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Research Article

More environmental resources consumption in low-input intercropped maize-cowpea leads to the suppression of weed growth

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Abstract: The current research was conducted to assess weed growth suppression in intercropped maize and cowpea related to the utilization of some environmental resources, including solar radiation, soil moisture, and space. The study was performed using a randomized complete block design with three replications. An additive series was selected to design intercropping patterns. The research was conducted in Shadegan, Khuzestan, during the 2022-23 growing season. Treatments were D_1 (100% of maize density in pure stand + 25% of cowpea density in pure stand), D_2 (100% of maize density in pure stand + 50% of cowpea density in pure stand), D_3 (100% of maize density in pure stand + 75% of cowpea density in pure stand) and D_4 (100% of maize density in pure stand + 100% of cowpea density in pure stand) and maize and cowpea sole cropping. According to the results, the patterns of intercropping utilize more solar radiation and soil moisture than pure stands of maize and cowpea. When the density of cowpea in mixed cropping patterns was increased, more solar radiation and soil moisture were utilized, with D4 exhibiting 35% and 15% solar radiation interception compared to pure stands of maize and cowpea, respectively. The moisture content of the soil at D4 was the lowest, with 80% less soil moisture compared to the pure maize stand. The efficiency for preventing weed growth was higher in intercropping patterns. When cowpea is cultivated at 25% of its pure stand (the lowest density), the weed suppression efficiency is 21% compared to sole maize. When cowpea was cultivated in its pure stand at 100% density (the highest density), the weed suppression efficiency was 36% compared to sole maize. Similar results were seen for a pure stand of cowpea. As a final remark, intercropping can reduce weed growth when cowpea is cultivated in its highest density.

Keywords: mixed cropping, sustainability, weed dry weight

Introduction

Weed compete with crops for acquiring environmental resources such as water, light, space, and nutrients. Furthermore, weeds host insects and pathogens. Therefore, weeds are a significant factor that reduces crop growth and yield. Weeds may utilize up to 30-50% of the

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applied fertilizer and can also decrease soil water content by 20-40% (Abdulkareem *et al*., 2024). It has been reported that yield losses due to weeds may reach up to 100% when crops are poorly established (Gu *et al.,* 2021). There are several chemical and nonchemical methods for weed control. Chemical control not only has negative environmental effects but also incurs high costs for farmers. In addition, weeds may become resistant to chemical control, meaning that a weed species gains the ability to survive the application of a herbicide that previously controlled it (Knezevic et al., 2017). Some nonchemical weed control methods also have limitations. For example, hand removal of weeds is time-consuming and expensive, and machinery control of weeds requires high diesel fuel, emits CO2, and increases the risk of soil erosion (in the case of soil tillage) (Benaragama and Shirtliffe, 2013). Thus, interest in alternative weed-removal methods has increased. An eco-friendly way to reduce weed growth is to increase biodiversity in agricultural environments. Intercropping is the most direct way to increase biodiversity in agricultural ecosystems (Gu *et al.*, 2022).

Intercropping is the practice of growing two or more crop species simultaneously in one field (Villegas-Fernandez *et al.*, 2024). Intercropping has various goals, including maintaining ecological balance (Eskandari and Ghanbari, 2009), increasing dry matter production, especially in systems with low inputs (Lithourgidis *et al*., 2011), better use of environmental resources including light, nutrients, and water (Javanmard *et al*., 2009) and, therefore, better control of weeds (Vasilakoglou *et al*., 2008). The reason for the increase in weed suppression in intercropping compared to sole cropping is the more efficient use of environmental resources (Yu *et al*., 2024). When appropriate species are selected, the components of intercropping will not compete for the same ecological niches but will utilize environmental resources in a complementary manner (Hauggaard-Nielson *et al*., 2003).

If the plants in an intercropping system share similar physiological and morphological characteristics, there may be competition between them for the use of environmental resources (Chai *et al*., 2013). It has been reported that the reduction of light received by soybean *Glycine max* L. in intercropping with cereals may lead to a decrease in its yield (Liu *et al*., 2010). Competition or complementarity in the consumption of environmental resources is crucial in intercropping and may occur between the components of intercropping during the early stages of growth (Eskandari and Ghanbari, 2013). However, the increased use of environmental resources is one of the advantages of intercropping. As observed in the intercropping of maize and wheat, water harvesting was approximately 11% higher than in pure cultivation (Hu *et al*., 2016). In other reports, increased light harvesting has been observed in intercropping (Yang *et al*., 2014; Munz *et al*., 2014; Feng *et al*., 2024; Jin *et al*., 2024). Various reports have been presented on the positive effects of mixed cultivation in nonchemical weed control. It was reported that in the intercropping of millet (Pennisetum sp) and soybean, the growth of weeds decreased due to the high tillering power of millet (Samarajeewa *et al*., 2006). In another study, it was observed that the increase in the number of maize plants in intercropping with beans led to a decrease in weed biomass (Rostami *et al*., 2009).

Considering the mutual effects of species in intercropping, this experiment aimed to investigate the use of environmental resources in the intercropping of maize and cowpea and its possible effect on reducing the dry weight of weeds compared to pure cultivation.

Materials and Methods

This experiment was conducted using a randomised complete block design (RCBD) with three replications in Shadegan, Khuzestan Province, during the 2022-23 growing season. The climate of the region was hot and dry, with a latitude of 32°29 `N, a longitude of 48°22` E, and an elevation of 5 m above sea level. Some soil characteristics are presented in Table 1.

Table 1 Some physical and chemical properties of the soil at the research site.

Depth (cm)	texture	P_2O_5 (ppm)	K_2O (ppm)	pH	EC ($mm.cm^{-3}$)	OC (%)
0-30	loam	18	285	7.91	2.39	0.45

The treatments included two pure cultivation treatments of maize and cowpea, as well as four different combinations of mixed cultivation using the additive series. In an additive series, the density of crops is higher than that of a pure stand. In this case, the density of one plant may remain constant while the density of the other plant increases, or the density of both plants may increase in intercropping. In pure cultivation treatments, maize and cowpea were planted at densities of 6.7 and 20 plants m^{-2}, respectively (Tajbakhsh, 1996; Koocheki and Banayan-Aval, 1993). Combinations of additive series maize and cowpea mixed cropping included D_1: 100% density of pure cultivation of maize + 25% of pure cultivation of cowpea, D_2: 100% density of pure cultivation of maize + 50% of pure culture of cowpea, D_3: 100% The density of pure maize cultivation + 75% of pure cowpea cultivation density and D_4: 100% of pure maize cultivation density + 100% pure cowpea cultivation density. Plots with dimensions of 4 × 3 meters were used for cultivation, which included six rows of four-meter-long plantings. On one side of each row, maize was sown at 100% of its pure culture density, and on the other side of the row, according to the combination of mixed crops, different ratios of cowpea density were added. In lower cowpea densities, the distance on the row was chosen in such a way that the entire length of the row was cultivated with cowpea**.**

In this research, a cross 704 (SC704) maize hybrid was used, which is a dual-purpose hybrid (seed and fodder) (Tajbakhsh, 1996). Maize and cowpea (Parto cultivar) were planted simultaneously on March 1, 2022. The first irrigation was done immediately after planting. Irrigation was done normally, when both plants needed water, because the water uptake by cereals and legumes in mixed cultivation is almost the same (Ofori and Stern, 1987). No chemical materials (fertilizer or pesticide) were applied during the experiment.

To investigate the effect of mixed intercropping on light absorption, photosynthetic active radiation (PAR) was measured three times during the growing season, once every two weeks, after the canopy establishment at intervals of 12-14 hours, using a photometer model SF-80T. For this purpose, the amount of light at the top of the canopy and the soil surface at five randomly selected points was measured in each plot, and its average was used as the absorption rate of photosynthetic active radiation for that plot (Eskandari and Ghanbari, 2009):

$$PL\ (\%) = [1-(L_1/L_2)] \times 100 \qquad [1]$$

In which, PL is the percentage of light passing through the canopy, L_1 is the light intensity at ground surface, and L_2 is the light intensity before reaching the top of the plants**.**

Considering that soil water balance was expected to be affected by planting systems, soil water content was measured three times during the growing season, after canopy establishment, at intervals of two weeks. For this purpose, sampling was conducted at three different points in each plot, and one sample from the mixture of samples was used to determine the soil moisture content by the weight method. In this manner, the samples were oven-dried (48 h at 70 °C), and then the moisture content of the soil was calculated based on the weight of the samples before and after drying (Eskandari and Ghanbari, 2013). The soil temperature was also measured at a depth of 0 to 10 cm three times during the growing season, and at three points in all plots. The average temperature at these three points was used as the soil temperature for that plot (Ghanbari-Bonjar, 2000).

At the harvesting stage, the aerial parts of the plant were harvested by hand from the surface of each plot and separated by species, including maize, cowpea and weeds. Broad-leaved weeds included pigweed *Amaranthus retroflexus*, purslane *Portulaca oleracea* and rough cocklebur *Xanthium strumarium*, and narrow-leaved weeds included cockspur grass *Echinochloa crus-galli*. The samples were oven dried (48 h at 70 °C), and the total dry weight per unit area was calculated.

The complementarity of intercropping components in the consumption of environmental resources was determined, using the following equation (Willey, 1990):

$$RYT = (F_{12}/F_{11}) + (F_{21}/F_{22}) \quad [2]$$

In which, RYT is the relative yield total, F_{12} is the weight of dry forage of cowpea in intercropping, F_{11} is the weight of dry forage of cowpea in sole cropping, F_{21} is the weight of dry forage of maize in intercropping, and F_{22} is the weight of dry forage of maize in pure stand.

Weed smothering efficiency by intercropping was measured using the following equation (Sharma and Banik, 2013):

$$ESW = [(DR_1-DR_2)/DR_2)] \times 100 \quad [3]$$

Where DR_1 is the dry weight of weeds in pure cultivation of maize and cowpea and DR_2 is the dry weight of weeds in mixed crops of maize and cowpea.

Analysis of variance of the data and mean comparison were carried out using MSTATC and Duncan's multiple range test, respectively.

Results

Table 2 presents the variance analysis of the data, and Table 3 displays the mean comparison for the measured traits. Planting systems had a significant effect on the absorption of photosynthetically active radiation (PAR) ($P < 0.05$) (Tables 2 and 3). The highest percentage of light absorption was observed in the intercropping of maize (100%) and cowpea (100%), which was not significantly different from the treatment of maize (100%) and cowpea (75%). Maise pure stand had the lowest amount of light absorption (Table 2).

Table 2 Analysis of variance of the effect of environmental absorption of intercropped maize and cowpea as double crop.

Source of Variance	df	Mean Square								
		Intercepted light			Soil moisture			Soil temperature		
		Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Replication	2	15.1	11.5	6.1	11.2*	2.5	13.1	4.2*	1.6	4.0
Cropping system	5	59.9*	136.6*	32.3*	49.2**	67.1**	250.3*	12.4**	30.1*	117.5**
Error	10	18.7	109.36	12.12	2.5	2.49	156.56	0.83	6.29	4.33
CV (%)		16.03	19.95	11.78	10.23	8.66	19.32	4.18	9.50	9.96

* indicates significant difference at $P \leq 0.05$ and ** indicates significant difference at $P \leq 0.01$.

Table 3 Mean comparison for absorbing different environmental resources by different cropping systems.

Cropping system	Intercepted light (%)			Soil temperature (ºC)			Soil moisture (%)		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
C	23.6d	43.9d	52.3d	25.0 a	28.3 a	32.7a	25.8 a	20.5 a	23.1b
D_1	38.7b	60.0b	76.9b	21.7 b	24.3 b	28.3b	20.6 b	19.4 ab	20.1bc
D_2	46.6b	62.0b	79.2ab	21.3 b	23.0 b	27.0b	20.4 b	19.0 ab	18.6bc
D_3	48.9ab	74.4ab	82.2a	19.7 c	21.0 bc	27.3ab	19.3 b	17.5 b	12.6c
D_4	51.5a	76.6a	82.5a	17.3 c	18.0 c	22.7c	18.9 b	11.1 c	10.4c
B	33.7c	57.5c	69.5c	25.0 a	27.7 a	33.3a	28.5 a	20.1 a	29.6a

Different letters indicates significant differences at $P \leq 0.05$ according to Duncan's multiple range test; C: maize pure stand; D_1: intercropping of maize (100%) and cowpea (25%); D_2: : intercropping of maize (100%) and cowpea (50%); D_3: : intercropping of maize (100%) and cowpea (75%); D_4: : intercropping of maize (100%) and cowpea (100%); B: cowpea pure stand.

Soil moisture content was significantly affected by cultivation systems (Tables 2 and 3). In the early stages of growth (the first stage of sampling), soil moisture was not significantly different between mixed cropping systems and was approximately 40% lower than that of pure crops. In the second stage of sampling, although the treatments of maize (100%) + cowpea (25%), maize (100%) + cowpea (50%) and maize (100%) + cowpea (70%) consumed more soil moisture than pure crops, the lowest soil moisture belonged to the intercropping treatment of maize (100%) + cowpea (100%).

According to the data, dry forage yield of both crop (maize and cowpea) as well as the dry weight of weeds was significantly affected by the cultivation systems (Table 4); So that the yield of dry matter in intercropping systems, especially in the case of adding cowpea with 75 and 100% of the optimum density (D_3 and D_4), was about 15 and 75% higher than that of the pure cultivation of maize and cowpea, respectively (Table 5).

The lowest (1.25) and the highest (1.58) relative yield totals (RYT) were observed in the intercropping systems of D1 and D4, respectively, indicating that increasing the density of cowpea in intercropping led to a more efficient use of environmental resources (Tables 6 and 7).

Table 4 Mean squares of the data for dry forage and weeds weights under the condition of different cropping systems.

Source of Variance	df	dry matter yield	Dry weight of weeds
Replication	2	43655.6	1457.43
Cropping system	5	1561674.8**	17299.83**
Error	10	9118.42	811.03
CV (%)		6.01	8.16

** :Significant at the 1% probability level.

Table 5 Mean comparison of the data for dry forage and weeds weights under the condition of different cropping systems.

Cropping system	Dry matter yield (g/m^2)	Weeds dry weight (g/m^2)
C	1621 b	421 ab
D_1	1771 ab	331 bc
D_2	1945 ab	318 bc
D_3	2015 a	293 c
D_4	2033 a	269 c
B	521 c	462 a

Different letters indicates significant differences at $P \leq 0.05$ according to Duncan's multiple range test; C: maize pure stand; D_1: intercropping of maize (100%) and cowpea (25%); D_2: intercropping of maize (100%) and cowpea (50%); D_3: intercropping of maize (100%) and cowpea (75%); D_4: intercropping of maize (100%) and cowpea (100%); B: cowpea pure stand.

Table 6 Mean square of the data for relative yield total (RYT) and the efficiency for prevention of weed growth (ESW_m and ESW_c) under the condition of different intercropping systems.

Source of Variance	df	RYT	ESW_m	ESW_c
Replication	2	0.053*	30.25*	4.00^{ns}
Cropping system	3	0.205*	129.0*	110.75*
Error	6	0.049	28.25	16.0
CV (%)		6.17	18.63	11.19

* and ns: significant at $P \leq 0.05$ and not significant, respectively.

Table 7 The effect of different intercropping systems of RYT.

Intercropping system	RYT
D_1	1.25c
D_2	1.47b
D_3	1.56a
D_4	1.58a

D_1: intercropping of maize (100%) and cowpea (25%); D_2: intercropping of maize (100%) and cowpea (50%); D_3: intercropping of maize (100%) and cowpea (75%); D_4: intercropping of maize (100%) and cowpea (100%); Different letters show significant difference at $P \leq 0.05$ according to Duncan's multiple range test.

Broad-leaved weeds, including pigweed *Amaranthus retroflexus*, purslane *Portulaca oleracea*, and rough cocklebur *Xanthium strumarium*, and narrow-leaved weeds, such as cockspur grass *Echinochloa crus*-galli, were found in sole and inter-cropping patterns. Dry weight of all weeds, except *Xanthium strumarium* was affected ($P \leq 0.01$) by cropping patterns (Fig. 1).

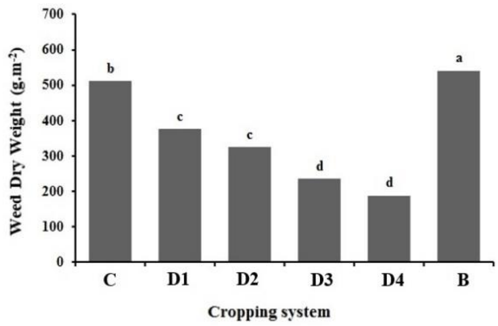

Figure 1 Effect of cropping system on weeds dry weight (g.m^{-2}).
Different letters indicates significant differences at $P \leq 0.05$ according to Duncan's multiple range test; C: maize pure stand; D_1: intercropping of maize (100%) and cowpea (25%); D_2: intercropping of maize (100%) and cowpea (50%); D_3: intercropping of maize (100%) and cowpea (75%); D_4: intercropping of maize (100%) and cowpea (100%); B: cowpea pure stand.

The process of changes in the dry weight of weeds was similar to that of the product, resulting in a smothering efficiency of 27% and 35% compared to sole cropping of maize and cowpea, respectively (Figs. 2 and 3). In other words, the weed population in intercropping was 21% and 35% lower than that of pure stands of maize and cowpea, indicating that the increase in dry matter production in intercropping systems has also led to a decrease in the weed dry weight.

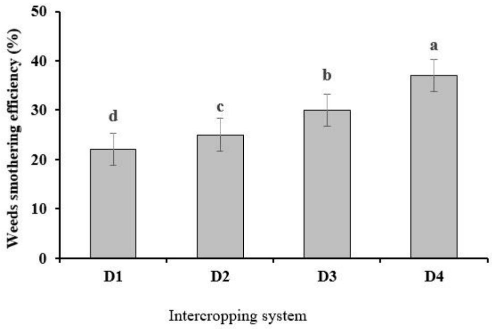

Figure 2 The effect of different cropping system on the prevention of weed growth (ESW) compared to maize pure stand.
D_1: mix cropping of corn (100%) and cowpea (25%); D_2: mix cropping of maize (100%) and cowpea (50%); D_3: mix cropping of maize (100%) and cowpea (75%); D_4: mix cropping of maize (100%); Different letters show significant difference at $P \leq 0.05$ according to Duncan's multiple range test.

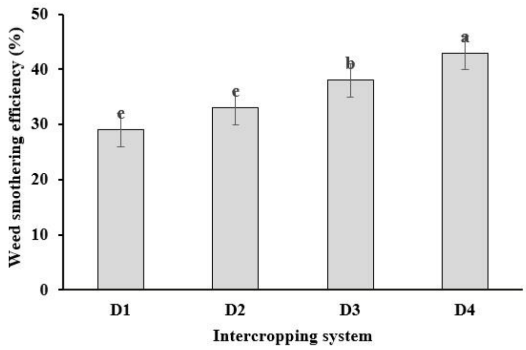

Figure 3 The effect of different cropping system on the prevention of wed growth (ESW) compared to cowpea pure stand.
D_1: mix cropping of corn (100%) and cowpea (25%); D_2: mix cropping of maize (100%) and cowpea (50%); D_3: mix cropping of maize (100%) and cowpea (75%); D_4: mix cropping of maize (100%); Different letters show significant difference at $P \leq 0.05$ according to Duncan's multiple range test.

Discussion

Due to the difference in the arrangement of foliage and the shape of the canopy (morphological differences), maize and cowpea in intercropping can be more efficient in absorbing PAR. The light that is not absorbed by the maize is absorbed by the cowpea at the bottom of the canopy, resulting in increased efficiency of PAR absorption. In intercropping, especially during the early stages of growth, light is distributed more evenly across the leaf surface, which increases the efficiency of intercropping in converting photosynthetically active radiation (Jahansooz *et al*., 2007). Similar results regarding more absorption of PAR in intercropping have been reported by other researchers (Ghanbari *et al*., 2010; Eskandari, 2011; Kanton and Dennett, 2008). In a research, it was announced that the intercropping of wheat and beans absorbs PAR more efficiently than the pure cultivation, because the solar radiation that may be wasted due to the low growth of wheat at the beginning of the season and aging of the beans at the end of the season, can be used more efficiently by growing a mixture of wheat and beans (Ghanbari-Bonjar, A. and Lee, H. 2002), which is consistent with the results of the present research.

The trend of higher soil moisture consumption in mixed cropping treatments compared to pure cultivation (especially pure cowpea cultivation) was also maintained at stage 3 (Table 2). The soil moisture content in the pure corn cultivation was higher than in the mixed cultivations. The existence of differences between the components of mixed cultivation in terms of root characteristics, especially root depth, allows mixed cultivation to utilise a larger volume of soil to absorb water with higher efficiency (Peter *et al*., 1999).

Since the soil temperature under the canopy of mixed crops was lower than that of pure maize cultivation (Table 3), the lower amount of soil moisture content in intercropping treatments compared to pure corn cultivation cannot be due to more evaporation from the soil surface. Due to their more compact root systems (in terms of length and density) (Eskandari, 2020), mixed crops can absorb water from the soil layers, resulting in a drier soil profile compared to pure crop plots (Stoltz and Nadeau, 2014).

It was reported that in the mixed cultivation of wheat and lentils, the difference in components in terms of root characteristics increased the efficiency of water use and yield (Ahlawat and Aharama, 1985), which is consistent with the findings of the present experiment.

According to the results, the interspecific competition was lower than the intraspecific competition. Maize and cowpea, at least partially, utilized environmental resources differently, resulting in greater dry matter production in intercropping systems compared to sole cropping systems. In fact, more absorption of photosynthetically active radiation and soil moisture content (Table 3) in intercropping led to more dry matter production in intercropping compared to pure cultivation.

The RYT denotes the benefits of an intercropping system in utilising environmental resources more effectively than their pure stands. The RYT value greater than unity (1.0) indicates the complementarity of the intercropping components in environmental resource acquisition, while a value less than one (1.0) is considered a poor performance of the intercrops in utilising environmental resources (Maitra *et al*., 2021). However, in all mixed cropping treatments, the RYT was greater than one, indicating the advantage of mixed cropping over pure cropping in terms of resource consumption. In other words, maize and cowpea were complementary in their use of environmental resource acquisition. Due to the morphological difference (arrangement of branches and leaves and the shape of the canopy), maize and cowpea intercropping can be more effective in absorbing PAR. The light that is not absorbed by maize at the top of the canopy is absorbed by cowpeas at the bottom of the canopy and thus increases PAR absorption. Solar radiation, which may be wasted due to the low growth of maize at the beginning of the season and the senescence of cowpeas at the end of the season, can be used more efficiently by cultivating a mixture of maize and cowpea. Similar results have been reported in barley-vetch intercropping (Mohsen Abadi *et al*., 2007) and maize-millet intercropping (Shaygan et al., 2008), indicating the complementarity of intercropping components in the utilisation of environmental resources.

Covering a larger soil surface and increasing plant diversity in mixed cropping have been introduced as two important factors in intercropping that reduce the growth of weeds (Eskandari, 2020), as these factors limit the availability of environmental resources for weeds. Light limitation has been identified as a crucial factor in reducing weed growth (Eskandari, 2020). In this study, maize with a high height was found to be effective in reducing light on the ground surface. On the other hand, cowpea, with its creeping structure and greater ground surface coverage, provided light for shorter weeds, leading to lower weed growth.

Since intercropping produced more dry matter than pure cropping, it is expected that the use of environmental resources in intercropping was more than pure cropping, which limited the growth of weeds in intercropping. More soil surface coverage and greater plant diversity in intercropping have been introduced as two important factors in mixed cultivation that reduce the growth of weeds (Poggio et al., 2005), as these factors decrease the provision of environmental resources for weeds.

Light limitation has been identified as a crucial factor in reducing weed growth (Willey, 1990). In the current research, maize with a higher height than cowpea was more effective in reducing light on the ground surface. On the other hand, cowpea, with its creeping structure and ability to cover a larger ground surface, provides less light for weeds. In other research, reducing the growth of weeds has been identified as one of the benefits of intercropping (Midya et al., 2005; Banik et al., 2006; Seyedi et al., 2012), a finding consistent with the results of the present study.

Conclusion

Maise and cowpea had a complementary relationship in the use of environmental resources, such as water, light, and space, because the relative yield total (RYT) in all intercropping treatments was greater than one. The limitation of environmental resources in intercropping reduced the growth of weeds, because the effectiveness of weed suppression in mixed cultivation was higher than that of pure cultivation. Therefore, it is recommended to use the intercropping of maize and cowpea with 100% density of both plants to produce dry matter to suppress weed growth.

Statement of Conflicting Interests

The Authors state that there is no conflict of interest.

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جلوگیری از رشد علف‌های هرز در کشت مخلوط کم‌نهاده ذرت و لوبیا با مصرف بیشتر منابع محیطی

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چکیده: پژوهش حاضر با هدف ارزیابی رشد علف‌های هرز در کشت مخلوط ذرت و لوبیا در ارتباط با مصرف برخی منابع محیطی اجرا گردید. آزمایش به‌صورت بلکوهای کامل تصادفی در سه تکرار انجام شد. برای طراحی الگوی کشت مخلوط، از روش افزایشی استفاده شد. پژوهش در شهرستان شادگان، استان خوزستان، در طول فصل زراعی ۱۴۰۲-۱۴۰۱ انجام شد. تیمارها شامل D_1 (۱۰۰ درصد تراکم کشت خالص ذرت + ۲۵ درصد تراکم کشت خالص لوبیا)، D_2 (۱۰۰ درصد تراکم کشت خالص ذرت + ۵۰ درصد تراکم کشت خالص لوبیا)، D_3 (۱۰۰درصد تراکم کشت خالص ذرت + ۷۵ درصد تراکم کشت خالص لوبیا) و D_4 (۱۰۰درصد تراکم کشت خالص ذرت + ۱۰۰ درصد تراکم کشت خالص لوبیا) بود. طبق نتایج، الگوهای کشت مخلوط در مقایسه با کشت خالص ذرت و لوبیا، مقدار بیشتری از تشعشعات خورشیدی و رطوبت خاک را مصرف کردند. وقتی تراکم لوبیا در الگوهای کشت مخلوط افزایش یافت، میزان بیشتری تشعشعات خورشیدی و رطوبت خاک مورد بهره‌برداری قرار گرفت جایی‌که D_4 در مقایسه با کشت خالص ذرت و لوبیا به‌ترتیب ۳۵ و ۱۵ درصد جذب تشعشعات خورشیدی بیشتری داشت. محتوای رطوبتی خاک در تیمار D_4 کم‌ترین مقدار را داشت جایی‌که ۸۰ درصد کم‌تر از رطوبت خاک در کشت خالص ذرت بود. کارآیی جلوگیری از رشد علف‌های هرز در الگوهای کشت مخلوط بیشتر از کشت خالص بود. وقتی لوبیا در ۲۵ درصد تراکم کشت خالص کشت شد (کم‌ترین تراکم) کارآیی جلوگیری از رشد علف‌های هرز ۲۱ درصد بیشتر از کشت خالص ذرت بود. وقتی لوبیا در ۱۰۰ درصد تراکم کشت خالص کشت شد (بیشترین تراکم) کارآیی جلوگیری از رشد علف‌های هرز ۳۴ درصد بیشتر از کشت خالص ذرت به‌دست آمد. نتایج مشابهی در مورد کشت خالص لوبیا ثبت گردید. به‌عنوان نتیجه نهایی، کشت مخلوط، زمانی‌که لوبیا در بالاترین تراکم خود کشت شود، می‌تواند در کاهش رشد علف‌های هرز مؤثر باشد.

واژگان کلیدی: پایداری، کشت درهم، وزن خشک علف‌هرز