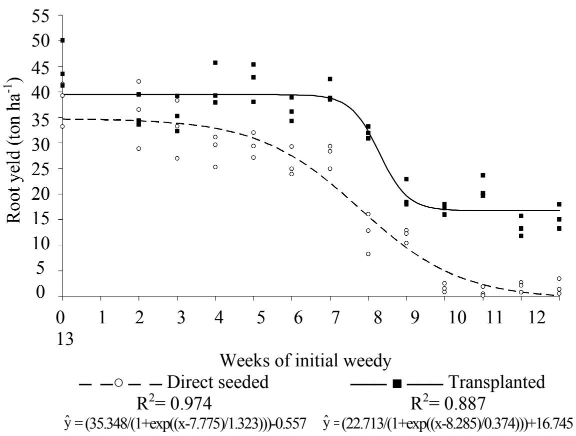

Figure 3. Root yield regression data for direct seeded and transplanted table beet crop submitted to increasing weeks of initial weed coexistence with the crop

In theory, the weed community could be left growing in coexistence with transplanted beet crop up to the 6th WAP without yield reduction, while direct seeded beet crop would not be negatively affected by the weed interference up to the 2nd WAP (Table 3). Horta et al. (2004) observed that the weed community could grow in coexistence with beet plants up to just before 3rd week after seeding and up to just after 4th week after transplanting. This period is driven by environmental and crop management conditions (PITELLI, 1985), in addition to specific weed community composition, weed density and weed distribution.

Accepting around 5% yield loss of table beet roots (KAVALIAUSKAITĖ; BOBINAS, 2006), the initial period without weed interference should be 4th and 7th WAP for direct seeded and transplanted table beets, respectively. The limiting date of this period shows the time that weed interference irreversibly reduces economic crop yield and determines the benchmark for the first weed control. So, the energy and the biomass accumulated by weed communities can return into the soil, contributing to crop development (PITELLI, 1985). Thus, the knowledge of this period may also give support to optimize weed control, decreasing the cost of managing weeds.

Conclusion

Transplanted table beet was more effective in restraining weed interference than the direct seeded one, so that crop-weeds coexistence could remain for longer period after planting without reducing crop yield when crop was transplanted. Thus, direct seeded crop was more susceptible to weed interference than the transplanted one.

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