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Effect of Row Spacing in the Period Prior to Weed Interference in Peanut Cultivation Under Azorean Conditions

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Abstract

Peanut cultivation currently plays a minor role in Portuguese agriculture, despite the country's favorable soil and climatic conditions. In the Azores archipelago, where agriculture is a key economic activity, peanut production has recently sparked interest among rural producers. Weeds pose a major threat to crop development, particularly for short-cycle species like peanuts. This study aimed to determine the period prior to weed interference (PPI) in peanut crops under two row spacings (40 cm and 60 cm) on São Miguel Island, Azores. Eight treatments were established—0–15, 0–30, 0–45, 0–60, 0–75, 0–90 days after emergence (DAE), full-season coexistence, and a weed-free control—to represent increasing periods of weed competition. A randomized block design with four replicates was used for each spacing. The weed community included eight species, with *Cyperus* spp., *Digitaria* spp., *Amaranthus blitum*, and *Portulaca oleracea* being the most prevalent. Weed interference throughout the entire cycle led to yield losses exceeding 81% and 86% at 40 cm and 60 cm row spacings, respectively. The PPI was defined at a 5% yield reduction threshold, which is a commonly accepted benchmark in weed science to determine the beginning of the critical period of weed interference.

Keywords: weed competition; periods of interference; row spacings; yield reduction; yield losses

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1. Introduction

Historical records of peanut production in mainland Portugal point to the Algarve region, particularly in Aljezur, where it was known as Alcagoita. Once important in that area, it has since lost significance. In the 1980s, a national association of peanut producers was created; however, cultivation was eventually abandoned, and the organization dissolved.

Peanut production became limited to personal consumption and sales in organic grocery stores. In 2015, the Portuguese company Torriba, in partnership with the multinational PepsiCo, promoted peanut production in the Ribatejo region, with 75 hectares dedicated to snack peanut production [1].

In Portugal's insular territories, particularly in the Azores archipelago, peanuts were once considered a traditional crop, especially on São Miguel Island (Eastern Group) [2]. However, production has remained artisanal and small-scale, mainly due to the lack of mechanization, labor shortages, and region-specific challenges such as high humidity and strict environmental regulations, including the prohibition of most synthetic herbicides. These factors have constrained the expansion and modernization of peanut cultivation in the region, despite the recent renewed interest from some producers.

In this context, weed management emerges as one of the most critical challenges for peanut production in the Azores. Weed plants have gained significant importance in modern agriculture, particularly in peanut cultivation, due to the damage they cause to the crop. Their interference triggers serious problems during the production and development cycle of the crop, in addition to making harvesting more difficult and devaluing the quality of the grain. This occurs because of competition for abiotic factors such as nutrients, water, light, and space, which are necessary for the crop to establish itself [3]. Therefore, when implementing a crop, it is essential to understand the entire weed activity to prioritize certain species according to their significance, as not all weed species have the same level of interference with the crop [4].

The degree of interference is associated with the damage caused to the crop, and this is generally greater the longer the period of coexistence [5]. Pitelli et al. [6] had already observed that the coexistence of weeds with the peanut crop leads to a reduction in pod production, grain quantity and yield, as well as plant population and aerial development. Typically, this varies depending on the location where the crop is being implemented [7], the weed community [8], the cultivar [9], row spacing [10], soil and climatic conditions, cultural practices, and the extent of the crop coexistence with the weed community [11]. For the peanut crop to achieve better competitive performance against the weed community, it is important to adopt cultural practices that promote the normal development of the crop over the weeds, such as the use of an appropriate spatial arrangement [12].

In the specific case of the Azores, where chemical control is limited and climatic conditions favor rapid weed growth, the need for integrated, preventive, and early control strategies becomes even more pressing. Therefore, defining the optimal weed-free period is essential to ensure the establishment and productivity of the crop under these restrictive conditions.

Owing to the above, the objective of this study was to determine the period prior to interference (PPI) of weed species present in peanut crops under two sowing spacings, 40 cm and 60 cm between rows, on the island of São Miguel, Azores.

2. Materials and Methods

2.1. Experiment Setup: Soil Preparation and Sowing

Two field experiments were conducted in the municipality of Ribeira Grande, in the locality of Porto Formoso, on the island of São Miguel, Azores, PT (37°49′12″ N, 25°25′14″ W). The soil at the site is sandy loam (20–40% clay, up to 50% silt, and 50–90% sand). It has a hydraulic conductivity of about 25 m h^{-1}, a field capacity of 21% by volume, and a wilting point of around 9% [13]. The climate is temperate oceanic, and the experimental period began at the end of spring.

The two main plots underwent mechanized soil preparation, with plowing followed by two harrowing steps. Sowing was carried out manually on 14 June 2023; this date was chosen based on traditional practices of local peanut producers on São Miguel Island, and on favorable environmental conditions such as soil temperature and moisture, observed in preliminary trials conducted in the region, with four seeds per hole, spaced 20 to 25 cm apart in the planting row, aiming for a density of 14 plants per linear meter. One area had a row spacing of 40 cm, while the other had a spacing of 60 cm.

The peanut seeds were purchased locally, still in their shells, and referred to as "amendoim do nosso". This variety is preferred by local producers due to its organoleptic characteristics, though its genetic characterization is unknown. The genotype is considered a local landrace with erect growth habit and a four-month life cycle, and produces pods containing one to five seeds with reddish skin. The cultivation was performed organically, without irrigation or any soil fertility supplements, in alignment with local traditional farming practices and to avoid confounding effects from agrochemical use.

2.2. Experimental Design

In both trials, the blocks were arranged to control for minor variations in slope and wind exposure, ensuring better uniformity of soil conditions. The experimental units consisted of five sowing rows, each 5 m in length, resulting in an area of 8 m^2 for the 40 cm inter-row spacing and 12 m^2 for the 60 cm spacing. The two outer rows of each experimental plot were discarded, as they served as borders; effectively, the usable area consisted of the three central rows of each plot, excluding the first meter from each end of the rows. This resulted in 3.6 m^2 of sample area for trials with 40 cm between rows and 5.4 m^2 for trials with 60 cm spacing between rows.

In each area, eight treatments were applied regarding the periods of crop coexistence with weed plants: 0–15, 0–30, 0–45, 0–60, 0–75, 0–90 days after emergence (DAE), 0—harvest, and one control without weed coexistence. For each row spacing, a randomized block design with four replications was used, giving a total effective sample area of 115.2 m^2 for the 40 cm spacing and 172.8 m^2 for the 60 cm spacing.

2.3. Climatological Data

The Azores is a temperate oceanic climate, has temperatures ranging between 13 °C and 25 °C, rarely falling below 10 °C or exceeding 27 °C, and average relative humidity of 80% [14,15], which are favorable conditions for the proper development of the peanut crop.

The data on rainfall, relative humidity, and minimum, maximum, and average temperatures for the experimental period were collected by the Santana Meteorological Station and are presented in Table 1.

Table 1. Temperatures (minimum, maximum, and average), relative humidity (RH) of the air, and rainfall during the experimental period.

	Temperature (°C)			RH	Rainfall
Month	**Max**	**Min**	**Average Temperature**	**(%)**	**(mm)**
June	24.5	16.1	20	88.2	15
July	25.8	15.3	20.4	80.5	16.5
August	37.7	20.4	27.3	81.1	48.5
September	30.0	17	24.6	79.5	43.2
October	24.5	17.5	21.2	84.4	42.8

Source: Azores Hydrometeorological Network by the Santana Weather Station, Ribeira Grande, São Miguel, Azores.

The climatic conditions recorded during the experiment in 2023 were consistent with the historical averages for the region over the past 10 years. Slight variations in maximum temperatures were observed in August and September, but no significant anomalies were detected in temperatures or rainfall. Therefore, the year 2023 can be considered representative of the typical climatic pattern for São Miguel Island.

2.4. Evaluation of the Weed Community

Weed plants present in two randomly selected sampling areas of 0.25 m^2 within the experimental plots were removed, identified, separated by species, and counted. The weed species were identified based on the manual by Mueller-Dombois & Ellenberg (1974) [16]. Fresh mass determination was performed using a scale with a precision of 0.01 g. After the end of their respective coexistence periods, the experimental plots were kept weed-free until harvest through periodic, manual weeding every 7–10 days. The evaluation of the weed community was carried out at the end of each coexistence period for each plot.

2.5. Harvest

The peanut harvest was carried out manually on 9 October 2023, 117 days after sowing (107 days after emergence). To determine productivity, 10 plants were randomly and widely harvested from the 3 central rows per sample block. Each sample was identified and left to rest in a cool, well-ventilated area to allow the plants to dry slightly naturally until data processing. The pods were counted, weighed using a scale with a precision of 0.01 g, and later manually shelled to count the kernels. During data collection, a distinction was made between marketable pods.

2.6. Evaluated Parameters

The weed community data allowed for the calculation of the relative importance (RI) of the weed community. Its calculation consists of an index encompassing three factors: relative frequency, related to the occurrence of the species; relative density, based on the number of individuals of the species; and relative dominance, referring to biomass accumulation, following formulas proposed by [16]. The density and dry matter accumulation of the plants in the weed community were decisive factors in relating the interference effect of the weeds on peanut crop production.

2.7. Data Analysis

The productivity data analysis was conducted separately for each row spacing scenario, and the results were subjected to regression analysis using the Boltzmann sigmoidal model, adapted by [17].

$$y = \frac{(P1 - P2)}{1 +^{(X - X0)/dX}} + P2$$

y = peanut pod productivity as a function of the coexistence periods (t ha^{-1}).

$P1$ = maximum yield obtained from plants kept weed-free throughout the entire cycle.

$P2$ = minimum yield obtained from plants coexisting with weeds for the maximum period (107 days).

$(P1 - P2)$ = yield losses.

X = upper limit of the coexistence period.

$X0$ = upper limit of the coexistence period, corresponding to the intermediate value between maximum and minimum yield.

dX = parameter indicating the rate of yield loss as a function of the coexistence time.

Data from the weed community (density, biomass, relative importance) were analyzed using descriptive statistics and plotted to observe trends in species dominance across coexistence periods.

Based on the regression equations, the periods before weed interference were determined using an arbitrarily set tolerance level of 5% yield reduction, compared to the treatment maintained without weeds. The regression analyses were conducted using the software Origin® 8 (Originlab Corporation, USA).

Mean comparisons were performed using the Tukey HSD test with Origin® 8 software (OriginLab Corporation, Northampton, MA, USA).

3. Results and Discussion

3.1. Weed Community

The weed community was similar in both sub-trials, consisting of eight species, with 80% being eudicots and 20% monocots. Among the eudicots, the families Amaranthaceae and Portulacaceae were notable, each represented by one species, while the family Polygonaceae had two different species, and Plantaginaceae had one species. Among the monocots, the families Cyperaceae and Poaceae stood out, each with one species (Table 2). Studies conducted with legumes in various geographical locations highlight the presence of some of the weed families found in this experiment, especially Poaceae and Cyperaceae, emphasizing their invasive potential and adaptability to different soil and climatic conditions [10,11].

Table 2. Composition of the weed community in the experimental areas.

Family	Scientific Name	Groups
Amaranthaceae	*Amaranthus blitum* L.	Eudicots
Asteraceae	*Sonchus oleraceus* L.	Eudicots
Cyperaceae	*Cyperus* spp.	Monocots
Plantaginaceae	*Plantago lanceolata* L.	Eudicots
Poaceae	*Digitaria* spp.	Monocots
Polygonaceae	*Polygonum lapathifolium* L. *Rumex azoricus* Rechinger	Eudicots
Portulacaceae	*Portulaca oleracea* L.	Eudicots

According to [18], the most common weeds in peanut fields in mainland Portugal are *Cyperus* spp., *Digitaria* spp., *Datura stramonium*, *Amaranthus* spp., and *Polygonum* spp. The authors [7], when investigating weeds in peanut crops in southern Brazil, found that the Poaceae family was highly representative. Similarly [19], in Paraíba, a northern region of Brazil, they also identified species like those found in the present study for peanut crop.

When analyzing the relative importance (RI) of the weed community in both experimental areas, the most significant species were *Cyperus* spp. *Digitaria* spp. *Amaranthus blitum*, and *Portulaca oleracea*, with the first two being the most relevant throughout the experimental period, due to either biomass production or population density. Despite seasonal differences, *Cyperus* spp. and *Digitaria* spp. consistently showed the highest RI values throughout the experimental period (Figures 1 and 2). In a study in the Ribatejo region, Portugal [20], in partnership with PepsiCo, Inc. and TORRIBA, the authors found weeds like those in this study, especially from the families Cyperaceae, Poaceae, Amaranthaceae, Portulacaceae, and Polygonaceae.

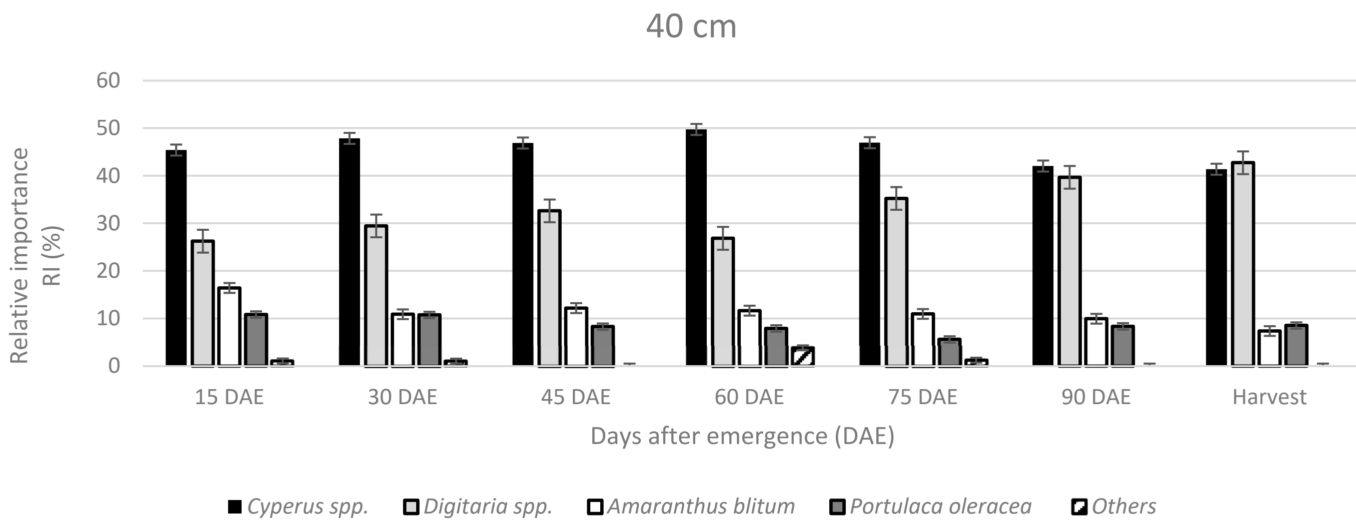

Figure 1. Relative importance (%) of major weed species (*Cyperus* spp., *Digitaria* spp., *Amaranthus blitum*, and *Portulaca oleracea*) over time in peanut cultivation with 40 cm row spacing. Each value represents the mean of four replicates. Error bars denote standard error. DAE = Days After Emergence.

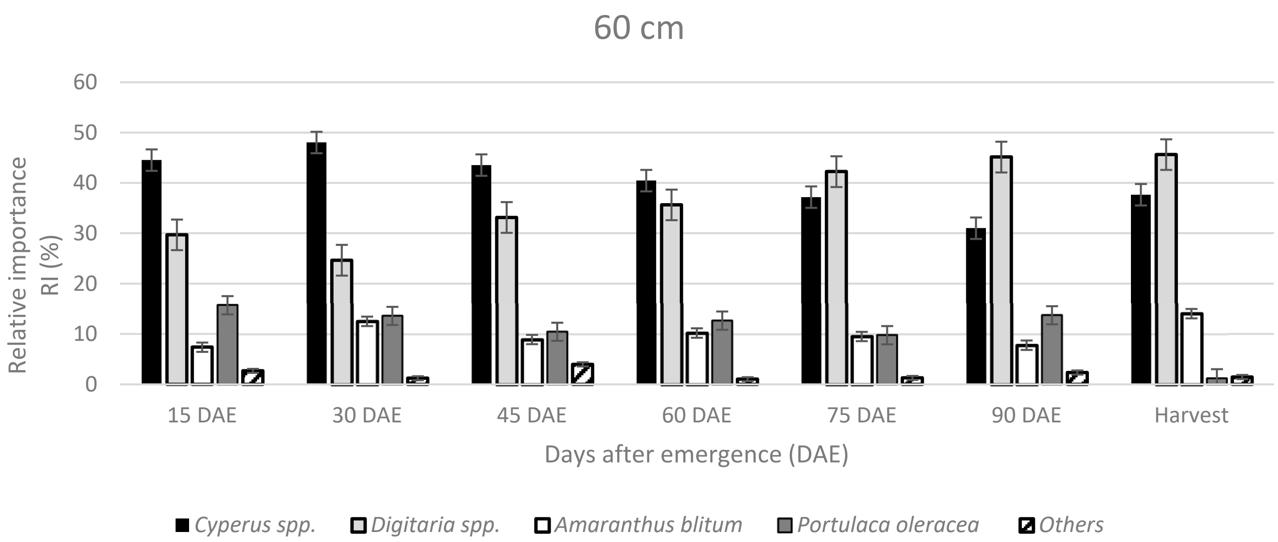

Figure 2. Relative importance (%) of the main weed species in peanut cultivation with 60 cm row spacing during the experimental period. Data are means of four replicates; error bars indicate standard error. DAE = Days After Emergence.

In the 40 cm row spacing, *Cyperus* spp. maintained a relative importance (RI) above 40% throughout the entire experimental period, peaking at 50% at 60 DAE (Figure 1). This was due to the high number of individuals recorded during this evaluation, exceeding 699 individuals per m^2, with a fresh mass of 1369 g m^{-2} (Figures 3 and 4), marking the highest population density recorded for this spacing.

In the 60 cm row spacing, this species showed increasing RI values from 15 DAE (44%) to 30 DAE (48%), followed by a reduction at 45 DAE (43%) and further decreasing to 31% at 90 DAE (Figure 2). This reduction was primarily due to the sharp decline in the number of individuals of this species found in the area, from 727 individuals per m^2 at 45 DAE (the highest plant density recorded in this experiment) to approximately 200 individuals per m^2 by the harvest period at 105 DAE (Figures 4 and 5). The fresh mass also decreased significantly, from 943.5 g m^{-2} at 75 DAE to around 300 g m^{-2} at 90. Plants of the genus *Cyperus* are the most widespread and harmful weeds in the world, found in different agroecosystems [21].

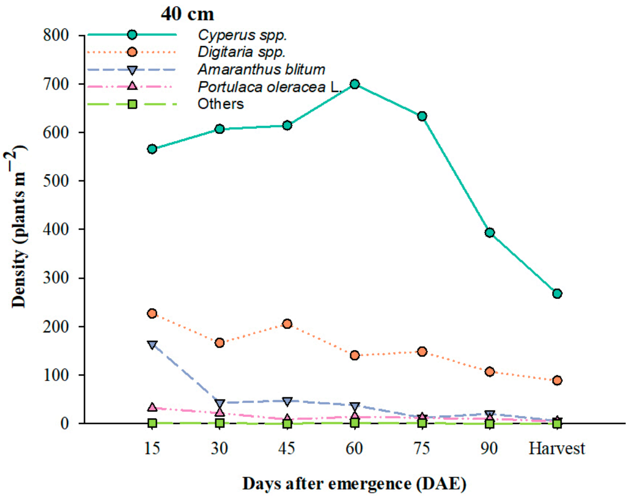

Figure 3. Plant density (plants m^{-2}) of the most abundant weed species in 40 cm spaced peanut plots across the experimental period. Values represent means ± SE of four replications. DAE = Days After Emergence.

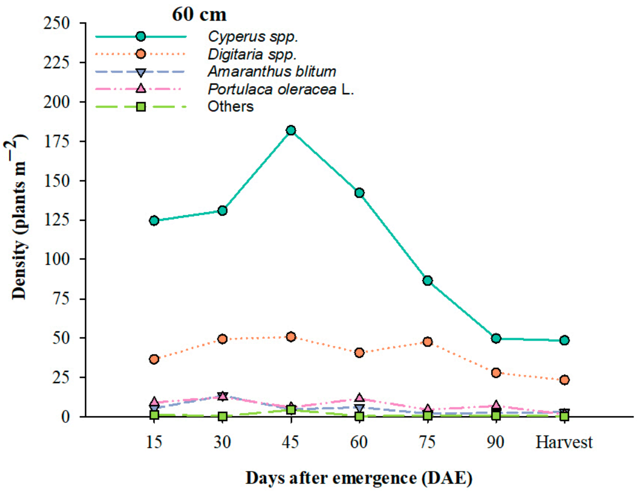

Figure 4. Density (plants m^{-2}) of the principal weed species observed in peanut plots with 60 cm spacing over time. Data are expressed as mean ± SE of four replicates. DAE = Days After Emergence.

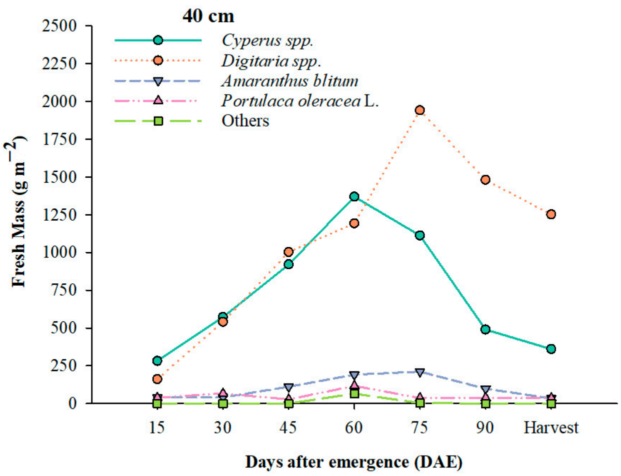

Figure 5. Fresh biomass accumulation (g m^{-2}) of dominant weed species at each sampling time in peanut plots with 40 cm row spacing. Data are mean values from four replicates; error bars indicate standard error.

When analyzing *D. ciliaris*, its relative importance was low at the beginning of the experimental period but increased towards the end, varying from 26% (15 DAE) to 43% (harvest) in the 40 cm row spacing and from 29% (15 DAE) to 45% (harvest) in the 60 cm row spacing (Figures 1 and 2). This increase is attributed to the exponential rise in fresh mass throughout the experimental period, especially up to 75 DAE, exceeding 1900 g m^{-2} at 40 cm and 2500 g m^{-2} at 60 cm by 75 DAE (Figures 5–8) [22]. This suggests that the fresh mass production by the weed community can infer its competitive ability; higher biomass production leads to increased competition for resources like nutrients, water, and light, which results in reduced crop productivity.

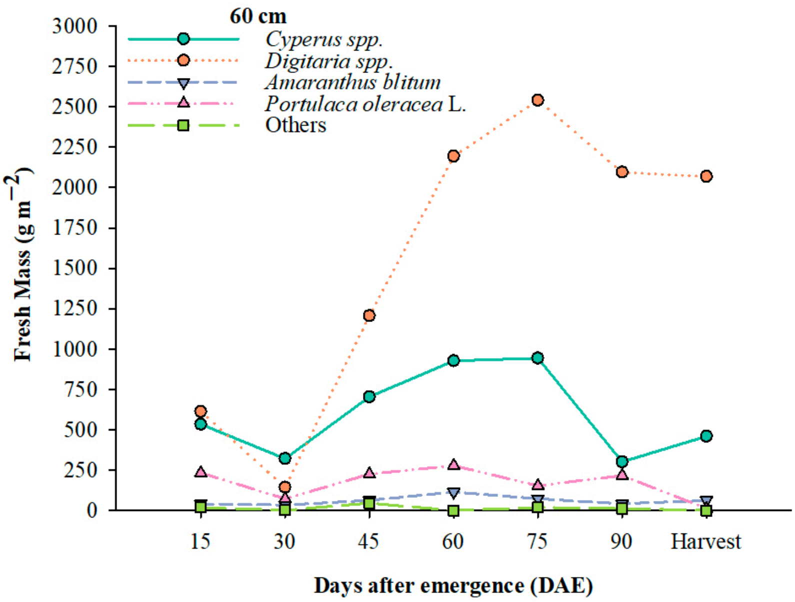

Figure 6. Fresh biomass (g m^{-2}) of the main weed species in peanut plots under 60 cm row spacing throughout the growing season. Results are shown as mean ± SE (n = 4). DAE = Days After Emergence.

Figure 7. Peanut plants coexisting with weeds over a 75-day (75 DAE) experimental period. Note: Test before (**A**) and after (**B**) weeding, with a 60 cm spacing between rows.

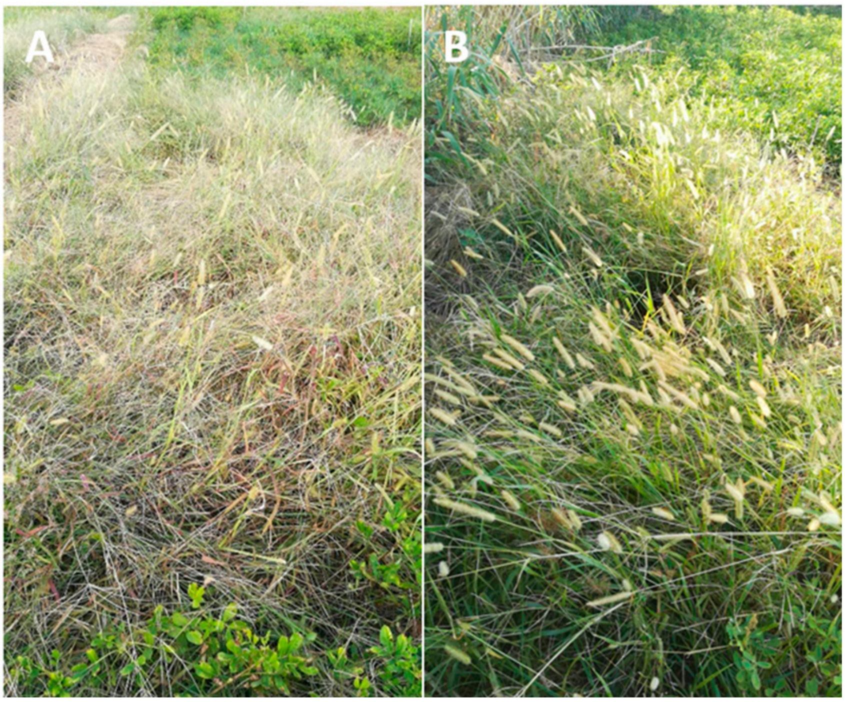

Figure 8. Peanut plants coexisting with weeds throughout the growing cycle, at the harvest stage. Note: Spacing between rows of 40 cm (**A**) and 60 cm (**B**).

The density of *D. ciliaris* varied from 226 to 88 individuals per m^2 in the 40 cm spacing, with the highest values recorded at 15 DAE (226 individuals per m^2) and 45 DAE (205 individuals per m^2), decreasing to the lowest value by harvest (Figure 3). In the 60 cm spacing, plant density ranged from 203 individuals per m^2 at 45 DAE to 103 individuals per m^2 at harvest, showing an increase in density from 15 DAE to 75 DAE, followed by a decrease to the lowest number of individuals at harvest (Figures 4 and 8). The genus *Digitaria* includes several species, such as *D. ciliaris, D. sanguinalis*, and *D. horizontalis*, among others. *D. ciliaris*, known by various names, infests cultivated areas with different crops [23], posing a significant concern for farmers.

The species *Amaranthus blitum* and *Portulaca oleracea*, although present throughout the peanut crop cycle, had the lowest indices, always below 17% (Figures 1 and 2). Despite observing approximately 160 individuals of the *Amaranthus* genus at 15 DAE in the 40 cm row spacing, there was a quantitative reduction of the species, with both species exhibiting linear behavior from 30 DAE onwards, never exceeding 60 individuals per m^2 (Figure 3). Throughout the experiment, fluctuations in the mass of these species were observed, but it never exceeded 250 g m^{-2} in both row spacings tested (Figures 5 and 6).

3.2. Crop Production

The analysis of peanut pod production from the experiment showed that the presence of the weed community throughout the entire growing cycle drastically reduced all analyzed parameters (Tables 3 and 4). In the 40 cm row spacing, even with only 15 days of coexistence with the weeds (15 DAE), production data decreased by approximately 20%, with reductions of 17% in pod number, 20% in total seeds per plant, 17% in seed number, and 19% in pod weight for marketable products (Table 3). In the 60 cm row spacing, a different pattern was observed, with the highest reductions occurring from 30 DAE onwards, exceeding 40% in pod number and total seeds per plant, and 38% in pod weight per plant. In commercial production, the reduction was around 42.5% (Table 4). In addition to increased shading, reduced canopy closure and greater light penetration between rows may have allowed more weed growth. Root competition and inefficient resource use due to wider spacing may also have contributed to higher yield losses [24].

Table 3. Average production data (peanuts in shell) per plant depending on the coexistence periods for the 40 cm spacing treatment between rows. Porto Formoso- São Miguel, Azores.

40 cm DAE	Nº Pods	Weight Pods (g)	Nº Total Seeds	Nº Marketable Pods	Weight Marketable Pods (g)
0	17.25 ± a	28.32 ± 2.89 a	41.75 ± 4.75 a	13.50 ± 1.48 a	25.20 ± 2.57 a
15	14.00 ± ab	22.87 ± 0.77 ab	33.00 ± 2.12 ab	11.25 ± 0.42 ab	20.47 ± 0.67 ab
30	11.20 ± c	17.50 ± 1.03 bc	24.00 ± 2.16 bc	8.50 ± 0.77 bc	15.47 ± 1.03 bc
45	6.50 ± cd	9.52 ± 2.12 cd	13.75 ± 3.02 cd	5.00 ± 1.12 cd	8.90 ± 1.92 cd
60	6.25 ± cd	9.52 ± 0.91 cd	13.50 ± 0.99 cd	4.50 ± 0.63 cd	8.37 ± 0.81 cd
75	5.50 ± d	8.52 ± 0.69 d	12.75 ± 1.33 cd	4.00 ± 0.36 d	7.52 ± 0.72 d
90	5.25 ± d	7.92 ± 0.44 d	11.25 ± 0.99 cd	4.00 ± 0.36 d	7.00 ± 0.48 d
Harvest	3.00 ± d	5.27 ± 1.55 d	6.75 ± 1.47 d	2.25 ± 0.67 d	4.77 ± 1.54 d
F trat	19.24 **	23.62 **	19.46 **	20.96 **	22.98 **
CV (%)	26.29	24.86	28.23	26.40	25.09

Mean ± standard error followed by the same letter in the column do not differ from each other in the Tukey test. ** significant at 1% probability. CV (%) = coefficient of variation.

Table 4. Average production data (peanuts in shell) per plant depending on the coexistence periods for the 60 cm spacing treatment between rows. Porto Formoso-São Miguel, Azores.

60 cm DAE	Nº Pods	Weight Pods (g)	Nº Total Seeds	Nº Marketable Pods	Weight Marketable Pods (g)
0	21.00 ± 1.02 a	27.97 ± 3.02 a	47.00 ± 3.07 a	13.00 ± 1.25 a	21.40 ± 3.10 a
15	17.50 ± 1.15 a	25.17 ± 1.48 a	40.00 ± 3.53 a	11.75 ± 1.39 a	19.87 ± 2.30 a
30	12.25 ± 1.28 b	15.80 ± 1.10 b	28.00 ± 3.06 bc	7.50 ± 0.42 b	12.17 ± 0.64 b
45	8.00 ± 0.99 bc	11.47 ± 1.31 bc	18.50 ± 2.31 c	6.00 ± 0.65 bc	9.87 ± 1.11 bc
60	5.75 ± 0.42 cd	7.55 ± 0.07 cd	12.25 ± 0.77 d	3.50 ± 0.12 bc	6.25 ± 0.23 bc
75	4.50 ± 0.26 cd	5.55 ± 0.31 cd	9.75 ± 0.68 d	3.25 ± 0.21 c	4.97 ± 0.31 bc
90	4.25 ± 0.65 cd	5.25 ± 1.07 cd	9.00 ± 1.47 d	2.75 ± 0.42 c	4.72 ± 0.94 bc
Harvest	2.75 ± 0.43 d	3.83 ± 0.80 d	7.00 ± 1.30 d	2.50 ± 0.36 c	3.65 ± 0.77 c
F trat	52.86 **	33.89 **	35.85 **	21.99 **	18.54 **
CV (%)	19.52	25.03	23.80	28.14	31.16

Mean ± standard error followed by the same letter in the column do not differ from each other in the Tukey test. ** significant at 1% probability. CV (%) = coefficient of variation.

In the wider 60 cm row spacing, productivity reductions were also intermediate at 45 DAE for pod number, pod weight, and total seed count per plant, but were significantly pronounced for marketable products (Table 4). The reductions were drastic, like those in the 40 cm spacing, with almost three pods per plant, weighing around four grams and having seven seeds per pod.

For the 40 cm row spacing, from 45 DAE (Table 3), the data showed the lowest productivity values, consistent until harvest, demonstrating that longer coexistence periods with weeds result in greater losses. Up to 45 DAE of weed coexistence, the average loss was around 60%, and by 90 DAE, it exceeded 65% for pod number. For marketable pods, the reduction was 62% at 45 DAE and 70% at 90 DAE compared to the no-weed treatment.

In the 60 cm spacing (Table 4), reductions were also substantial but occurred later. By 60 DAE, reductions in pod number, pod weight per plant, and total seed count per plant were around 70%, increasing to 78% by 90 DAE. Marketable pod production showed significant reductions earlier, with a 53% decrease in pod number at 45 DAE and 75% at 90 DAE.

Comparing productivity between spacings, there was greater significance up to 30 DAE, after which production decreased to nearly half. Despite higher total pod and seed production per plant in the 60 cm row spacing, plants in the 40 cm spacing had a higher mass of marketable pods up to this period. This suggests that while the wider spacing increased pod production, a larger percentage of the pods were nonviable and showed size differences (Figures 9 and 10).

Figure 9. Production of peanut plants without coexistence with weeds (**A**), with coexistence up to 60 DAE (**B**), and in permanent contact until harvest (**C**), with a spacing of 40 cm between rows.

Figure 10. Production of peanut plants without coexistence with weeds (**A**), with coexistence up to 60 DAE (**B**), and in permanent contact until harvest (**C**), with a spacing of 60 cm between rows.

Extrapolating data to a hectare, using the Boltzmann regression analysis (Table 5), peanut productivity in the absence of weeds was 9.91 and 6.53 tons per hectare for the 40 cm and 60 cm row spacings, respectively. Yield values refer to peanut pods including shells. With full weed infestation throughout the crop cycle, productivity dropped to 1.84 and 0.89 tons per hectare, highlighting productivity losses of 81% and 86% for the 40 cm and 60 cm row spacings, respectively (Table 5). Thus, final production varies with row spacing and the duration of weed coexistence.

Table 5. Parameters determined for Boltzman sigmoidal equations adjusted to productivity data (t ha^{-1}) depending on the periods of coexistence of the peanut crop with the weed community. Porto Formoso-São Miguel, Azores.

Parameters	40 cm	60 cm
A_1	9.91	6.53
A_2	1.84	0.89
d_x	13.87	14.87
R^2	0.96	0.98
Decrease in production (%)	81	86

obs.: A_1 (maximum production obtained in plants kept weeded throughout the cycle), A_2 (minimum production obtained in plants in coexistence with weeds during a maximum period of 105 days), d_x (parameter that indicates the speed of production loss depending on the time of coexistence) and R^2 (regression coefficient).

The researchers [25] tested a prostrate variety of peanut with a seeding density of 10 and 15 plants m^{-1}, in conditions free from weed interference, and achieved yields between 6000 and 6500 kg ha^{-1} for a row spacing of 60 cm. This result is like what was observed in the present study. However, the reduction in productivity when weeds were present throughout the entire growing cycle was about 60% according to these authors, whereas in this experiment, the loss exceeded 90% (Table 5).

In the 60 cm row spacing, the loss was higher because the crop had more difficulty covering the soil, which allowed the weed community to accumulate large amounts of fresh biomass, especially towards the end of the experimental period. This development led to increased shading and a greater likelihood of pest and disease issues, ultimately reducing and degrading the quality of the final product.

The rate of productivity reduction associated with weed interference (Table 5) was greater in the 60 cm row spacing arrangement. This was due to the large biomass gains by the weed community, which increased competition not only for nutrients and available water but also for light due to shading. In the 40 cm row spacing arrangement, there was less competition from weeds due to the greater ease with which peanut plants covered the soil, making it harder for weeds to compete for resources.

Other researchers working with different peanut genotypes in various regions have shown that weed competition can lead to significant losses in production, ranging from above 50% [9,25,26] to as much as 80% reduction [27,28]. This competition also complicates harvesting and diminishes the value and quality of the product.

3.3. Period Prior to Interference (PPI)

Allowing for a 5% reduction in peanut productivity, a period of only 5 days of coexistence with weeds was found for the 40 cm row spacing and 7 days for the 60 cm row spacing (Figure 11). This indicates a very short period of coexistence with weeds without significant productivity losses, highlighting the sensitivity of peanut plants to resource competition, especially during the early stages of vegetative development, as suggested by [19].

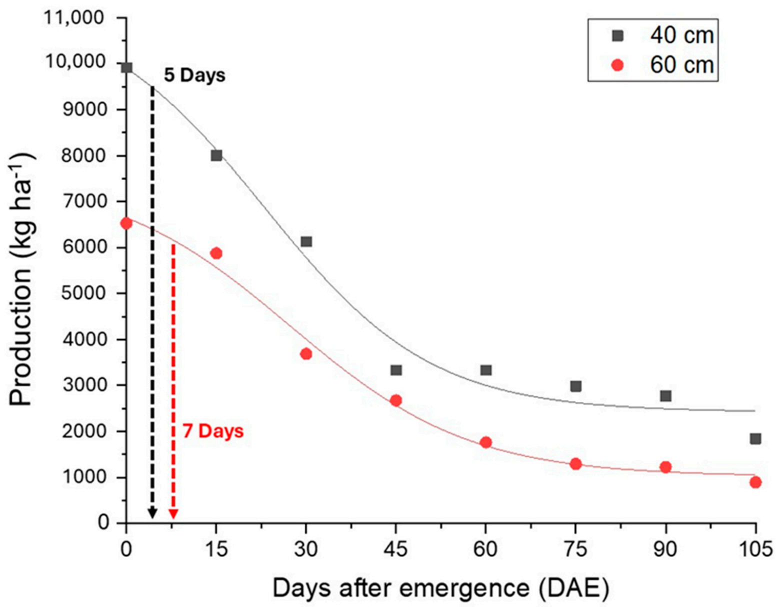

Figure 11. Period Prior to Interference (PPI) for the productivity reduction limit in peanut crop of 5% for row distances of 40 and 60 cm. Porto Formoso—São Miguel, Azores. The dotted vertical lines indicate the PPI, i.e., the maximum period during which weeds can coexist with the crop without causing yield losses greater than 5% (5 days for 40 cm spacing and 7 days for 60 cm spacing).

However, other authors found longer coexistence periods, exceeding 15 days for [26] and over 20 days for [25]. This difference may be attributed to the prostrate architecture of the genotypes used in those studies [25], which argue that upright cultivars tend to have shorter coexistence periods compared to prostrate cultivars, which helps to explain the differences in the periods obtained.

The Period Prior to Interference (PPI) for both spacings was a maximum of 1 week, regardless of the spacing used (Table 5 and Figure 11). This data point is of utmost importance to farmers, as it highlights the need to control weeds as quickly as possible, whether manually (biologically or in other ways), as in this experiment, or chemically. It is crucial to address weed issues early and not allow them to persist in the cultivation area for long periods, as this will lead to a drastic reduction in productivity.

4. Conclusions

Under the conditions of the experiment, in both tested spacings, the most relevant species were *Cyperus* spp., *Digitaria* spp., *Amaranthus blitum*, and *Portulaca oleracea*, which had the highest relative importance values (e.g., *Cyperus* spp. $\geq$ 40% RI throughout). The presence of weeds throughout the entire growing cycle resulted in losses exceeding 81% and 86% for plants sown at 40 cm and 60 cm spacings, respectively. The period prior to interference, with a 5% arbitrary reduction in productivity, was achieved with a maximum of 1 week of coexistence, demonstrating how sensitive peanut plants are to competition, especially during the early stages of their vegetative development.

Although the 60 cm row spacing resulted in a greater number of pods per plant in weed-free conditions, the 40 cm spacing provided more effective soil coverage and better suppression of weed growth. Therefore, in scenarios with limited weed control, the 40 cm spacing is recommended. When efficient and systematic weed control is feasible, the 60 cm spacing may also be used to maximize pod development.

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