

Control potency of corn and soybean intercropping on weeds at different irrigation condition

Abstract

For study of Control potency of corn and soybean intercropping on weeds at different irrigation condition a field experiment was conducted using split plot with three replications in Zanjan region in 2010-2011 growing season. Irrigation factor in main plot were inclusive 7, 9 and 11 day once irrigation and cropping pattern factor comprised, pure cropping of corn (100%), pure cropping of soybean (100%), replacement (2:2) and additive intercropping of corn (100%) and soybean (20%). The gathered results showed that the highest yield obtained in the control group and the 9 days irrigation regimens. There were not any significant differences in yield components between the control group and the 9 days irrigation regimen. The highest grain yield was obtained from the additive intercropping pattern. Irrigation level had no effect on yield of soybean, and the highest yield was obtained in sole cropping of soybean, but, it did not show significant difference with intercropping. The interaction between irrigation and cropping pattern is not significant in any of the parameters studied in soybean and corn. The results of variance analysis showed no significant difference among irrigation period at dry mater in all weeds studied. Among pattern cropping at dry mater in all weeds were significant difference at 1% ($p < 0.01$). The results of means comparison of weeds dry mater showed that additive intercropping had lowest weeds dry mater except foxtail grass than other patterns cropping. Pure cropping had highest weeds dry mater than intercropping.

Keywords: Pattern cropping; Additive intercropping; Replacement intercropping; Pure cropping; Weeds

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Introduction

Due to the incidence of problems by indiscriminate application of chemicals in agriculture, most of the farmers have focused their attention on sustainable agriculture. The sustainable agriculture should not only be regarded as a set of methods, but it can be considered as some kind of vision, where various economic, social and even philosophical aspects are considered.¹⁻³

Sustainable agriculture has many advantages in comparison of using solar energy and its conversion to agricultural products, without soil, water and the environment degradation.⁴ Intercropping is one of the main components of sustainable agriculture which led to yield increases and greater use of plants from environmental factors. Plant community cover land over a shorter period of time in intercropping and lead to the absorption or efficiency of light.⁵ In intercropping, biological interactions and mutual impacts of these factors is one of the interesting subjects to improve production systems. Nowadays, it has been confirmed that the efficiency of the resources could be used to improve the sustainable agriculture.

Water is one of the major factors in arid and semiarid regions.⁶ Furthermore, population growth along with the natural lack of water and indiscriminate water consumption in agriculture need more attention. This is especially having particular importance in arid and semiarid places such as Iran. In this regard research activities about deficit irrigation seem necessary and urgent in this field in order to enhance sustainable agricultural development and cultivation of fertile lands.

Understanding of the relationships between deficit irrigation and soil with every stages of crop's growth, application of modern methods of irrigation, and improving irrigation efficiency all would be helpful in this regard. The intercropping is one of the agricultural strategies for increasing water productivity to make maximum use of soil moisture.^{7,8}

Weed through competition for nutrients, water and light damage to crops, thereby leading to reduced performance are. The hand with the development of agricultural monoculture day will be more reliance on chemical control methods. This dependence addition to environmental and human losses that are this dependence addition to the human and environmental damage that is caused to a range of herbicides for weed resistance and the need for higher doses of herbicide stronger and increase the cost of production comes.⁹ All of this has led scientists to believe that the implementation of an integrated weed control system. The system determines the need to control the most important objectives constitute.¹⁰ Intercropping systems use resources more effectively than monoculture based and therefore reduced the amount of material available for weeds.¹¹

Corn is an herb that due to high compatibility with most plants can be grown in mixture so that about 60 percent of maize in tropical Latin America, and is often mixed agriculture with herbs such as beans and soybeans grown.^{12,13} Singh and Tripathi^{14,15} the trial found the number and dry weight of weeds between the rows of corn planted two rows of beans dropped sharply. They said that they reduce the damage caused by weeds in intercropping maize with beans, covered by the soil better than the monoculture of corn. Study on the effect additive intercropping sorghum and cowpea on the population and weed

biomass at Deficit irrigation conditions showed The weed biomass was grown under irrigation levels and patterns So that lowest weed biomass was obtained in the control treatment and With the increase in bean intercropping with sorghum weed biomass was significantly decreased.¹¹

Material and methods

This study was carried out in farming season of 2012 in Zanjan University Research Farm (Zanjan, Iran). Zanjan has an average annual rainfall of 293.5mm, and have dry climate. The city is placed at 26degrees and 37minutes north latitude and 48 degrees and 49.5minutes east longitude. Zanjan is located at the high of 1634 meters above sea level. This experimental study was carried out at three replicate on a divided plots. For obtaining the best irrigation regimens for the control group (the seven days irrigation regimen) the crop water requirement (maize) was calculated using Zanjan synoptic data over the past 10years using the Crop Water software (version 8). These data showed that the final water requirement for the main crop is 9460 cubic meters per acre.

The different irrigation regimens were applied on main plots in the seven (control group), nine and eleven day's irrigation regimens (test groups) until the end of the growing season. Application of different irrigation interval was done after the four-leaf stage of corn plant. The amount of irrigation was based on the crop (maize) need. The amounts of water consumption were measured regularly in each period using meter mounted in the ground. The cropping pattern was the second dividing agent and the main groups were divided to the four subgroups. These subgroups were as follows:

- i. Corn monoculture (100 percent);
- ii. Soybean monoculture (100%);
- iii. Additive intercropping composes of 100% maize plus 20% soya;
- iv. Replacement intercropping of corn and soybean with 2:2 mixing ratio (50% soy +50% corn).

Three separate surveys of intercropping pattern was carried out at Zanjan University Research Farm and the above mentioned intercropping strategies were found as proper intercropping patterns. The distances of rows for corn and soybean cultivation choose as 75 and 37.5cm, respectively. The 20% of the desired level were considered as optimum densities of maize. The ratio of the pair wise and crop equivalent units was carried out for calculation of additive intercropping. Planting strategies for this study was carried out as follow:

- i. Monoculture of crops were planted using wooden ruler with 15cm intervals between plants;
- ii. Monocultures of soybean were planted with 8 cm spacing and on both sides of the stacks.

In additive intercropping of maize, seeds were planted with desired spacing and with 15 cm between each two plant at one side of watermark, and soy with ratio of 20% in another side of watermark. In replacement intercropping, corn seeds were planted in 2rows with optimal density and 8 row of soy at its side. There were five rows, six meter long for monoculture and additive intercropping.

The Maxima spices were used for corn which considered as 3V at present study. The seed is produces, sorting, and packing in Hungary with precise care and under controlled conditions regarding to the similar studies such as Ghorchiyani et al.,¹⁶ study. The Williams soy cultivar was used as soybean sample which is a common cultivar in the most provinces of Iran and belongs to unlimited growing and medium ripening species and was bought from Seed and Plant Improvement Institute (Karaj, Iran). The irrigation operation was conducted based on main plants water needs (corn), but crust breaking, cleaning and other farming works were performed based on conventional routines of the region. Due to the lack of a pest or disease, no chemicals or pesticides were utilized during the growing season. Sampling for yield and biological yield measurement of both plants were performed at the end of the growing season. For estimation of the dry weight of weeds, they are collected in three steps (once at a month) in the related plot by throwing a 50×50cm quadrate randomly and were placed in a 60°C oven for 48h to measure their dry weight, after removal of weeds from each other.

Common indices and methods were used for comparison of the usefulness of intercropping and monoculture cropping. Many studies uses the land equality ratio is a criteria used by researcher for assessment of intercropping effects. This criterion specifies that how much land is necessary for harvesting same amount of product from one acre intercropping cultivar in comparison of a monoculture crop. In other words, it's explaining the ratio of land necessary for monoculture compared to intercropping. To determine this index, the LER equation been used as explained in equation 1.

Equation (1):

$$LER = \sum n = I m Y_i Y_{ii}$$

Where the Y_i is the yield of species (per unit area) in intercropping and the Y_{ii} explains the maximum yield of the same species (per unit area) in monoculture farming.

Dominance index will be used if the two species are mixed together using an alternative method, which is calculated from the equation 2 as explained as follows.

Equation (2):

$$A_{ij} = [(W_{ij}W_{ii}) - (W_{ji}W_{jj})] / 2$$

Where the A_{ij} is the predominance of i species to species j , W_{ii} and W_{jj} are the indicator of i and j yield in monoculture and the W_{ij} and W_{ji} shows the i and j yield in Intercropping.

For utilization of the abovementioned index in additive intercropping the equation 3 is used as follows:

Equation (3):

$$A_{ij} = (Y_{ij}Y_{ii}) - (Y_{ji}Y_{jj})$$

Where the Y_{ii} and Y_{jj} are the yield species per unit area in pure culture and the Y_{ij} and Y_{ji} indicates the yield species per unit area in intercropping

If $A=0$, shows that there is no rivalry between the two species. Otherwise, there is a competition between the two species.

To measure photo synthetically active radiation reached the bottom of the canopy, Photo synthetically active radiation measured by the device ACCU PAR model LP-80 in 3 Steps (Once every 30

days). Measured above the canopy of corn, soybean canopy above and below the canopy occurred.

Finally, the results were reported by descriptive statistics using the MSTAT-C (version 2.10) software package. The comparison of means was performed using the Duncan's multiple range tests. A 5% or lower p-value is considered to be statistically significant.

Results and discussion

The results showed that soybean grain yield and biological yield was influenced by the cropping pattern ($P < 5\%$). Whereas, soybean grain yield and biological yield is not affected by irrigation Course. The results of the ANOVA statistics test of the irrigation course effect and cultivation pattern on grain yield and biological yield of corn and soybeans are shown in Table 1.

The results of comparing means showed that the highest monoculture's yield rate of soy seed was 1240kg/ha. But there was no significant difference between the replacement intercropping patterns. The lowest seed yield of soybean from additive intercropping pattern was 165.8kg/ha. It seems that the reduction of soybean yield was related to lower soya density, limited light source in additive intercropping and its negative effect on flowering, and shading of corn bush. Inhibitory effect of a grass species on limiting light for a legume species have been reported.¹⁷

As shown in Table 2, the maximum grain yield was related to the 7days irrigation regimen (9446kg/ha) and the minimum value was related to the eleven days irrigation regimen (6459kg/ha). However, the irrigation period of every seven day and nine day was not significantly different regarding to this trait.

As claimed by Tavakoli et al.,¹⁸ the decline of yield wasn't exactly corresponds with water use reduction, but it's generally nonlinear trend; and previous results shown that reduction of yield is much less than water consumption decline. It seems that it's the main reason of insignificant relationship between corn yield and raise of irrigation day from 7 to 9days. The results of the comparison of means Table 2 showed that the highest seed yield was obtained from the additive intercropping, but it was not significantly different from monoculture cropping. There wasn't any competitive pressure of soya on corn in the additive intercropping, but also because of its proximity to corn, there has been a slight increase in corn production and possibly soy have been contributed with corn yield (Table 3).

Dominant weed species observed in the field include pigweed, lambs quarters, foxtail, barnyard grass and field bindweed. The relative density of weed species is shown in Figure 1. The statistical analysis results of crop pattern on the dry weight of weeds are shown in Table 4.

Dry weight of Common lamb's quarters: the effect of intercropping on dry weight of lamb's quarters was significant at 1% probability level (Table 1). Soybean monoculture with 60.54grams per square meter has devoted the highest and additive intercropping with 20.14grams per square meter has devoted the lowest dry weight of lambs quarters (Figure 2). With respect to Figure 2, a difference can be seen statistically between the additive intercropping with alternative intercropping as well as maize monoculture and soybean monoculture. It seems that the competitive pressures arising from the presence of maize and soybean together results in reduced weed growth in intercropping treatments compared to monoculture. In intercropping,

especially additive intercropping, the rate of photosynthetic active radiation reached the bottom canopy is lower, resulting in germination and reduced weed growth (Figure 3). Other researchers have also reported a reduction in the weed dry weight in intercropping systems than monoculture.¹¹

Dry weight of slender foxtail: Results from the analysis of variance showed that the effect of cultivation type on dry weight of foxtail was significant at probability level of 5% (Table 1). As shown in Figure 4, the foxtail dry weight is affected by culture type and minimum and maximum dry weight of foxtail are dedicated to alternative intercropping treatments with 13.89g per square meter and soybean monoculture with 46.62grams per square meter, respectively. According to Figure 4, intercropping decreased the dry weight of foxtail significantly, but the monoculture of both crops (maize and soybean) increased dry weight of foxtail to both intercropping treatments. It has been observed that the ability of intercropping to compete with weeds depends on factors such as crops, cultivars, and so on. In intercropping systems, because of the presence of several plants and systems multi-layered as well as crops better use of photosynthetically active radiation, the weeds' problem is less than monoculture system. It seems that lower weed dry weight in alternative and additive intercropping is due to this reason.

Dry weight of creeping jenny

According to the analysis of variance of traits, the effect of cultivation type on dry weight of field bindweed was significant at 1% probability level (Table 1). As shown in Figure 5, maize monoculture treatment and additive intercropping with 4.013 and 0.282grams per square meter have devoted the highest and lowest dry weight of field bindweed, respectively. According to Figure 5, no significant difference was statistically observed between the whole pattern of maize and soybean monoculture with each other and the additive and alternative cultivation. However, the field bindweed dry weight was decreased by applying intercropping treatments and additive intercropping showed the maximum decrease in terms of dry weight of field bindweed.

Pigweed dry weight: based on the table of analysis of variance (Table 1), cultivation type had a significant effect on the dry weight of Pigweed at probability level of 1%. As seen in Figure 6, the maximum dry weight of Pigweed is devoted to soybean monoculture treatment with 18.05g per square meter and lowest dry weight of Pigweed to additive intercropping treatment with 9.843grams per square meter, respectively. According to Figure 6, no difference was statistically observed between the soybean monoculture treatments and alternative intercropping.

Evaluation of intercropping advantages

The results of highest land equality ratio calculation shown that land equality ratio were greater than one except every 11day irrigation treatment course; and intercropping is more advantageous than monoculture system, so that highest land equality ratio have been observed in a1b4 cropping pattern (intercropping replacement and every 7day irrigation) which was 1.628 (Table 5). This LER value indicated that yielding from a hectare of land in intercropping system was 8723.52kg (sum of corn and soy crop), and we need 62% more land for producing the same amount of crop in monoculture system.

Dominance index (A)

The index shows the dominance of species A to species B in intercropping. If the value of this index is equal to zero indicates that there is no rivalry between the two species, in other words, intraspecific competition is equal to intraspecific competition. In other states, negative and positive signs indicate the dominance and recessive species, respectively.

The results of calculating the dominance index (Table 5), (Table 6) showed that in all treatments of additive intercropping, maize was dominant and soybean was recessive and at all alternative intercropping treatments, soybean was dominant and maize was recessive. When the condensation of a plant in the intercropping is more, it will be dominant and vice versa, when its condensation is reduced, it will be recessive. Study of the distribution of photosynthetically active

radiation (PAR) in monoculture and intercropping canopy profiles

Results of analysis of variance of photosynthetically active radiation at the above soybean and maize canopy and bottom of mixed canopy are shown in Table 2. Effect of irrigation levels on the amount of photosynthetically active radiation at the above soybean and maize canopy and bottom of mixed canopy was not significant. But the effect of planting pattern on photosynthetically active radiation was significant at 1% level. The results of the comparison of means (Figure 6) showed that the additive intercropping system compared to the alternative and monoculture patterns in utilization of photosynthetically active radiation was more effective and prevented a waste of light. So that, the least photosynthetically active radiation reached to soil of the bottom of canopy of intercropping was obtained as 368.8 micromoles per square meter in second from additive pattern.

Table 1 ANOVA of the effects of irrigation course and cultivation pattern on Grain yield and biological yield of corn and soybeans

Variation Resources	df	ms			
		Corn Grain Yield	Biological Yield of Corn	Soybean Grain Yield	Biological Yield of Soybean
Iteration	2	8988418.83 ^{ns}	200000.94 ^{ns}	675352.253 ^{ns}	31379.07 ^{ns}
Irrigation Course	2	23379262.09*	1401691.03**	1045347.64 ^{ns}	29654.71 ^{ns}
First Error	4	1565386	167484	400357.8	56963.03
Intercropping	2	31660019.85**	162003.387**	3275710.533**	215735.11**
Irrigation × Intercropping	4	1068931.25 ^{ns}	92007.89 ^{ns}	206561.280 ^{ns}	16540.54 ^{ns}
Second Error	12	3501387	81516.32	184966.5	25902.6
Coefficient of Variation (Percent)		7.51	16.54	16.03	30.32

Table 2 Comparison of the effects of irrigation level and cultivation pattern on Grain yield and biological yield of corn and soybeans

Feature treatment	Corn grain yield	Biological yield of corn	Soybean grain yield	Biological yield of soybean
A1	9446 ^a	21254 ^a	1043 ^a	6027 ^a
A2	8271 ^a	17157 ^b	1074 ^a	5012 ^a
A3	6459 ^b	13363 ^c	468.4 ^a	4713 ^a
B1	9016 ^a	17713 ^b	-	-
B2	-	-	1240 ^a	4698 ^b
B3	9262 ^a	21341 ^a	165.8 ^b	4157.4 ^b
B4	5898 ^b	18563 ^a	1179 ^a	7068.2 ^a

A1, irrigation every seven days; A2, irrigation every nine days; A3, irrigation every 11 days B1, maize monoculture; B2, soy monoculture; B3, additive intercropping (20% soy+100% corn); B4, replacement intercropping with 2 to 2 ratio

Table 3 Comparison of the effects of irrigation and intercropping of maize and soybean traits

Irrigation	Cropping pattern	Biological yield of corn	Corn grain yield	Biological yield of soybean	Soybean grain yield
A1	B1	1987.02 ^{abc}	10453.7 ^a	-	-
	B2	-	-	544.31 ^{bc}	1433.20 ^a
	B3	2039.23 ^{ab}	10470.3 ^a	447.08 ^c	204.91 ^b
	B4	2349.84 ^a	7233.6 ^{abc}	803.86 ^{ab}	1489.91 ^a
A2	B1	1686.82 ^{bcd}	8988.2 ^{ab}	-	-
	B2	-	-	491.25 ^c	1558.46 ^a
	B3	1461.16 ^{cd}	10179.5 ^a	515.45 ^{bc}	179.40 ^b
	B4	1999.20 ^{abc}	5646.8 ^{bc}	853.13 ^a	1482.72 ^a
A3	B1	1310.71 ^d	7306.8 ^{abc}	-	-
	B2	-	-	373.88 ^c	727.89 ^{ab}
	B3	1407.16 ^d	7257.3 ^{abc}	284.66 ^c	113.08 ^b
	B4	1290.95 ^d	4812.7 ^c	463.45 ^c	564.25 ^b

A1, irrigation every seven days; A2, irrigation every nine days; A3, irrigation every 11 days B1, maize monoculture; B2, soy monoculture; B3, additive intercropping (20% soy+100% corn); B4, replacement intercropping with 2 to 2 ratio

Table 4 Mean squares for effect of irrigation and cropping pattern on the dry weight of weeds

Variation Resources	ms					
	df	<i>Amaranthus retroflexus</i>	<i>Chenopodium album</i>	<i>Alopecurus myosuroides</i>	<i>Convolvulus arvensis</i>	<i>Echinochloa crusgalli</i>
Iteration	2	890.154 ^{ns}	12979.10 ^{**}	6476.927 [*]	24.379 ^{ns}	791.159 ^{ns}
Irrigation Course	2	240.559 ^{ns}	345.176 ^{ns}	748.152 ^{ns}	0.735 ^{ns}	34.240 ^{ns}
First Error	4	367.813	205.313	504.121	11.416	559.45
Intercropping	3	255.097 ^{ns}	6669.680 ^{**}	1767.575 [*]	22.574 ^{**}	365.858 ^{**}
Irrigation × Intercropping	6	86.640 ^{ns}	77.265 ^{ns}	16.959 ^{ns}	1.563 ^{ns}	112.569 ^{ns}
Second Error	18	114.165	372.084	467.523	236.783	236.783
Coefficient of Variation (Percent)		11.81	16.07	15.76	12.61	19.47

** , * and ns are significance level at 1%, 5% and non-significant, respectively.

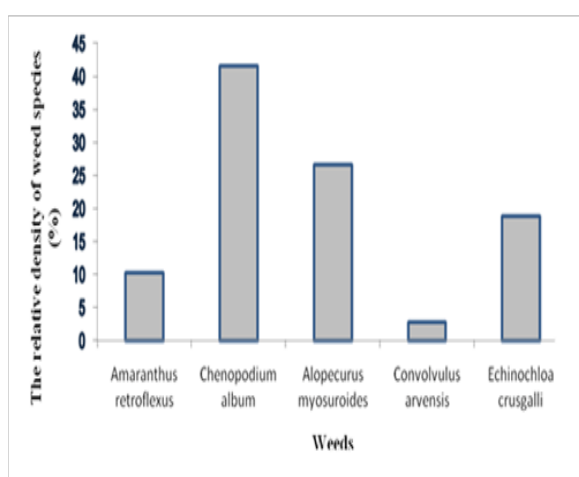
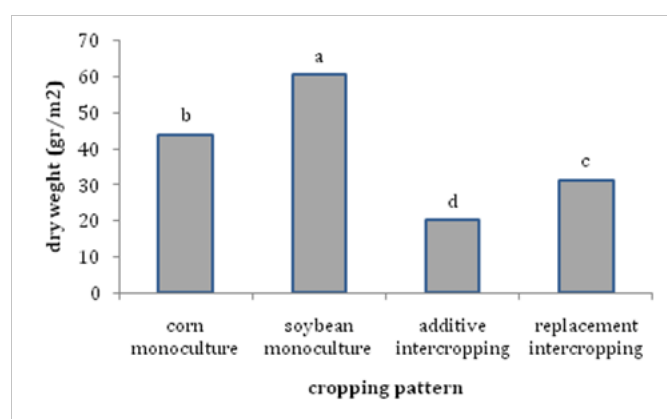
Table 5 Values of evaluation criteria of the usefulness of different intercropping treatments

Corn Grain Yield (Kg/Ha)	Soybean Grain Yield (Kg/Ha)	LER	A	
A1B1	10753.65	-	-	-
A1B2	-	1433.198	-	-
A1B3	10350.3	204.908	1.093	0.858
A1B4	7233.612	1489.908	1.628	-0.173
A2B1	8988.15	-	-	-
A2B2	-	1558.462	-	-
A2B3	10179.46	179.398	1.061	1.017
A2B4	5646.757	1482.715	1.476	-0.183
A3B1	7306.8	-	-	-
A3B2	-	727.893	-	-
A3B3	7257.29	113.077	0.747	0.837
A3B4	4812.798	564.251	0.809	-0.058

A1, irrigation every seven days; A2, irrigation every nine days; A3, irrigation every 11 days B1, maize monoculture; B2, soy monoculture; B3, additive intercropping (20% soy+100% corn); B4, replacement intercropping with 2 to 2 ratio

Table 6 Mean squares for effect of irrigation and cropping pattern of photo synthetically active radiation (PAR)

Variation resources	Mean square			
	df	Above the corn canopy	Above the soybean canopy	Low canopy
Iteration	2	16372.799*	20662.174**	135253.132 ^{ns}
Irrigation Course	2	2803.965 ^{ns}	3465.215 ^{ns}	71013.444 ^{ns}
First Error	4	1113.632	1077.507	52765.642
Intercropping	3	6664954.34 ^{ns}	5804960.655**	271406.324**
Irrigation × Intercropping	6	1235.16 ^{ns}	5171.141 ^{ns}	4689.935 ^{ns}
Second Error	18	1675.40	3001.063	12615.843
Coefficient of variation		3.17	5.18	18.89

**Figure 1** The relative density of weed species (In order of dominance in the field).**Figure 2** Dry weight chenopodium album in corn and soybean intercropping pattern.

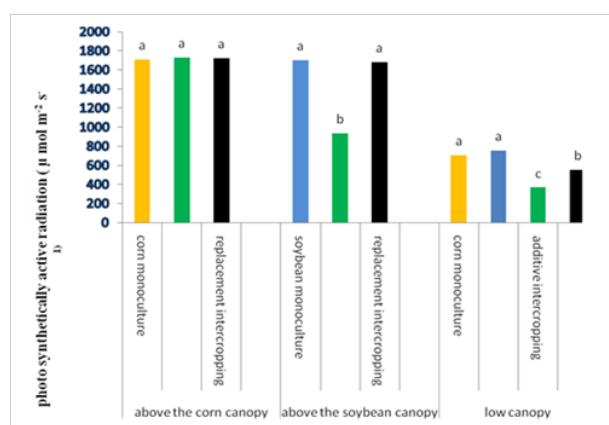


Figure 3 Average distribution of photo synthetically active radiation (PAR) in monoculture and mixture of corn and soybean canopy profiles.

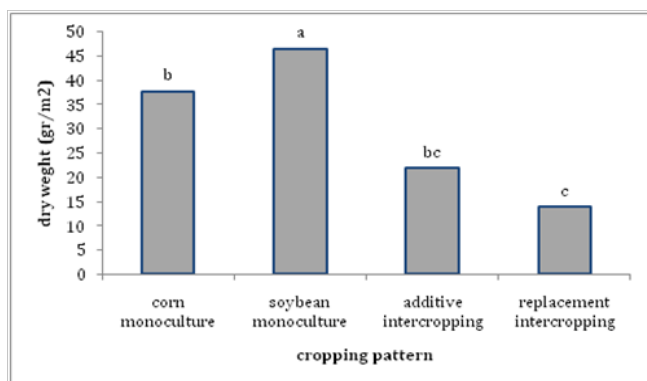


Figure 4 Dry weight Alopecurus myosuroides album in corn and soybean intercropping pattern.

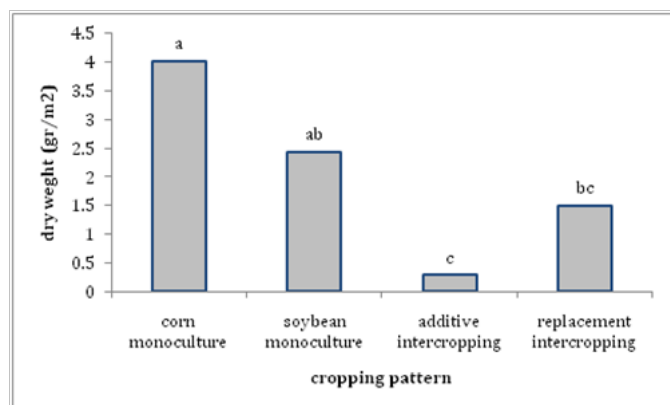


Figure 5 Dry weight Convolvulus arvensis album in corn and soybean intercropping pattern.

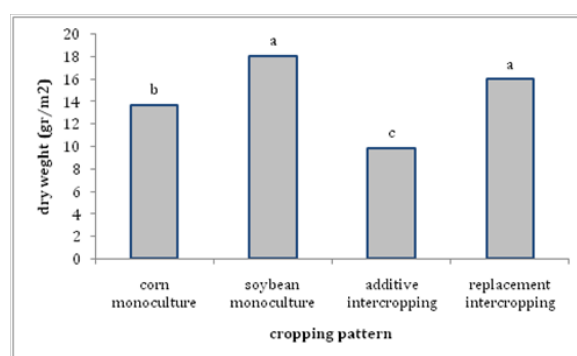


Figure 6 Dry weight Echinochloa crusgalli album in corn and soybean intercropping pattern.

Conclusion and recommendations

The results showed that the culture type strongly affect the dry weight of weeds. In this study, both treatments of intercropping reduced the dry weight of weeds than monoculture of both maize and soybean. So that the additive intercropping treatments showed a better control effect on most studied weeds, so that it has devoted the lowest weed dry weight to itself. One of the main factors that cause better control over weeds in intercropping patterns than monoculture is the better ground cover by plants in these cultivation patterns and better and more use of photosynthetically active radiation in these patterns.

Given that soybean and maize varieties that are cultivated in the region may be different from each other in terms of competition capabilities with weeds; it is recommended to perform a test with various indigenous populations of maize and soybean. Considering that the damage of different species of weeds to the product is not the same, it is recommended to examine the critical period of any important weeds such as pigweed, lamb's quarters, etc.

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None.

Conflict of interest

The author declares no conflict of interest.

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