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Weed interference periods in common bean sown in two densities under arid conditions[1]

Jorge Luis Tejada[2], Carlos Zacarias Joaquim Júnior[3]*, Inácio João Barbosa[4], Leandro Borges Lemos[5], Pedro Luís da Costa Aguiar Alves[6]

ABSTRACT - The degree of interference varies with cultural practices, and there is a lack of information regarding the weed interference periods in common beans under arid conditions. Thus, this study carried out an experiment with 12 (TPM) and another with eight plants m^{-1} (EPM) to compare the weed interference periods in two sowing densities and characterize the weed community. The experimental design comprised randomized blocks with four replications for the increasing periods of control and coexistence: 0 - 15, 0 - 30, 0 - 45, 0 - 60, 0 - 75, and 0 - 90 days after emergence (DAE). Weeds were analyzed using the phytosociological method, and their dry mass was correlated with productivity. The period before interference (PBI), the critical period for weed control (CPWC), and the total period of interference prevention (TPIP) were determined using a nonlinear regression analysis of productivity. *Nicandra physaloides* (L.) Gaertn., *Setaria verticillate* (L.) P. Beauv. and *Sorghum halepense* (L.) Pers. were the most relevant species. The TPIP and CPWC were 13 and 17 days shorter, respectively, at TPM. The PBI had four more days in TPM than in EPM. The EPM and TPM yields were 137.6 and 800 kg ha^{-1}, respectively, when weed dry mass was maximum. This last fact, combined with the increase in PBI and decrease in CPWC in TPM, meant that the crop sown at the highest density had a greater competitive advantage over weed community.

Keywords: *Phaseolus vulgaris.* Arid conditions. Weed phytosociology.

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*Author for correspondence
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[1]This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001
[2]Department of Plant Sciences, College of Agronomy, La Molina National Agrarian University (UNALM), La Molina, Lima, Peru, jorgetejada@lamolina.edu.pe (ORCID ID 0000-0002-2102-1578)
[3]Center for Agro-Veterinary Sciences, College of Agronomy, Santa Catarina State University (CAV/UDESC), 88520-000, Lages-SC, Brazil, cjoaquim188@gmail.com (ORCID ID 0000-0001-8681-9946)
[4]Faculty of Agronomy, Federal University of Rio Grande do Sul (FA/UFRGS), 90040-060, Porto Alegre- RS, Brazil, inacio.barbosa@unesp.br (ORCID ID 0000-0002-2192-7441)
[5]Department of Crop Production, Center of Agricultural and Veterinary Sciences, São Paulo State University "Júlio de Mesquita Filho" (FCAV/UNESP), 14884-900, Jaboticabal-SP, Brazil, leandro.lemos@unesp.br (ORCID ID 0000-0003-1781-1267)
[6]Department of Biology, Center of Agricultural and Veterinary Sciences, São Paulo State University "Júlio de Mesquita Filho" (FCAV/UNESP), 14884-900, Jaboticabal-SP, Brazil, pl.alves@unesp.br (ORCID ID: 0000-0003-2348-2121)

INTRODUCTION

The common bean is appreciated for providing most of the protein in the diet, enriching soils, capturing carbon from the atmosphere, and being a source of employment, especially in family farming (FAO, 2018). In Peru, it is the most widely planted and consumed legume (Valladolid, 2016), mainly by small producers. Furthermore, northern Peru is one of the primary centers of genetic diversity (FAO, 2018), with 30 commercial classes and 74 cultivars planted in the coastal, mountain, and forest macro-regions. Thus, it is the only legume with this versatility in the Andean country (Valladolid, 2016). However, despite this diversity, the crop is subject to interference from weeds, which can quantitatively and qualitatively reduce its production, which justifies the need for weed management.

Weed management in arid conditions is a challenge for bean production given the crop's low competitive ability and the abundance of water-efficient species in this environment, such as *Sorghum halepense* (L.) Pers., *Nicandra physaloides* (L.) Gaertn. and *Setaria verticillate* (L.) P.Beauv. The former is the most important due to its high seed production, ability to resprout from rhizome fragments, resistance to herbicides (Squires; Walsh, 2021), and ability to survive under dry conditions (Peerzada *et al*., 2017).

Weed interference with the common bean includes competition for environmental resources and allelopathy, leading to production losses ranging from 12 to 80% (Karavidas *et al*., 2022; Mielle *et al*., 2019; Oliveira *et al*., 2019). Interference periods are intervals in the crop in which weeds may or may not interfere. According to Pitelli and Durigan (1984) there are three types: period before interference or PBI (period of coexistence with weeds that does not result in significant yield losses), total period of interference prevention or TPIP (total length of time in which weeds must be removed), and critical period for weed control or CPWC (time interval of the TPIP in which weed control is mandatory).

Cultural treatments such as sowing density alter weed interference and can benefit the crop. Parreira *et al*. (2012) found a 4-day increase in the PBI of weeds in bean plants sown at 15 plants m^{-1} when compared to the PBI in 10 plants m^{-1}. Their results show that the higher density increased the crop's tolerance to weeds and suppressed some species. Iqbal *et al*. (2022) stated that high sowing density can be an environmentally harmless, cost-effective, and water-efficient weed management strategy.

Given the crop's importance and the need for technical information on the weed interference periods in common beans under arid conditions, studies of this sort can improve the weed community's management, making the crop's production more efficient. Therefore, this study aimed to compare the weed interference periods under two bean sowing densities, characterize the weed community, and evaluate the effect of weed dry mass on crop productivity under arid conditions.

MATERIAL AND METHODS

The experiments were set up in a field at the Universidad Nacional Agraria La Molina (UNALM), in the district of La Molina (12°05'06" S, 76°57'06" W, and 251 m altitude), in the province and region of Lima, Peru. According to the Köppen climate classification, the local climate is typified as BWh, which is typical of arid regions with a rainfall deficiency in all seasons (Arnfield, 2020). Climatic conditions showed a lack of rainfall during the experiments (Figure 1).

The soil is of the Torrifluvent type, common in arid, sandy areas with high pH values (Soil Survey Staff, 2015). The soil has 230, 260, and 510 g kg^{-1} of clay, silt, and total sand, respectively. Table 1 shows its chemical characterization.

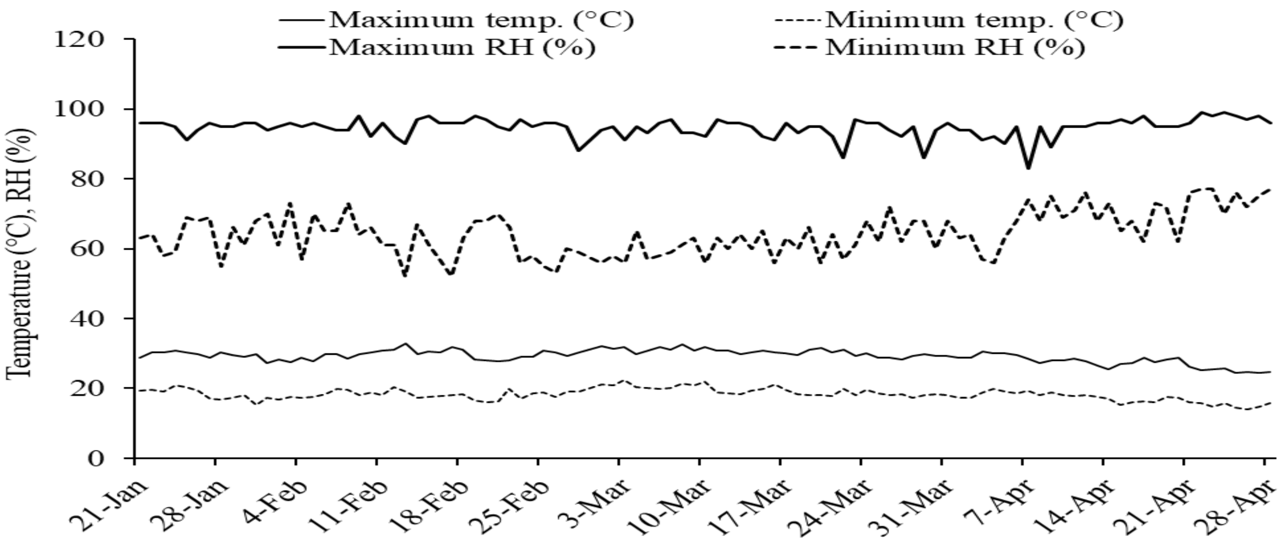
Soil preparation was conventional. It included a disk plow, a disk harrow, and a 3-point furrower. The Canario 2000-INIAA cultivar (Type I determinate growth habit) was sown by hand on January 21, 2021. The field was divided into two experiments with different densities (8 and 12 plants m^{-1}) and 0.8 m row spacing. Before sowing, the seeds were treated with fungicides, and then, preventative and curative applications of pesticides were made to control pests and diseases.

The crop's nutritional demand was 60, 80, and 20 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. It was estimated based on soil analysis and the nutrients that the crop extracts. The first fertilization occurred when the primary leaves developed. It included applying 207 kg ha^{-1} of a mixture of 40% urea, 100% diammonium phosphate, and 100% potassium chloride. The second fraction of urea (64 kg ha^{-1}) was applied at the stage of the third open trefoil.

Irrigation was carried out using furrows, applying water according to the crop's needs and environmental conditions, and prioritizing the critical periods of full vegetative development, flowering, and pod formation and filling. The total water depth at the end of the crop cycle was between 360 and 400 mm ha^{-1}.

At 95 days after sowing (DAS), at harvest time, the plants were uprooted by hand and left in the field until the grains reached the right moisture for threshing. After 48 hours, the plants were beaten using a mechanical threshing machine to remove the grains, weigh them, and determine their moisture content using a Burrows DMC550® portable moisture meter.

Figure 1 - Temperature and Relative Humidity (RH) during the experiment in 2021



Source: Alexander Von Humboldt Weather Station. Department of Environmental Engineering, Physics, and Meteorology. UNALM School of Sciences

Table 1 - Analysis of the soil's chemical characterization in the experimental area

pH	EC (1:1)	OM	P	K	Ca	Mg	K	Na	H + Al	SB	CEC	BS
(1:1)	dS/m	g dm^{-3}	---- mg dm^{-3} ----		------------------------------ mmol$_c$ dm^{-3} ------------------------------							%
7.8	0.9	11.4	37.6	294	78.7	13.5	5.4	1.6	0	99.2	99.2	100

pH: Potential of hydrogen, EC: Electrical conductivity, OM: Organic matter, SB: Sum of bases, CEC: Cation exchange capacity, BS: Base saturation

The experimental design comprised randomized blocks, with 12 treatments in four replications. From the first to the sixth treatment, the crop coexisted with weeds from emergence until 15, 30, 45, 60, 75, and 90 days, after which they were controlled with a hand hoe until harvest. From the seventh to the 12 th treatment, the crop remained free of weeds for the same periods, after which the weeds coexisted with the crop until harvest. The experimental plot comprised four rows, spaced 0.80 m apart and 4.0 m long, disregarding one row on each side and 0.5 m from the ends as borders.

In the treatments without control, weeds were collected at the end of each coexistence period. In the treatments with control, the samples were taken at harvest. A 50 cm metal frame was used and dropped four times in the center rows of each treatment. The weeds within the frame were identified, counted, and taken to an oven with forced air circulation for 72 hours at 70 °C to obtain their dry mass. The results were used to calculate the relative frequency (the population's relevance regarding area occupation), relative density (the population's relevance in numerical terms), relative dominance (reflects dry mass accumulation), and the importance value index and relative importance value (reflect the population's relevance), according to the Mueller-Dombois and Ellenberg (1974) methodology.

The yield data was subjected to non-linear regression analysis using the Boltzmann sigmoidal model for each sowing density according to Eq. 1.

$$Y = \frac{(A1 - A2)}{1 + e^{\frac{(X - X0)}{dx}}} + A2 \qquad (1)$$

Where: Y = grain yield in kg ha^{-1}; A1 = maximum yield in the treatments with control during the cycle; A2 = minimum yield in the treatments without control during the cycle; X= upper limit of the coexistence or control period in "days"; X_0 = upper limit of the coexistence or control period, corresponding to the mid-value between the maximum and minimum yields; dx = speed of yield loss or gain as a function of the coexistence or control period.

The interference periods were delimited using the sigmoidal model curves, considering an arbitrary 5% yield loss and comparing the weed-free treatment throughout the cycle. Furthermore, yield correlation analyses were carried out with the weed dry mass over increasing coexistence periods. All the analyses were carried out using the OriginPro® software.

RESULTS AND DISCUSSION

Weed community composition

At a density of 12 plants m^{-1} (TPM), 15 species were recorded. They were distributed among ten families (Table 2), with 80% belonging to the eudicotyledonous class and 20% to the monocotyledonous class. At a density of 8 plants m^{-1} (EPM), the eudicotyledonous class accounted for 73% of species, and the monocotyledonous class accounted for 27% (Table 3). This greater presence of eudicotyledonous weeds in the experiments results from this class having the highest percentage of species (75%) of all angiosperms (Simpson, 2019). Thus, finding more species of this group living with beans is common.

The control treatments had fewer species than the coexistence treatments at both sowing densities (Tables 2 and 3) because the control periods were more beneficial to the crop, creating an unfavorable environment for the number of weed species. Another explanation would be that the control would have eliminated some species that did not have abundant seeds in the soil and were, therefore, not found in the final assessment. Thus, it is important to analyze the seed bank in studies on weed competition (Pardo *et al*., 2019).

Amaranthus retroflexus only appeared in TPM (Table 2), probably due to its good germination capacity under lower light conditions (Qasem, 2019). *Eclipta prostrata* and *Coronopus didymus* were recorded only in EPM (Table 3) since *C. didymus* is uncompetitive and does not thrive in shaded environments and *E. prostrata* has positive photoblastic seeds (Sharpe; Boyd, 2019) or light-dependent for germination.

Weed density at two bean sowing densities

At TPM, the density of the species tended to decrease as coexistence increased. However, the density of *S. verticillata* increased from 75 (30.6 plants m^{-2}) to 90 DAE (89.3 plants m^{-2}) (Figure 2A). Therefore, this species would be tolerant of high competition and/or insensitive to a shortage of light to germinate. According to Franke *et al*. (2009), *S. verticillata* seeds may or may not be insensitive to light and can, therefore, germinate in many environments. In EPM, *N. physaloides* and *S. verticillata* showed the highest densities at 30 DAE (96 and 194.4 plants m^{-2}, respectively). Meanwhile, *S. halepense* had 96 plants m^{-2} at 90 DAE (Figure 2B).

The average densities of *N. physaloides* (52.6 plants m^{-2}) and *S. verticillata* (58 plants m^{-2}) were higher in EPM than in TPM during the coexistence periods. *Setaria verticillata* had the highest average density values in TPM and EPM, which can be explained by its high prolificacy according to Mollaee *et al*. (2020), it can produce 120 seeds per panicle and 42 tillers per plant). In EPM, the

Table 2 - Weed species in the coexistence (CO) and control (CT) treatments at the bean sowing density of 12 plants m^{-1}

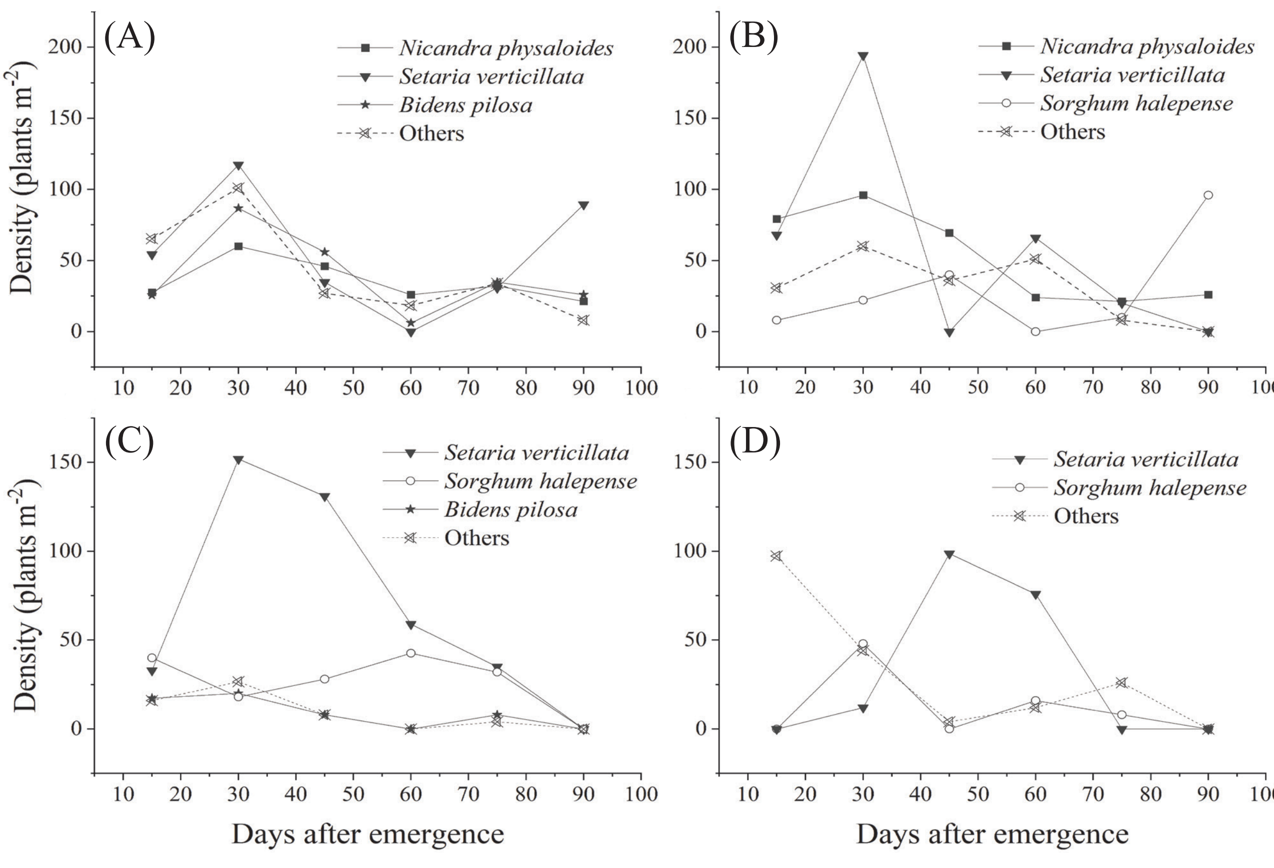
Family	Scientific name	Common name	CO	CT
Eudicotyledonous				
Aizoaceae	*Trianthema portulacastrum* L.	black pigweed	X	
Amaranthaceae	*Amaranthus dubius* Mart. ex Thell.	red spinach	X	X
Amaranthaceae	*Amaranthus retroflexus* L.	red-root amaranth	X	
Asteraceae	*Bidens pilosa* L.	hitch hikers	X	X
Boraginaceae	*Heliotropium angiospermum* Murray	scorpion's tail		X
Boraginaceae	*Heliotropium curassavicum* L.	salt heliotrope	X	
Chenopodiaceae	*Chenopodium murale* L.	nettle-leaf goosefoot	X	
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	common morning-glory	X	
Euphorbiaceae	*Acalypha infesta* Poepp.		X	X
Euphorbiaceae	*Ricinus communis* L.	castor bean	X	
Portulacaceae	*Portulaca oleracea* L.	common purslane	X	
Solanaceae	*Nicandra physaloides* (L.) Gaertn.	apple-of-Peru	X	X
Monocotyledonous				
Poaceae	*Eleusine indica* (L.) Gaertn.	goosegrass		X
Poaceae	*Setaria verticillata* (L.) Beauv.	hooked bristlegrass	X	X
Poaceae	*Sorghum halepense* (L.) Pers.	Johnson grass	X	X

average density of *S. halepense* was higher than in TPM (Figures 2A and 2B), due to its better adaptation to the greater luminosity and space in EPM. According to Batista *et al*. (2016), *S. halepense* has high competition in the bean plant since it has the C4 photosynthetic mechanism and quickly establishes itself in areas with light.

Table 3 - Weed species in the coexistence (CO) and control (CT) treatments at the bean sowing density of 8 plants m^{-1}

Family	Scientific name	Common name	CO	CT
		Eudicotyledonous		
Aizoaceae	*Trianthema portulacastrum* L.	black pigweed	X	
Amaranthaceae	*Amaranthus dubius* Mart. ex Thell.	red spinach	X	X
Asteraceae	*Bidens pilosa* L.	hitch hikers	X	X
Asteraceae	*Eclipta prostrata* (L.) L.	false daisy	X	
Brassicaceae	*Coronopus didymus* (L.) Smith.	lesser swine-cress	X	
Chenopodiaceae	*Chenopodium murale* L.	nettle-leaf goosefoot	X	X
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	common morning-glory		X
Solanaceae	*Nicandra physaloides* (L.) Gaertn.	apple-of-Peru	X	X
		Monocotyledonous		
Poaceae	*Eleusine indica* (L.) Gaertn.	goosegrass		X
Poaceae	*Setaria verticillata* (L.) Beauv.	hooked bristlegrass	X	X
Poaceae	*Sorghum halepense* (L.) Pers.	Johnson grass	X	X

Figure 2 - Weed density in the coexistence periods at 12 (A) and 8 plants m^{-1} (B) and in the control periods at 12 (C) and 8 plants m^{-1} (D) of the 'Canario 2000-INIAA' bean plant



The density of *S. verticillata* was maximum at 30 DAE (152 plants m^{-2}) with control (Figure 2C), which means 60 DAE with coexistence in TPM. Therefore, the highest densities of *S. verticillata* were in the longest coexistence periods (Figures 2A and 2C), thus demonstrating its prolificacy in arid conditions. In this environment, interference with the bean plant is more significant in fields with maize as a predecessor crop, where the herbicide atrazine is routinely used (atrazine does not control *S. verticillata*).

The average densities of *Amaranthus dubius* and *Eleusine indica* (belonging to the "other" group) had, respectively, 85% and 64.3% fewer plants in the TPM experiment than in the EPM experiment during the control periods. Boyd *et al*. (2017) explained that *E. indica*, which has a prostrate habit, can be controlled by favoring the crop's vigor and cover. *Amaranthus dubius* does not have the aggressiveness of other species of the same genus (it is even eaten as a leafy vegetable in some places in Peru) and can be affected by shading.

With increasing weed control at both sowing densities (Figures 2C and 2D), the number of individuals of *S. halepense* tended to increase as weeding became more frequent due to the resprouting of rhizomes, which can form more vigorous plants than those originating from seeds (Karkanis *et al*., 2020).

Weed dry mass at two bean sowing densities

In the TPM density in coexistence periods (Figure 3A), *N. physaloides*, *S. halepense*, and *S. verticillata* produced the highest dry mass throughout the experiment, representing 80.5% of the weed community's dry mass at 75 DAE. The high dry mass values of *N. physaloides* in TPM (Figure 3A) show its great capacity for extracting and accumulating nutrients, even though it is under intense competition. According to Matos *et al*. (2018), increasing the soil's N, P, and K levels favored dry mass production and the accumulation of these macronutrients in *N. physaloides*. It explains the species' abundance in the Peruvian coastal soils, which are considered to have good fertility due to their fluvial origin (Peru, 2022).

All species showed a reduction in dry mass at 90 DAE in TPM, except for *S. verticillata*, which showed an increase from 44.5 g m^{-2} to 441.2 g m^{-2} at 75 and 90 DAE with coexistence, respectively (Figure 3A), illustrating its good dry mass accumulation capacity. According to Ernst and Tolsma (1992), *S. verticillata* produces high biomass seedlings mainly in fertilized soils than in nutrient-poor soils. Thus, it explains its constant presence in commercial bean production fields on arid soils, where fertilizers are commonly applied. Therefore, the participation of *S. verticillata* in the interference with the bean plant is mainly due to its high biomass production and prolificacy.

In the EPM experiment (Figure 3B), *N. physaloides* always maintained a higher dry mass than the other species, reaching the maximum value (749.6 g m^{-2}) at 90 DAE with coexistence. On the other hand, *S. halepense* showed a higher average dry mass in EPM (159.3 g m^{-2}) than in TPM (84.9 g m^{-2}). The TPM density was detrimental to the dry mass accumulation of *S. halepense* due to the bean plant's greater cover. Therefore, a management strategy for *S. halepense* should focus on selecting competitive crops or planting at high densities and reducing row spacing of the chosen crop or cultivar (Squires; Walsh, 2021).

In TPM, *N. physaloides* and *S. halepense* showed the highest dry mass values at 15 DAE with 717.8 and 452 g m^{-2}, respectively, which decreased as the number of weeds increased (Figure 3C). In the EPM experiment, *N. physaloides* and *S. halepense* stood out in the control periods, showing the highest dry masses at 45 and 30 DAE, with 228 g m^{-2} and 338.4 g m^{-2}, respectively (Figure 3D). The species' dry mass tended to decrease as weeding became more frequent at both sowing densities due to the effect of weed control itself and the crop's progressive development.

Nicandra physaloides, *S. halepense*, and *S. verticillata* had the highest average dry mass values in TPM (194.1, 110.6, and 50.8 g m^{-2}, respectively), when compared to the EPM experiment (67.9, 58.9, and 34.8 g m^{-2}, respectively). Increased weed control favored crop cover in TPM. However, it created conditions for the dry mass accumulation of *S. verticillata* since it is not very sensitive to light shortage for its development and can show greater height and longer leaves under shading (Franke *et al*., 2009).

Relative importance of weeds in two bean sowing densities

In the TPM density, *N. physaloides* stood out with relative importance (RI) values of 48.7% and 38.5% at 60 and 75 DAE with coexistence, respectively (Figure 4A). The RI of *S. verticillata* remained below 20% until 75 DAE due to the cover produced by the crop in high density and other species in the weed community. However, at harvest time, the RI of *S. verticillata* increased to 41.2% as the cover decreased due to the bean plant's senescence (Figure 4A). In the EPM experiment, the highest RIs were from *N. physaloides* at 75 DAE (54.2%), 15 DAE (35.2%), and 45 DAE (47%), making it the main species interfering with the bean plant (Figure 4B).

At EPM density, the average RI of *N. physaloides*, *S. verticillata*, and *S. halepense* was 41.3%, 18%, and 20%, respectively. Meanwhile, at TPM density, it was 30.5%, 17%, and 16.6%, respectively. The better interception of solar radiation by the larger canopy in TPM allowed less PAR (Photosynthetically Active Radiation) to pass through, thus affecting the species mentioned. Mhlanga *et al*. (2016) reported a similar result. They detected greater PAR interception in maize sown at high density, resulting in lower weed dry mass production, one of the RI components.

Figure 3 - Weed dry mass in the coexistence periods at 12 (A) and 8 plants m^{-1} (B) and in the control periods at 12 (C) and 8 plants m^{-1} (D) of the 'Canario 2000-INIAA' bean plant

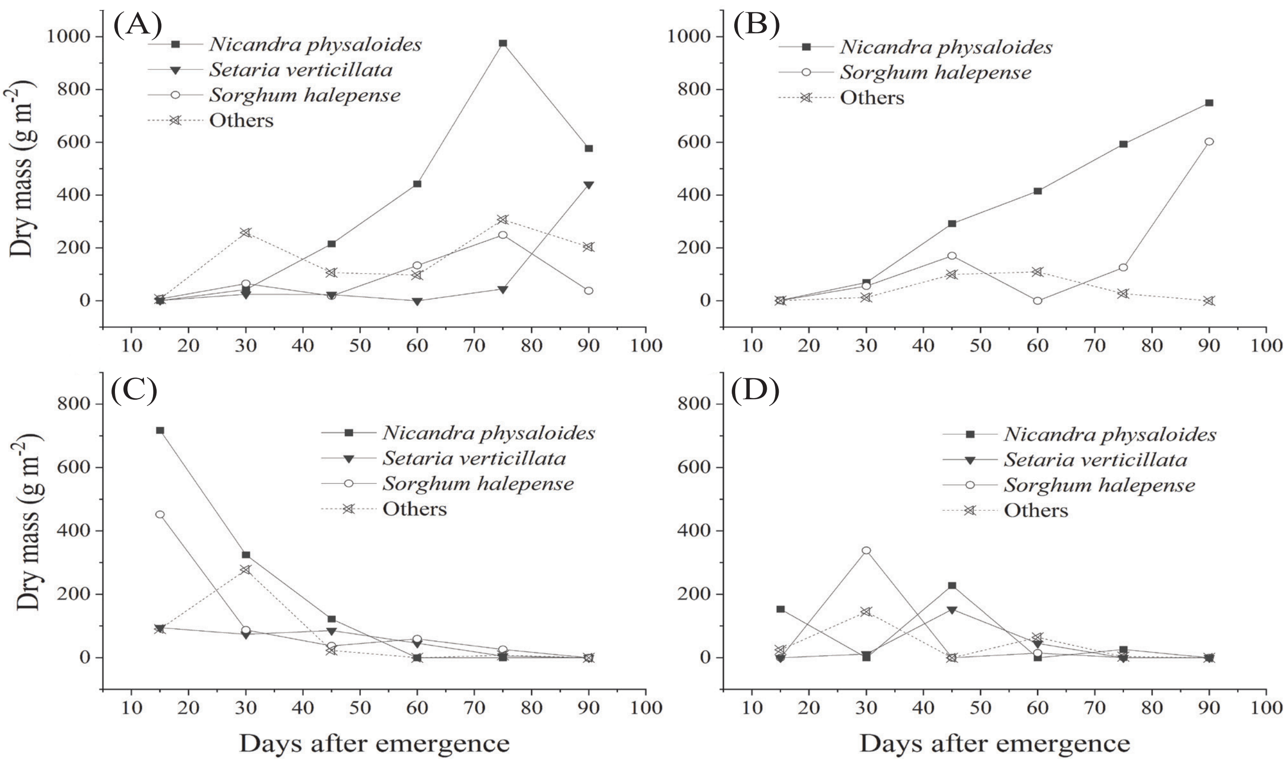
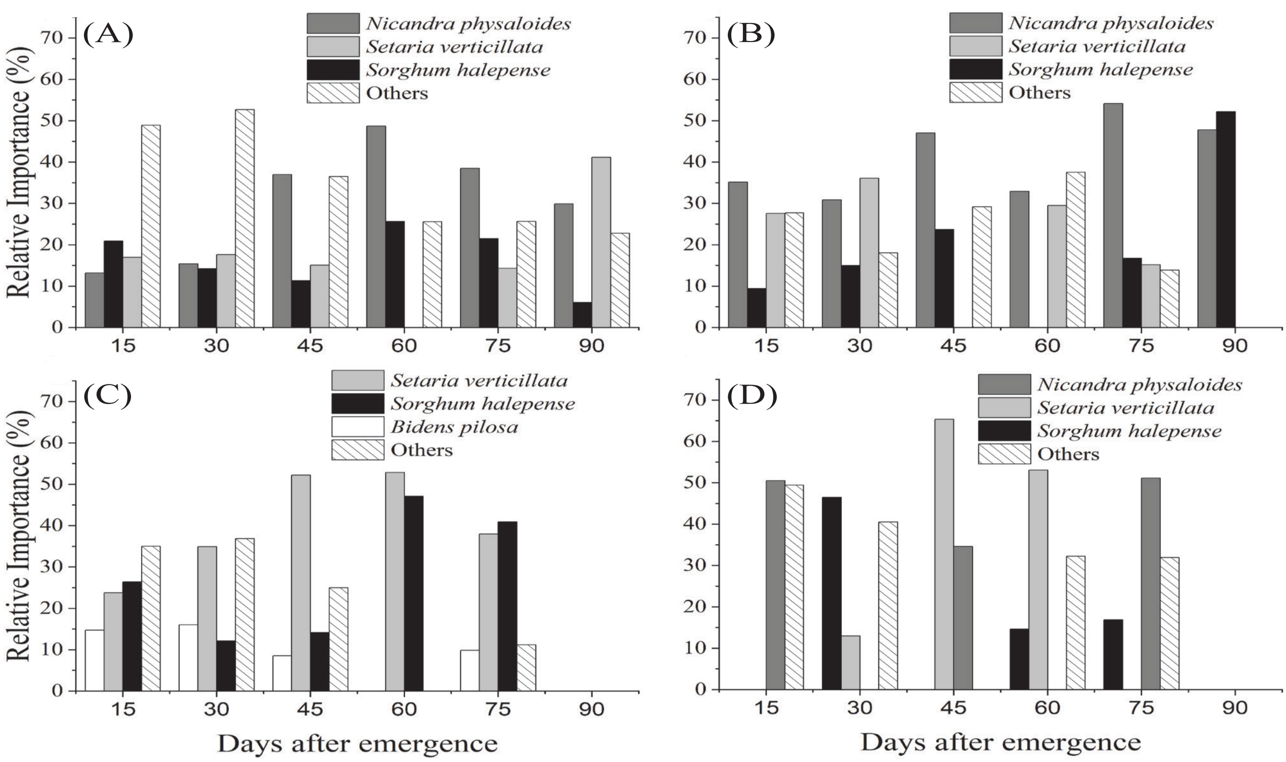


Figure 4 - Relative importance of weeds in the coexistence periods at 12 (A) and 8 plants m^{-1} (B) and in the control periods at 12 (C) and 8 plants m^{-1} (D) of the 'Canario 2000-INIAA' bean plant



The RI values in coexistence show the crop's ability to compete with weeds since both coexist for increasing periods. If the higher sowing density was more favorable to the crop, then the weeds should have lower RI compared to the RI at the lower sowing density, which was the case in this study. Similarly, Parreira *et al*. (2012) obtained lower values for density and dry mass (RI components) of some weeds at a density of 15 plants m^{-1}, compared to a density of 10 plants m^{-1} for common beans.

At the TPM density, the RI of *S. verticillata* increased as the control increased, up to 52.2% and 52.9% at 45 and 60 DAE, respectively (Figure 4C). On the other hand, *B. pilosa* showed RI below 17% during the experiment. Increasing control reduced the RI of *S. halepense* until 45 DAE (Figure 4C). In other words, the crop was potentiated by the control and competed well with this species until this period. The increase in RI at 60 and 75 DAE may be due to the late sprouting of the rhizome buds.

Regarding EPM density, weed control up to 60 DAE reduced the RI of *N. physaloides* and the "other" species (Figure 4D). In the latter group, *Eleusine indica* and *Chenopodium murale* were affected by the successive control and by the crop's better expansion. Therefore, they would be species sensitive to the lack of light. Thus, they could be controlled by planting beans in high density, using competitive varieties, or employing cover crops, as in the case of *C. murale*, according to Eslami and Ward (2021).

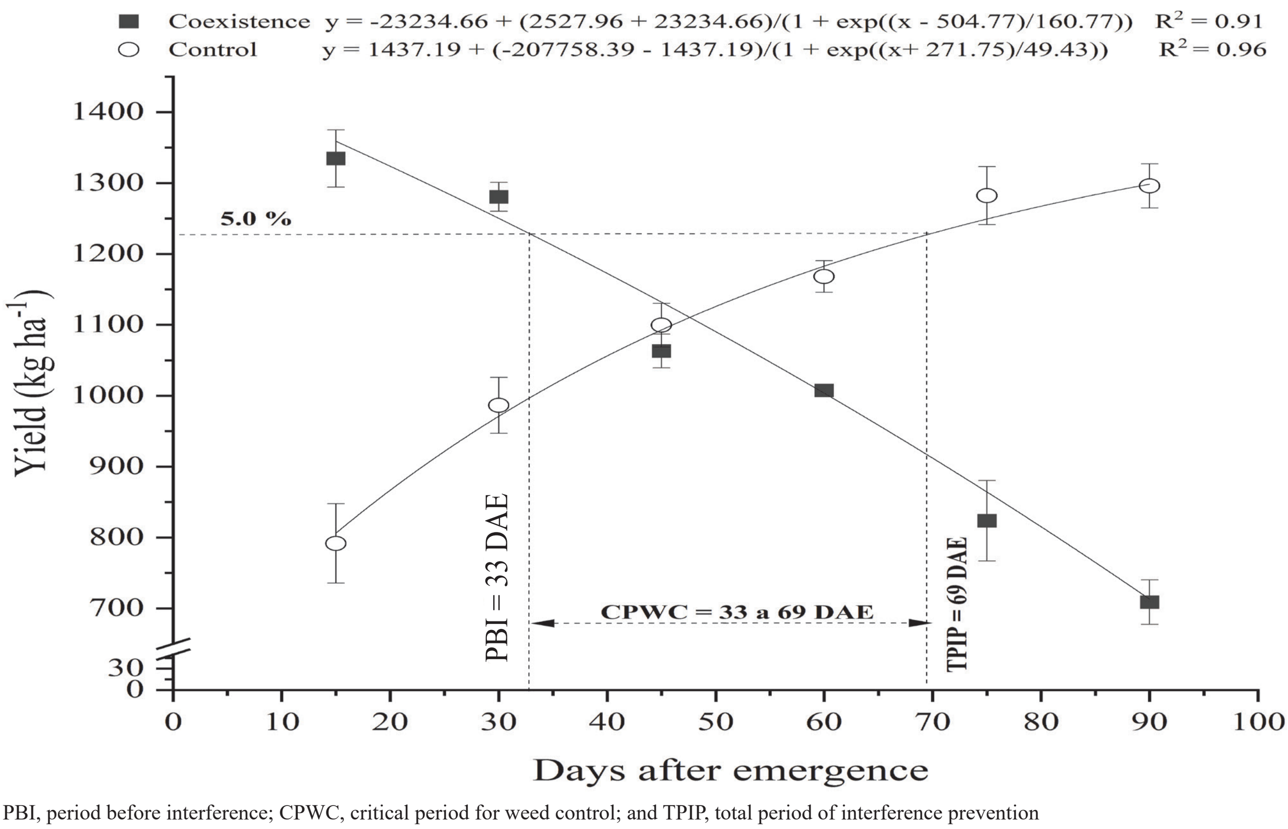
In EPM, the average RI of *S. verticillata*, *S. halepense*, and *N. physaloides* was 21.9%, 13%, and 22.7%, respectively. Regarding TPM density, the average RI values of *S. verticillata*, *S. halepense*, and *N. physaloides* were 33.6%, 23.4%, and 12.4%, respectively. In TPM, frequent weeding benefited the crop, producing a canopy that reduced the RI of *N. physaloides* compared to the EPM density.

On the other hand, the greater cover of the bean plant in TPM did not help reduce the RI of *S. halepense* and *S. verticillata* when compared to the EPM density. It may have been due to the greater difficulty in weeding in the high bean population, especially in the final stages, which may not have cut both species close to the ground.

Interference periods

At the TPM sowing density, the time the crop could live with weeds without compromising productivity (PBI) was 33 DAE. Furthermore, the TPIP was 69 DAE, and the CPWC occurred from 33 to 69

Figure 5 - Weed interference periods in the 'Canario 2000-INIAA' bean plant under a sowing density of 12 plants m^{-1}



PBI, period before interference; CPWC, critical period for weed control; and TPIP, total period of interference prevention

DAE, limiting the interval to 37 days (Figure 5). There was a 45.3% decrease in the yield of the bean crop that permanently coexisted with weeds (708.8 kg ha^{-1}) when compared to the crop with control throughout the cycle (1,296 kg ha^{-1}) (Figure 5).

In the EPM experiment (Figure 6), the PBI covered 29 DAE, and the TPIP, 82 DAE. As a result, the CPWC began at 29 DAE and lasted until 82 DAE, covering 54 days. The yield reduction was 92.9% in the bean plant coexisting with the weed community throughout the cycle (137.6 kg ha^{-1}) compared to the weed-free treatment (1,948.2 kg ha^{-1}) (Figure 6).

Under high sowing density conditions (TPM), the CPWC was 17 days shorter than the CPWC in EPM. Furthermore, the PBI at TPM exceeded the PBI at EPM by four days (Figures 5 and 6). The lower pressure of *N. physaloides*, *S. verticillata*, and *S. halepense* in TPM reflected in the length of the interference periods, with the CPWC and TPIP being shorter and the PBI being longer in TPM, compared to the EPM density. Similarly, Iqbal *et al*. (2022) found that better cover of cotton planted at high density shortened the TPIP compared to low sowing density.

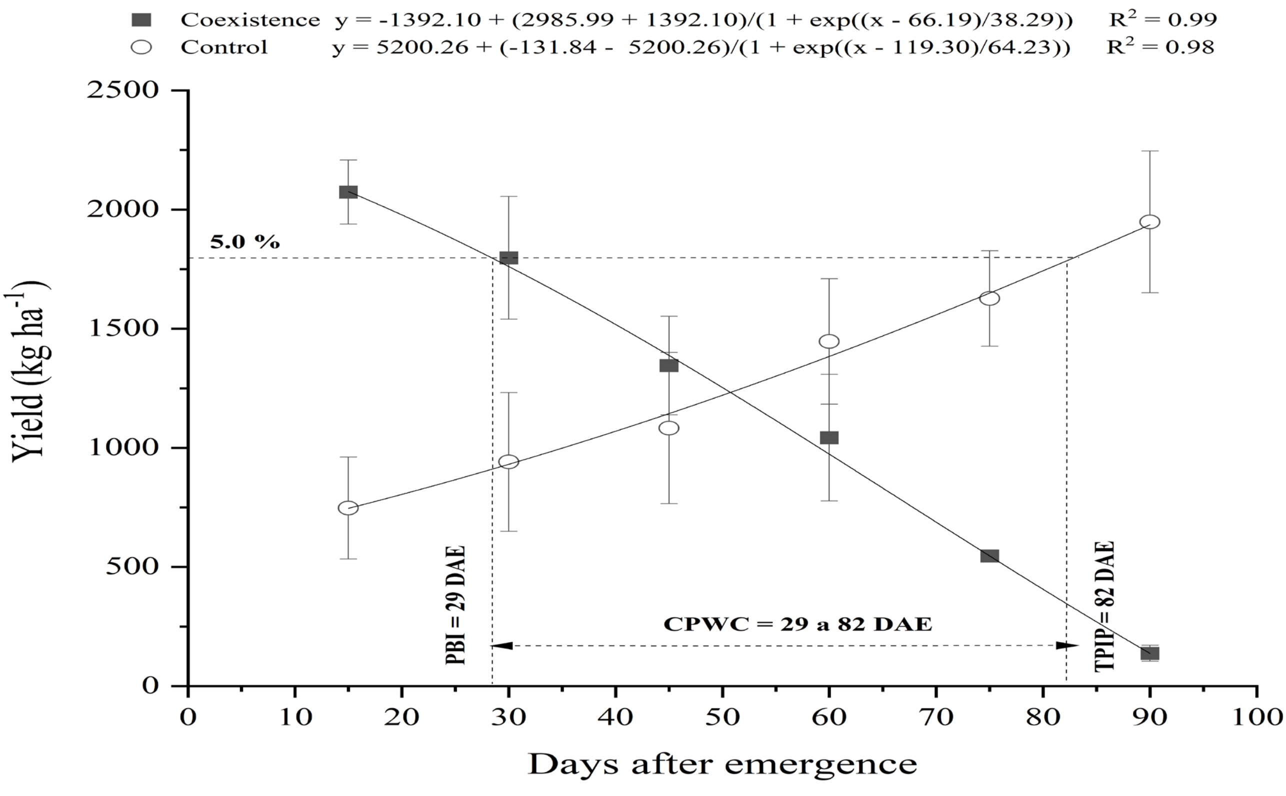
Bean yields at TPM were lower than at EPM, basically due to phytosanitary reasons and greater intraspecific competition. At this high sowing density, the temperature and the greater moisture retained in the soil favored the infestation of *Fusarium oxysporum* f. sp. *phaseoli* when the formation of the cover was maximum. Cruz *et al*. (2019) determined that the greatest development of fusariosis was at 27.1 °C, and the maximum severity of root rot in soybean seedlings was at 30 °C, temperatures close to those reported here.

Influence of weed dry mass on bean yields

As the weed dry mass increased, bean yield decreased at both sowing densities. However, this decrease was more pronounced at EPM density, with yields of 137.6 kg ha^{-1} (Figure 7B) compared to yields of 800 kg ha^{-1} at TPM (Figure 7A), when the weed community's dry mass was 1,352 g m^{-2}.

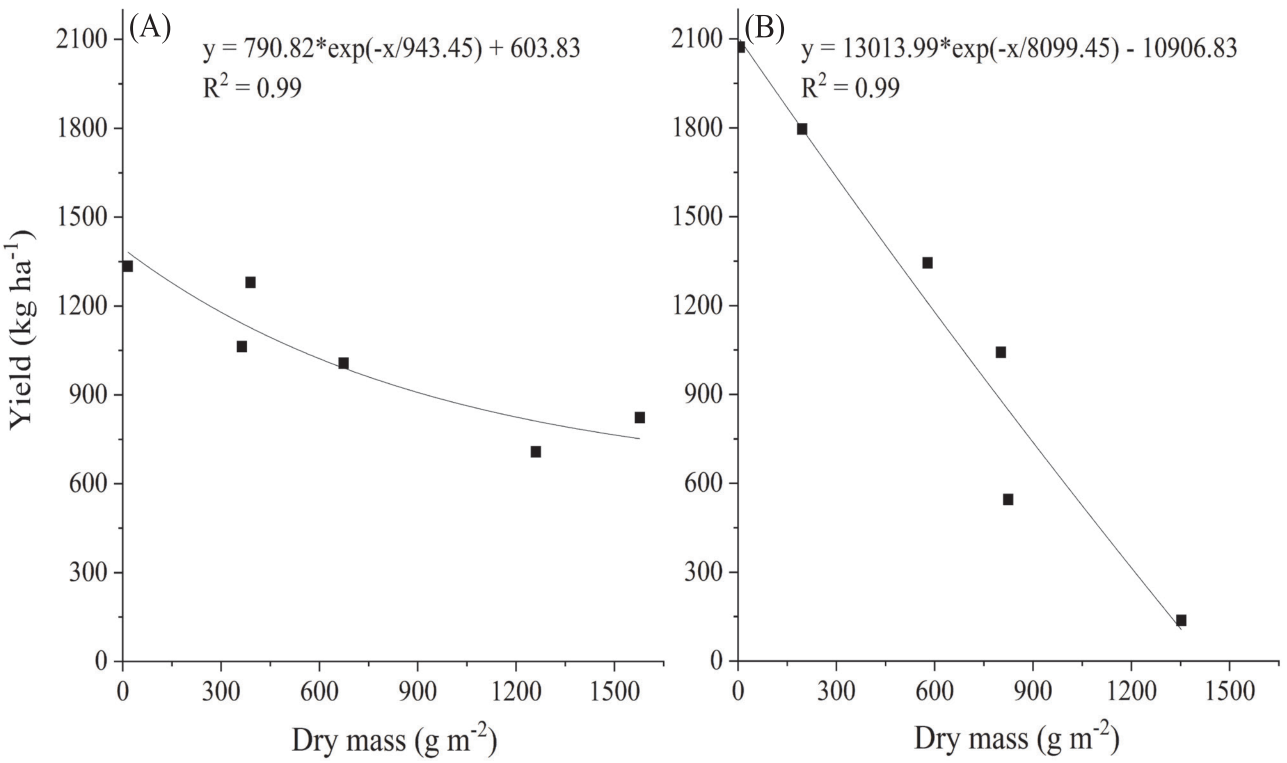
In TPM, the yield was less sensitive to the weed community's increasing dry mass than in EPM. Therefore, there was a greater competitive advantage for the bean plant at the higher sowing density, which confirms that the common bean's sowing density affects early soil cover and its ability to compete with weeds (Musana *et al*., 2020).

Figure 6 - Weed interference periods in the 'Canario 2000-INIAA' bean plant under a sowing density of 8 plants m^{-1}



PBI, period before interference; CPWC, critical period for weed control; and TPIP, total period of interference prevention

Figure 7 - Yield of 'Canario 2000-INIAA' bean at 12 plants m^{-1} (A) and 8 plants m^{-1} (B) as a function of weed dry mass



CONCLUSIONS

The bean density of 12 plants m^{-1} decreased the CPWC and the TPIP and increased the PBI, compared to 8 plants m^{-1}. Thus, it improved the crop's competitive ability with the weeds. The most relevant weeds, according to RI, were: *Nicandra physaloides*, *Setaria verticillata*, and *Sorghum halepense*. Bean yields decreased at both sowing densities as the weed community's dry mass increased. However, this decrease was more pronounced at a density of 8 plants m^{-1}.

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