Bioagro 37(2): 155-166. 2025 doi: http://www.doi.org/10.51372/bioagro372.2

EFFECT OF THE EMERGENCE TIME OF THE WEED *Raphanus raphanistrum* ON BEAN GROWTH IN TWO PLANTING SEASONS

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ABSTRACT

Common bean is seriously affected by weeds interference, which can vary according to the weed's emergence time and the crop's planting season. This study aimed to evaluate the effects of relative times of *Raphanus raphanistrum* emergence on white beans in winter and summer season. An experiment was carried out for each season in 1.2 m x 1.2 m beds using a randomized block design, with *Raphanus raphanistrum* emergence times of 0, 10, 20, 30, 40, and 50 days after bean emergence (DABE) and a control without the weed, in four replications. Height, number of leaflets, chlorophyll content, leaf area and dry matter of stems, leaflets, and fruit were determined in the crop. Also, weight of grains and pods per plant, weight of 100 grains and yield at harvest. Furthermore, dry matter of *Raphanus raphanistrum*'s stems, leaflets, and fruit was determined. The data was subjected to analysis of variance using the F test, and means were compared using Tukey test at 5 % probability level. The lowest values for bean grain weight (152.72 g plant^{-1}) and pod weight (223.67 g plant^{-1}) in winter season were recorded when *Raphanus raphanistrum* emerged at 10 DABE. The summer season showed the lowest bean grain and pod weight values (81.45 and 121.5 g plant^{-1}, respectively) when *Raphanus raphanistrum* emerged simultaneously with the crop. *Raphanus raphanistrum* emergence time altered its interference with beans. Moreover, planting season influenced crop and weed development, thus varying the effects of weed's relative time of emergence on the crop.
Additional keywords: *Phaseolus vulgaris*, weed interference, wild radish

RESUMEN

Efecto del momento de emergencia de la maleza R*aphanus raphanistrum* sobre el crecimiento del frijol en dos épocas de siembra

La interferencia de malezas en frijol blanco puede variar de acuerdo con el momento de emergencia de la maleza y la época de siembra del cultivo. El objetivo de este trabajo fue evaluar el efecto del momento de emergencia relativo de *Raphanus raphanistrum* (rabanillo) sobre frijol blanco, en invierno y verano. Se realizó un experimento para cada época de siembra bajo un diseño de bloques completos al azar, con los siguientes momentos de emergencia del rabanillo: 0, 10, 20, 30, 40 y 50 días después de la emergencia del frijol (DDEF) y un testigo sin rabanillo, con cuatro repeticiones. En el frijol se evaluó la altura, número de hojas, clorofila, área foliar, materia seca, peso de granos y vainas por planta, peso de 100 granos y rendimiento; mientras que en rabanillo se evaluó la materia seca del tallo, hojas y frutos. Los datos fueron sometidos a análisis de varianza con el test F y los promedios fueron comparados con el test de Tukey al 5% de probabilidad. El menor peso de granos (152,72 g planta^{-1}) y vainas (223,67 g planta^{-1}) de frijol en invierno se obtuvieron cuando el rabanillo emergió a los 10 DDEF. En verano, el cultivo tuvo el menor peso de granos y vainas (81,45 y 121,5 g planta^{-1}, respectivamente) cuando el rabanillo emergió a los 10 DDEF. El nivel de interferencia con el frijol dependió del momento de emergencia del rabanillo. La época de siembra influyó en el desarrollo del cultivo y la maleza, variando así el efecto del momento de emergencia del rabanillo sobre el frijol.
Palabras clave adicionales: Interferencia de malezas, *Phaseolus vulgaris*, rabanillo

Associate Editor: Dra. Georgina Vargas-Simón

INTRODUCTION

The common bean is one of the most important crops in the world due to its nutritional value. The beans have high levels of iron, zinc, fiber, and especially protein, making them an ally in the fight against hunger (Tejada *et al*., 2022). Furthermore, when grown by small farmers, beans provide nitrogen to the soil at a low cost, which improves soil fertility for other crops (Muimba,

Received: August 9, 2024 Accepted: February 24, 2025
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2018). In Brazil, white bean (*Phaseolus vulgaris*) belongs to the common bean group, the most expressive group compared to the black common bean and cowpea groups, with a 62 %, 18 %, and 20 % share of the total volume of bean production, respectively (Conab, 2023).

The bean plant adapts to different soil and climate conditions. It can be grown alone, in a consortium, or intercropped in three annual seasons: the water season (harvested from November to April), the dry season (harvested from April to July), and the winter season (harvested from July to October) (Coêlho, 2019). However, since it is subject to varying environmental conditions, it can suffer interference from different weed species.

Bean plants are very sensitive to weed competition, especially in the early stages of vegetative development (Scholten *et al*., 2011). Interference can reduce yield by up to 80 %, depending on the weed community (composition, density, and distribution), the crop itself (species, spacing, and density), and the period of coexistence and the season in which it occurs (Barroso *et al*., 2022).

The weed's emergence time will affect the crop's growth and yield to a greater or lesser extent because it is related to the interference period. Fleck *et al.* (2004) found that the delay in soybean emergence regarding weeds increased their negative effects on the crop. Parreira *et al.* (2007) showed that the closer the emergence of *Bidens pilosa* to the emergence of the 'Carioca' bean cultivar, the greater the negative effects on the crop.

Raphanus raphanistrum is one of the most important species in bean cultivation. It shows a high density, especially in areas of nitrogen top dressing (Oliveira *et al*., 2019). It has a great capacity for competition and a high amount of viable seeds, causing significant reductions in the yields of many crops (Kebaso *et al*., 2020) distributed in temperate and subtropical climate regions. Thus, its habitat is extremely vast (Iyda *et al*., 2019). Parreira *et al.* (2013) stated that the weed community living with the bean plant throughout its cycle caused losses in crop yield from 40.6 to 55.1 %, with *R. raphanistrum* being the most relevant species (it had the highest relative importance values).

Bearing in mind that the emergence time of weeds regarding the crop modifies competition relations, there is a lack of information on weed interference in white beans, and that *Raphanus raphanistrum* is a relevant species in the weed community that coexists with bean plants, studies including these aspects become fundamental in the efficient management of weeds. Therefore, this study aimed to evaluate the influence of the relative times of emergence of *Raphanus raphanistrum* on the growth and yield of white beans sown in winter and summer season.

MATERIALS AND METHODS

Description of the experimental site. The experiment was conducted during the winter season (July to October 2020) and the summer season (January to April 2021) in an area attached to the Weed Laboratory, Universidade Estadual Paulista, São Paulo, Brazil (21°15'17"S, 48°19'20"W and 590 m altitude). According to the Köppen classification, the region's climate is of the Cwa type, subtropical, relatively dry in winter and with summer rains. Table 1 shows the meteorological data for the experimental periods.

The soil was of the Dark Red Latosol type with a clay texture. The pH was 5.5 and 5.3, organic matter was 20 and 19 g dm^{-3}, P was 52 and 75 mg dm^{-3}, K was 2.7 and 2. 9 mmol$_c$ dm^{-3}, Ca was 29 and 39 mmol$_c$ dm^{-3}, Mg was 8 and 9 mmol$_c$ dm^{-3}, and H+Al was 17 and 19 mmol$_c$ dm^{-3}. The former value corresponds to winter season and the latter to summer season.

Experiment conduction. After preparing the soil by mechanically turning it over, the beans were sown manually in plots delimited by 1.2 m x 1.2 m cement borders in two central rows spaced 0.5 m apart, at a density of 12 plants m^{-1}. The cultivar was IPR Garça, of the white commercial group, with a type I erect growth habit, an early cycle, and resistance to anthracnose and common mosaic.

The plants were irrigated whenever visually necessary. All practices to maintain the crop's health were carried out with preventive and corrective applications of insecticides and fungicides. A sowing fertilization of 6 g plot^{-1} of 08-28-16 fertilizer and a top dressing of nitrogen with urea (19 g plot^{-1}) at the stage of the bean plant's third open leaf were carried out in both harvests.

Table 1. Meteorological data during the experiments. Jaboticabal-SP, 2020 and 2021

Months	Maximum temperature (°C)	Minimum temperature (°C)	Average temperature (°C)	Relative Humidity (%)	Rainfall (mm)
	Winter season (2020)				
July	29.6	13.9	21.2	55.7	0.0
August	30.2	13.8	21.3	49.8	3.6
September	34.9	18.0	26.1	42.8	16.3
October	34.5	20.2	26.3	54.5	77.0
Summer season (2021)					
January	31.8	20.7	25.2	73.6	138.8
February	31.4	19.7	24.6	73.4	91.7
March	31.5	19.8	24.8	72.2	65.2
April	30.7	16.2	22.5	65.2	32.3

Experimental design and treatments. The experiment was designed in randomized blocks, with seven treatments in four replications, totaling 28 experimental plots. The treatments comprised six relative times of emergence of *Raphanus raphanistrum* (wild radish): 0, 10, 20, 30, 40, and 50 days after bean emergence (DABE), with a weed-free control. In other words, bean plants emerged on day 0, while wild radish seedlings with two expanded leaflets were transplanted between bean rows at 0, 10, 20, 30, 40 and 50 DABE. Wild radish density was equivalent to 9 plants m^{-2}, with three plants in each crop row spaced about 25 cm from the bean plants.

Evaluated characteristics. At 49 days after emergence of bean plants, when they began senescence, the following variables were assessed: height, number of leaflets, relative total chlorophyll content using a ChlorofiLog-Falker equipment, leaf area with a LI 3000A-LiCor meter, and dry matter of stems, leaflets, and fruit.

At harvest time (67 days after emergence), the weight of 100 grains of the beans and yield per plant (weight of grains and pods). Furthermore, the dry matter of stems, leaflets, and fruit was determined for wild radish. The dry weight of the bean and wild radish was obtained after drying in a forced-air circulation oven at 70 °C for 96 hours and then weighed using a 0.01 g precision scale.

Statistical analysis. After confirming the normal distribution of errors using the Shapiro-Wilk test, the data collected during the experimental period was submitted for analysis of variance using the F test. The means were compared using the Tukey test at 5 % probability level according to the time of emergence using the AgroEstat software version 1.1.0 (Barbosa and Maldonado, 2015).

RESULTS AND DISCUSSION

Winter season. There was no difference between the treatments in height, number of leaflets, leaf area, and relative total chlorophyll content of the bean plant. There was an average 35.5 % reduction in bean stem dry matter when wild radish emerged at 20 and 40 DABE compared to the weed-free crop (control) (Table 2). When the wild radish emerged along with the crop (0 DABE), the bean plant had 2.12 g of plant $leaflets^{-1}$, the lowest value of the treatments. Regarding fruit dry matter, the 0 DABE treatment were 48.4 % lower compared to the control (Table 2). The greatest negative effect of wild radish on the bean was on the dry matter of the crop's leaflets when both plants emerged at the same time. In other words, the longer time the bean plant spent with the weed affected the crop's photosynthetic activity and, as a result, decreased its dry weight. These findings agree with Rashidi *et al*. (2021). They found that competition between common bean and *Digitaria sanguinalis* reduced the crop's photosynthesis and consequently decreased its ability to produce biomass.

Regarding the effect of the relative time of wild radish emergence on the weight of 100 grains of the bean plant, there were no significant differences between the treatments. The lowest values for bean grain weight (179.65 and 152.72 g plant^{-1}) and pod weight plant^{-1} (257.95 and 223.67 g plant^{-1}) were recorded when the wild radish emerged next to or close to the emergence of the beans. The first value corresponds to 0 DABE, and the second to 10 DABE (Table 3). This result occurred because the 0 DABE and 10 DABE treatments corresponded to the longest periods of coexistence between beans and wild radish. Thus, the detriment to yield per bean plant was more significant. Barroso *et al*. (2010) showed that the grain weight of the common bean living with wild radish throughout the cycle in the winter season was 12 % lower than the control (weed-fee crop), a result similar to ours (16.2 %).

Table 2. Effect of wild radish emergence time in DABE (days after bean emergence) on height, number of leaflets, leaf area, relative chlorophyll content, and dry matter of the white bean's stem, leaflets, and fruit in winter season. Jaboticabal-SP, 2020

DABE	Height (cm)	Number of leaflets	Leaf area (cm^2)	Chlorophyll (RU)	Dry matter		
					Stem	Leaflets (g plant^{-1})	Fruit
Control	45.2	29.7	1271.6	48.2	3.72 a	2.67 b	6.82 a
0	45.5	30.7	928.37	48.9	3.22 a	2.12 c	3.52 b
10	41.7	36.0	1321.8	48.8	4.20 a	4.55 a	3.42 b
20	45.5	28.0	1127.8	48.8	2.60 b	3.37 a	5.77 a
30	44.7	43.5	1395.1	47.5	3.82 a	3.75 a	7.35 a
40	44.7	33.0	1174.7	49.2	2.20 b	3.42 a	6.90 a
F	0.45^{ns}	1.42^{ns}	0.39^{ns}	0.25^{ns}	9.98**	6.67**	50.8**
CV (%)	6.41	8.78	13.7	4.12	19.5	13.2	3.85

Means followed by the same letter do not differ by the Tukey test at 5 % probability. *and **: significant at 5 % and 1 % probability by the F test, respectively. ^{ns}: not significant. CV: Coefficient of Variation. RU: Relative units

Table 3. Effect of wild radish emergence time in DABE (days after bean emergence) on the weight of 100 grains, weight of grains and pods per bean plant, and dry matter of stem, leaflets, and fruits of wild radish in winter season. Jaboticabal-SP, 2020

DABE	Bean weight			Wild radish dry matter		
	100 grains (g)	Grains (g plant^{-1})	Pods	Stem	Leaflets (g plant^{-1})	Fruit
Control	35.9	214.32 a	303.52 a	----	----	----
0	36.5	179.65 b	257.95 c	47.37 a	4.97 c	96.63 a
10	35.4	152.72 c	223.67 d	42.21 a	13.14 a	24.30 b
20	33.6	225.65 a	319.04 a	3.47 b	5.50 c	3.79 c
30	34.0	244.69 a	348.25 a	2.23 b	8.56 b	0.71 d
40	36.4	189.38 b	270.24 b	1.40 c	4.18 c	0.20 e
50	35.0	228.22 a	316.06 a	0.46 d	1.13 d	0.04 f
F	1.22^{ns}	9.23**	12.66**	257.14**	171.84**	420.37**
CV (%)	1.61	2.40	5.86	15.8	7.30	26.8

Means followed by the same letter do not differ by the Tukey test at 5 % probability. *and **: significant at 5 % and 1 % probability by the F test, respectively. ^{ns}: not significant. CV: Coefficient of Variation.

The highest stem dry matter values for wild radish were recorded in the 0 and 10 DABE periods, which were 95 % higher on average than in the 20, 30, 40, and 50 DABE treatments. The lowest leaf dry matter for wild radish (1.13 g plant^{-1}) occurred when the weed emerged at 50

DABE (Table 3). The great photosynthetic and extractive capacity of the wild radish, reflected in the greater dry matter of the stems and fruits in the periods of greater coexistence with the crop (0 and 10 DABE), was responsible for the decrease in grain weight and pod weight plant^{-1} of the bean plant. Kebaso *et al*. (2020) indicated that established *R. raphanistrum* plants substantially deplete soil moisture and nutrients.

Regarding the dry weight of wild radish fruit, the treatments that stood out were 0 and 50 DABE, with the highest (93.63 g plant^{-1}) and lowest values (0.04 g plant^{-1}), respectively (Table 3). The biggest interference from the wild radish occurred when it emerged next to or close to the bean's emergence because of its high production of dry matter in the stems and, above all, in the fruit. Therefore, the species has produced many fruits (siliquas) and seeds, which explains its exceptional ability to infest crops. Pereira *et al.* (2018) stated that wild radish has a great capacity to produce viable seeds and pods that can contaminate the harvested grains.

When the wild radish emergence time was close to crop emergence (0 and 10 DABE), bean yields decreased. The 10 DABE treatment yielded an average of 30 % less than the control treatment and 20, 30, and 50 DABE treatments (Figure 1). The loss in bean yield when the wild radish emerged close to or at the same time as the bean emergence occurred due to the detriment of the weight of grains and pods per plant caused by the intense competition with the wild radish, even at a low density (9 plants of *R. raphanistrum* m^{-2}). Low populations of this species have been documented to cause yield losses in winter crops (Pereira *et al*., 2018) and soybeans (Galon *et al*., 2017), which aligns with our results.

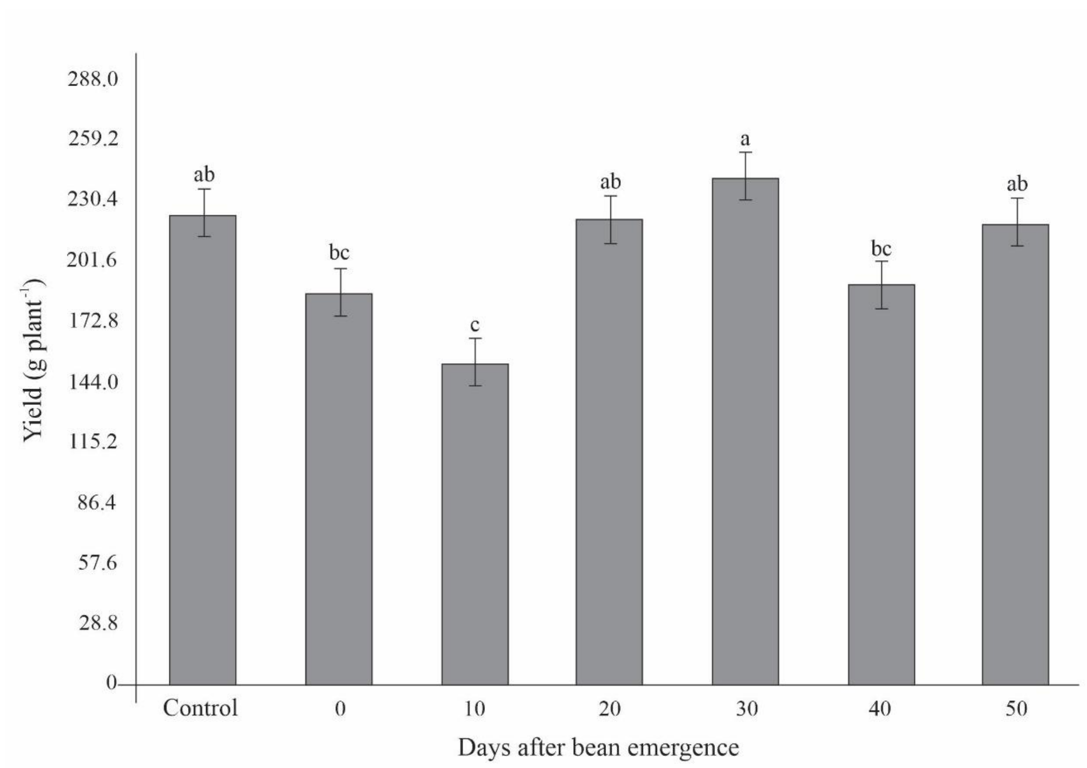

Figure 1. White bean yield in the winter season as a function of the relative time of emergence of *Raphanus raphanistrum* (expressed in days after bean emergence). Jaboticabal, 2020

Summer season. There were no differences between the treatments regarding the height, number of leaflets, and relative total chlorophyll content of the bean plant. For leaf area, the 10 DABE treatment (45.7 % higher) and the 30 DABE treatment (68.6 % lower) differed from the control (Table 4). The crop's greatest leaf area and height occurred when the wild radish emerged at 10 DABE compared to the leaf area and height of the weed-free bean plant. It is due to the SAS (shade avoidance syndrome) phenomenon, which comprises photomorphogenic changes in plants, such as an increase in leaf area and stem elongation, to improve the absorption of solar energy in response to an environment with neighboring plants that cause shading (Gong *et al*., 2015; Hijano *et al*., 2021). Regarding stem dry matter in the white bean, the 30 DABE treatment was around 53 % lower than the control. Regarding leaf dry matter, the 10 and 20 DABE treatments were 61 % and 40 % higher than the control, respectively (Table 4). Wild radish emergence times of 0 and 10 DABE reduced the dry weight of the crop's fruit by 66.3% and 68%, respectively, compared to the control without wild radish (Table 4).

Table 4. Effect of wild radish emergence time in DABE (days after bean emergence) on height, number of leaflets, leaf area, relative chlorophyll content, and dry matter of the white bean's stem, leaflets, and fruit in summer season. Jaboticabal-SP, 2021

DABE	Height (cm)	Number of leaflets	Leaf area (cm^2)	Chlorophyll (RU)	Dry matter		
					Stem	Leaflets	Fruit
					($g \cdot plant^{-1}$)		
Control	48.0	33.0	772.68 b	32.76	2.97 c	1.92 c	6.50 a
0	49.7	28.5	605.12 c	29.29	4.08 b	1.82 c	2.19 c
10	51.0	46.7	1424.8 a	31.65	7.41 a	4.93 a	2.08 c
20	49.5	31.2	819.71 b	31.65	4.96 b	3.20 b	4.58 b
30	44.0	24.5	447.20 d	34.74	1.40 d	1.46 d	4.41 b
40	48.5	28.2	806.21 b	30.92	3.68 b	2.17 c	5.19 b
F	1.13^{ns}	1.44^{ns}	39.2**	0.75^{ns}	42.6**	54.7**	66.8**
CV (%)	2.09	5.02	1.26	3.30	13.70	18.49	7.63

Means followed by the same letter do not differ by the Tukey test at 5 % probability. *and **: significant at 5 % and 1 % probability by the F test, respectively. ^{ns}: not significant. CV: Coefficient of Variation. RU: Relative Units. Data transformation for number of leaflets according to the formula of Box-Cox

The wild radish emergence times did not cause different results in the weight of 100 grains of beans (Table 5). The wild radish emergence time that coincided with crop emergence (0 DABE) affected the weight of grains and pods plant^{-1} of the beans, with the lowest values (81.45 and 121.5 g plant^{-1}, respectively) compared to the other treatments (Table 5). The wild radish damaged the yield per bean plant more when it emerged at the same time as the crop than at the other relative times of emergence of *R. raphanistrum*. Bressanin *et al*. (2013) also noted that the lowest average weight of pods plant^{-1} of the common bean was recorded when *Raphanus raphanistrum* emerged simultaneously with the crop (0 DABE) compared to when the wild radish emerged at 14 DABE.

The wild radish's highest leaf and fruit dry matter values (146.68 and 148 g plant^{-1}, respectively) were also recorded in the 0 DABE treatment (Table 5). On the other hand, the 40 DABE treatment provided the highest value (36 g plant^{-1}) of wild radish stem dry matter compared to the other treatments (Table 5). The conditions of the summer harvest were unfavorable to the cultivar IPR Garça because, due to its Andean origin, it develops better in moderate temperatures during the winter season in Brasil (Kajiwara *et al*., 2022; Silva *et al*., 2024). In this way, the wild radish took the opportunity to develop significantly and accumulate a greater amount of dry matter compared to the bean when both species emerged simultaneously. The wild radish's exceptional dry weight production has already been commented on by Scholten *et al*. (2011). They found that the wild radish's dry weight represented 95 % of the whole dry weight of the weed community at 80 days after emergence of the bean plant in periods of coexistence with weeds. Furthermore, Oliveira *et al*. (2019) found that the weeds that showed the highest dry weight values in periods of coexistence with bean plants were *Digitaria* spp., *Eleusine indica*, *Acanthospermum hispidum*, and *Raphanus raphanistrum*.

Table 5. Effect of wild radish emergence time in DABE (days after bean emergence) on the weight of 100 grains, weight of grains and pods per bean plant, and dry matter of stem, leaflets, and fruits of wild radish in summer season. Jaboticabal-SP, 2021

DABE	Bean weight			Wild radish dry matter		
	100 grains (g)	Grains ($g \cdot plant^{-1}$)	Pods	Stem ($g \cdot plant^{-1}$)	Leaflets	Fruit
Control	33.2	99.38 a	145.5 a	-----	-----	-----
0	33.8	81.45 b	121.5 b	6.0 d	146.68 a	148.0 a
10	33.9	160.77 a	230.0 a	10.67 c	84.0 a	94.5 a
20	35.6	164.56 a	232.5 a	28.0 a	124.0 a	120.5 a
30	35.9	143.18 a	207.5 a	26.21 a	26.67 b	81.3 a
40	33.5	137.52 a	197.0 a	36.0 a	16.67 b	34.5 b
50	35.4	118.17 a	171.0 a	19.32 b	2.00 c	6.5 c
F	1.56^{ns}	3.53*	3.63*	13.26**	137.71**	31.66**
CV (%)	9.2	12.64	11.33	17.0	7.67	13.9

Means followed by the same letter do not differ by the Tukey test at 5 % probability. *and **: significant at 5 % and 1 % probability by the F test, respectively. ^{ns}: not significant. CV: Coefficient of Variation

Regarding white bean yield, the treatments did not differ, except for the 0 DABE, which had the lowest yield compared to the other treatments. The 20 and 40 DABE treatments had an average yield 40 % higher than the 0 DABE treatment (Figure 2). The bean yields when the wild radish emerged at 50 DABE and the weed-free control were similar (Figure 2). Therefore, if the wild radish's emergence is spaced further apart from the bean's emergence, the weed's interference may be reduced, and consequently, there would be less detriment to the crop's yield. Yield is affected, among other factors, by the relative time of emergence of the weeds and the crop, with the most competitive weeds being those that emerge together with the crop or shortly afterward (Preston, 2014).

This information is relevant and applicable to the integrated management of wild radish since it is possible, through pre-emergent herbicides, to delay the emergence of the weed to keep the crop as long as possible without or with low competition with the weed community.

When comparing the two planting seasons, we can see that bean crop had a higher yield in the winter season (Figure 1) than in the summer season (Figure 2). The higher temperatures recorded in the summer season did not favor the crop since the plant has a C3 metabolism. Thus, when beans grown under high-temperature conditions, the photosynthetic rate is lower, mainly due to increased respiration and photorespiration (Karavidas *et al.*, 2022). However, according to Tejada *et al*. (2023), it may depend on the cultivar as those authors found that the common bean cultivar TAA Dama produced around 3000 kg ha^{-1} in the summer season and 1700 kg ha^{-1} in the winter season, which is explained by the cultivar's tolerance to high temperatures.

The winter season conditions favored the bean more than the wild radish, and the summer season favored the wild radish more than the crop, which can be seen by observing the weed's lower fruit dry matter in the winter season compared to the summer season (Table 6). This statement is confirmed by observing the percentages of variation in the dry weight of fruits (beans and wild radish) between the two planting seasons, noting that the dry weight of bean fruits decreased by different percentages in the summer season compared to the winter season, regardless of the treatments. On the other hand, the dry weight of wild radish fruits increased by significant percentages in the summer season compared to the winter season. (Table 6).

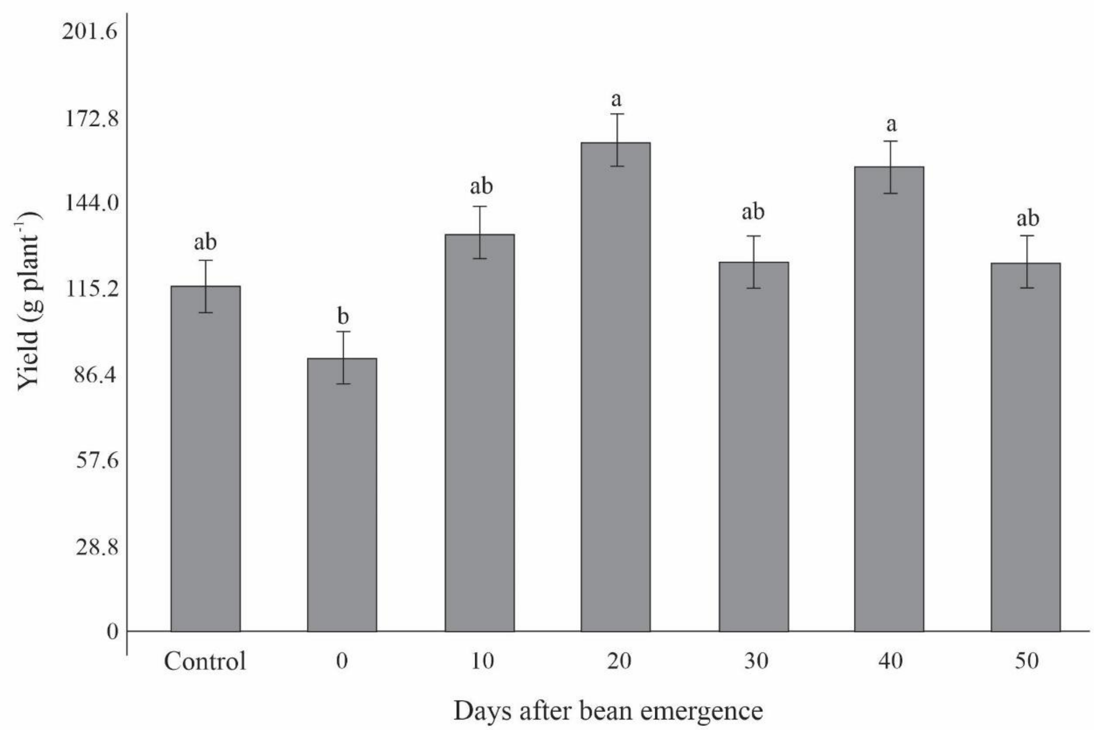

Figure 2. White bean yield in the summer season as a function of the relative time of emergence of *Raphanus raphanistrum* (expressed in days after bean emergence). Jaboticabal, 2021

Table 6. Percentage variation in dry matter of bean and wild radish fruits in two planting seasons, according to wild radish emergence time in DABE (days after bean emergence)

DABE	Bean fruit dry matter (g·plant^{-1})		Variation (%)	Wild radish fruit dry matter (g·plant^{-1})		Variation (%)
	Winter season	Summer season		Winter season	Summer season	
Control	6.82	6.50	-4.7	----	-----	-----
0	3.52	2.19	-37.8	96.63	148	53.2
10	3.42	2.08	-39.2	24.3	94.5	288.9
20	5.77	4.58	-20.6	3.79	120.5	3079.4
30	7.35	4.41	-40.0	0.71	81.3	11350.7
40	6.90	5.19	-24.8	0.2	34.5	17150.0
50	----	----	----	0.04	6.5	16150.0

Summer weather conditions had a positive influence on dry matter production of wild radish fruits, although not necessarily temperature, since according to Norsworthy *et al*. (2010) the optimum temperatures for the production of wild radish siliquas (fruits) are around 19 °C on average. Therefore, the factor that favored siliqua production was rainfall, which was higher in summer compared to winter (Table 1). In this respect, Eslami *et al*. (2010) verified that the number of seeds per wild radish plant increased by

402 % when water supply was not limiting, compared to when there was water deficit.

The planting season also influences the crop and the interference from the weed community, which could strengthen the cultivated plant, making it more competitive with the weeds. This was verified in the present study, noting that the winter season favored beans more than wild radish when the weed emerged 20 days after the beans, which was reflected in greater dry weight of the crop's fruits (5.77 g·plant^{-1}) compared to the dry weight of the weed's fruits (3.79 g·plant^{-1}) (Table 6). Kebaso *et al*. (2020) specified that changing the planting season and using competitive cultivars, among other methods, can minimize competition from *R. raphanistrum*.

Considering the wild radish emergence times that least affected the crop's yield, the best time in the winter season was 30 DABE (Figure 1). Meanwhile, in the summer season, it was 20 and 40 DABE (Figure 2). In the latter case, in practice, it would be advisable to delay wild radish emergence to 40 DABE because of the weed's better development in the summer season. In other words, under more favorable conditions for the weed, the time of emergence should be delayed as long as possible so that the crop can remain without competition for longer. According to Baker *et al*. (2021), the 2017/18 season was unfavorable to the crop compared to 2018/19 regarding the number of grains per pod of the common bean. Thus, the crop had more time with weed control in the unfavorable season to reach the maximum value of grains per pod.

Regardless of the planting season, the emergence of *Raphanus raphanistrum* close to or at the time of the emergence of white beans affected some of the crop's characteristics, which was reflected in the detriment of bean yield. Uljol *et al*. (2018) explained that the plants with the greatest development in a weed community germinate and emerge at the beginning of the crop cycle. Therefore, they are responsible for the most intraspecific and interspecific competition. In this sense, weeds with greater vegetative development (such as wild radish) become dominant, and those with lower development (such as bean plants) are suppressed or die. Aguyoh and Masiunas (2003) found that when beans emerged together with *Digitaria sanguinalis*, the crop had a 24.5 % reduction in leaf area compared to the weed-free control.

CONCLUSIONS

When wild radish emerged 10 days after bean emergence in the winter season and 0 days after bean emergence in the summer season and lived with the crop until harvest, there was a reduction in the accumulation of dry weight in the crop's aerial part. As a consequence, there was a reduction in the white bean's yield. In this situation, the wild radish accumulated more dry weight in the aerial part.

The results effectively show that the time of emergence of *R. raphanistrum* regarding white beans alters weed interference, which is reflected in some crop characteristics. Furthermore, the planting season influences the development of both the crop and the weed, which can vary the effects of the weed's relative time of emergence.

ACKNOWLEDGEMENTS

To the Weed Plant Laboratory of the Universidade Estadual Paulista "Júlio de Mesquita Filho" for providing the opportunity to carry out this study, to the Agronomic Institute of Paraná for their partnership in this investigation, and to the São Paulo State Research Support Foundation (FAPESP) for financial support in accomplishing this project (Proc. nº 2020/04580-5).

LITERATURE CITED

1. Aguyoh, J.N. and J.B. Masiunas. 2003. Interference of large crabgrass (*Digitaria sanguinalis*) with snap beans. Weed Science 51(2): 171-176.
2. Baker, C., A.T. Modi and A.D. Nciizah. 2021. Weeding frequency effects on growth and yield of dry bean intercropped with sweet sorghum and cowpea under a dryland area. Sustainability (Switzerland) 13(21).
3. Barbosa, J.C. and W. Maldonado Júnior. 2015. AgroEstat-Sistema para análises estatísticas de ensaios agronômicos. FCAV/UNESP. Jaboticabal, São Paulo.
4. Barroso, A.A.M., J.L. Tejada, L. Lemos, M.C. Parreira, P.M.J. Oliveira and P.L.C.A.

Alves. 2022. Biologia e Manejo de Plantas Daninhas na Cultura do Feijão-Comum (Série Técnica do LAPDA). Funep. Jaboticabal, São Paulo.

5. Barroso, A.A.M., M.S. Yamauti and P.L.C.A Alves. 2010. Interferência entre espécies de planta daninha e duas cultivares de feijoeiro em duas épocas de semeadura. Bragantia 69(3): 609-616.
6. Bressanin, F.N., P.R.F Giancotti, M.C. Parreira and P.L.C.A. Alves. 2013. Influence of *Raphanus raphanistrum* L. Density and Relative Time of Emergence on Bean Crop. Journal of Agricultural Science 5(10).
7. Coêlho, J.D. 2019. Produção de Grãos-Feijão, Milho e Soja. Etene. Fortaleza, Ceará.
8. Conab-Companhia Nacional de Abastecimento. 2023. Acompanhamento da safra brasileira de grãos, safra 2022/23. Conab. Brasília, Distrito Federal.
9. Eslami, S.V., G.S. Gill and G. McDonald. 2010. Effect of water stress during seed development on morphometric characteristics and dormancy of wild radish (*Raphanus raphanistrum* L.) seeds. International Journal of Plant Production 4(3): 159-168.
10. Fleck, N.G., M.A. Rizzardi, D. Agostinetto and A.A. Balbinot Junior. 2004. Interferência de picão-preto e guanxuma com a soja: efeitos da densidade de plantas e época relativa de emergência. Ciência Rural 34(1): 41-48.
11. Galon, L., R. Trevisol, C.T. Forte, S.P. Tironi, F.W. Reichert Júnior and A.L. Radunz. 2017. Competitive ability of bean cultivars with hairy beggarticks. Revista Caatinga 30(4): 855-865.
12. Gong, W.Z., C.D. Jiang, Y.S. Wu, H.H. Chen, W.Y. Liu and W.Y. Yang. 2015. Tolerance vs. avoidance: two strategies of soybean (*Glycine max*) seedlings in response to shade in intercropping. Photosynthetica 53(2): 259-268.
13. Hijano, N., I. Orzari, W.L. Colombo, M.P. Nepomuceno and P.L.C.A. Alves. 2021. Interferência: conhecer para usá-la a nosso favor. In: Barroso, A.A.M. and A.T. Murata (eds.). Matologia: Estudos Sobre Plantas Daninhas. Fábrica da Palavra. Jaboticabal, São Paulo. pp. 106-144.
14. Iyda, J.H., Â. Fernandes, F.D. Ferreira, M.J. Alves, T.C.S.P Pires, L. Barros *et al*. 2019. Chemical composition and bioactive properties of the wild edible plant *Raphanus raphanistrum* L. Food Research International 121: 714-722.
15. Kajiwara, V., V. Moda-Cirino and M. B. S. Scholz. 2022. Studies on nutritional and functional properties of various genotypes of Andean beans. Journal of Food Science and Technology 59(4): 1468-1477.
16. Karavidas, I., G. Ntatsi, V. Vougeleka, A. Karkanis, T. Ntanasi, C. Saitanis *et al*. 2022. Agronomic Practices to Increase the Yield and Quality of Common Bean (*Phaseolus vulgaris* L.): A Systematic Review. Agronomy 12(2).
17. Kebaso, L., D. Frimpong, N. Iqbal, A.A. Bajwa, H. Namubiru, H.H. Ali *et al*. 2020. Biology, ecology and management of *Raphanus raphanistrum* L.: a noxious agricultural and environmental weed. Environmental Science and Pollution Research 27(15): 17692-17705.
18. Muimba-Kankolongo, A. 2018. Leguminous Crops. In: Muimba-Kankolongo, A. (ed.). Food Crop Production by Smallholder Farmers in Southern Africa. Academic Press. London, United Kingdom. pp. 173-203.
19. Norsworthy, J. K., M.S. Malik, M.B. Riley and W. Bridges Jr. 2010. Time of Emergence Affects Survival and Development of Wild Radish (*Raphanus raphanistrum*) in South Carolina. Weed Science 58(4): 402-407.
20. Oliveira, S.C., L.R.S. Peres, N. Hijano and P.L.C.A. Alves. 2019. Period of Weed Interference in Bean With Nitrogen Fertilizer. Journal of Agricultural Science 11(5): 381-387.
21. Parreira, M.C., L.A. Peñaherrera-Colina, P.L.C.A. Alves and F.C.M. Pereira. 2013. Interferencia de malezas en el cultivo de frijol en dos sistemas de labranzas. Planta Daninha 31(2): 319-327.
22. Parreira, M.C., P.L.C.A. Alves and M.D.C.M.D. Pavani. 2007. Efeitos da época relativa de emergência de picão-preto (*Biden pilosa* L.) com a cultura do feijão (*Phaseolus

vulgaris L.). Revista de Agricultura 82(2): 197-203.

23. Pereira, M.R.R., C.C. Martins, A.C. Silva and D. Martins. 2018. Water Stress in the Production and Quality of *Bidens pilosa* and *Raphanus raphanistrum* Seeds. Planta Daninha 36.
24. Preston, C. 2014. Plant Biotic Stress: Weeds. In: Van Alfen, N. (ed.). Encyclopedia of Agriculture and Food Systems. Academic Press. London, United Kingdom. pp. 343-348.
25. Rashidi, S., A.R. Yousefi, M. Pouryousef and N. Goicoechea. 2021. Mycorrhizal impact on competitive relationships and yield parameters in *Phaseolus vulgaris* L.-weed mixtures. Mycorrhiza 31(5): 599-612.
26. Scholten, R., M.C. Parreira and P.L.C.A. Alves. 2011. Período anterior à interferência das plantas daninhas para a cultivar de feijoeiro 'Rubi' em função do espaçamento e da densidade de semeadura. Acta Scientiarum Agronomy 33(2): 313-320.
27. Silva, R.F., A.J. Carvalho, M.B.O. Silva, T.L.P.O. Souza, I. Aspiazú, J.A.E. Barbosa *et al*. 2024. Desempenho de linhagens de feijão-comum de "grãos especiais" no Norte de Minas Gerais. Revista Caderno Pedagógico 21(13): 1-24.
28. Tejada, J.L., L.B. Lemos and P.L.C.A. Alves. 2022. Does a high sowing density of common bean change the weed interference periods? Revista Brasileira de Ciências Agrárias 17(4).
29. Tejada, J.L., L.B. Lemos, E. Silva and P.L.C.A Alves. 2023. Planting season alters the interference of weeds in the common bean. Australian Journal of Crop Science 17(12): 902-909.
30. Uljol, L.H.O., S. Bianco, A.B.C. Filho, M.S. Bianco and L.B. Carvalho. 2018. Weed Interference on Productivity of Bell Pepper Crops. Planta Daninha 36: e018169642.