

Evaluation of Quality and Quantity of Corn and Soybean Grain Yield In Intercropping under Deficit Irrigation

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Abstract
This experiment been conducted in the Zanjan University's pilot farm in order to evaluate the yield and yield components of corn and soybean intercropping in deficit irrigation condition. The farm was prepared as split plots in complete randomized blocks with three iteration regimens. Different irrigation intervals were used in the main plots at three level of every seven day (control), every nine day, and every elven day interval; the cropping pattern was as follow: secondary plots for corn and soya monoculture, while the main plots were used for additive intercropping (100% corn plus 20% soy), replacement intercropping with 2:2 ratio (50% corn plus 50% soy). The greatest corn yield was obtained from every nine day irrigation interval after control group. Moreover, the corn yield was higher in intercropping than monoculture crops. The soybean seeds have not been affected by different irrigation interval and the best yield was obtained from monoculture of soy, while it has not any significant differences with intercropping yield. Intercropping shown superiority on monoculture in this experiment and every nine day irrigation interval was the best deficit irrigation method for grain yield in the intercropping.
Keywords: cropping pattern, grain yield, intercropping, deficit irrigation, Zanjan

Introduction

Agricultural to concept of ways and methods of the operation of water resources, soil and energy in order to provide food and clothing needs of human, constantly throughout history has been the foundation of economic, social, political and cultural development in over the world. One of the main needs of each dynamic activity is planning within the general objectives on it activity; agricultural sector also as one of the most important economic activities in various communities requires coherent planning in order to achieve development and confront with crises. Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of human, and is in balance with the environment. In other words, sustainable agriculture must be ecologically appropriate, economically justified and socially desirable. Objectives of sustainable agriculture have a closely associated with its definitions; objectives of the successful sustainable agriculture program are the following: provide food security along with increased quality and quantity, with considering the needs of future generations; conservation of water, soil and natural resources; conservation of energy resources inside and outside the farm; maintain and improving farmers profitability; maintain the vitality of rural communities; conservation of biodiversity (Eskandari, 2012a; Earles, 2005; Gruhn et al., 2000).

Intercropping of legumes and cereals has great advantages. Increased productivity and optimal use of available resources (land, labor, time, water and nutrients), increasing the efficiency of land use (Dhima et al., 2007), high quality forage production (Al-Masri, 1998), and damage Reduction of pests and weeds (Vasilakoglou et al., 2008) are considered the benefits of and cereals intercropping compared to their sole cultivated plants.

Intercrop systems may improve yield stability, allowing more consistent yields (Willey, 1979;. Fukai and Trenbath, 1993), and efficient use of the resources, allowing reductions in costly inputs (Keatings and Carberry, 1993) Cereal–legume intercrops are among the most frequently used and most productive (Ofori and Stern, 1987). Corn–soybean intercrops have been shown to be more productive than corn monocrops (Ahmed and Rao, 1982; Putnam et al., 1985). The soybean component adds valuable nitrogen to the soil (Singh et al1986), and improves overall protein content of the resulting silage (Herbert et al., 1984; Martin et al (1990). Further, this intercrop system reduces weed growth (Tripathi and Singh, 1983; Carruthers et al., 1998).

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones of the world. Irrigation is today the primary consumer of fresh water on earth (Shiklomanov 1998), and thus agriculture has the greatest potential for solving the problem of global water scarcity. Consequently, improvements in management of agricultural water continue to be called for to conserve water, energy and soil while satisfying society's increasing demand for crops for food and fiber (Kassam et al. 2007). Innovations for saving water in irrigated agriculture and thereby improving water use efficiency are of paramount importance in water-scarce regions. Conventional deficit irrigation is one approach that can reduce water use without causing

significant yield reduction (Kirda et al.2005).
The results of studies conducted on intercropping of corn and cowpea beans in the Zanjan region suggest the increased in both products yield in intercropping. Researchers have stated that the highest grain yield of corn in hectares was obtained in additive intercropping with 100% corn plus 20% cowpea ratio, and the maximum cowpea yield in acres was obtained in replacement intercropping with 33% corn and 67% cowpea ratio (Jamshidi et al., 1390).
There are a group of other indices that evaluate the level of yield of the plant as well as economic usefulness of plants in intercropping than monocultures. Such indices includes land equality ratio (LER), relative crowding coefficient (RCC), and relative value total (RVT).
The purpose of current experiment was: evaluation of corn and soybean yield and yield components in intercropping under the low irrigation condition, in order to identifying the possibility of improving the corn and soybean yield through intercropping under low irrigation condition.

Material and methods

This research was carried out in May of 1390 farming season in Zanjan University Research Farm. Zanjan has a highland cold and dry climate, and have average annual rainfall of 293.5 mm, the distribution of which began in late November and lasts until mid-spring. The city is located at 48 degrees and 49.5 minutes east longitude and 26 degrees and 37 minutes north latitude. Zanjan is 1634 meters high above sea level. Based on the study purpose, experiment was conducted in three replicate on a divided plots and in a randomized complete block design with two factors. The irrigation treatments were applied on main plots as follows:

1. Seven days irrigation regimen: This plot treatment were performed regularly and irrigated every week until the end of the growing season.
2. Nine days irrigation regimen: This plot treatment were performed regularly and irrigated every nine days until the end of the growing season.
3. Eleven days irrigation regimen: This plot treatment were performed regularly and irrigated every eleven days until the end of the growing season.

For this purpose, the main crop water requirement (maize) was calculated using Zanjan synoptic data over the past 10 years, and application of Crop Wat version 8 software. These data have shown that the final water requirement of main crop is 9460 cubic meters per acre. This amount was considered as a control treatment (every 7 days).
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 amount of water consumption was measured regularly in each period using meter mounted in the ground.
The second factor was cropping pattern, which consisted of monoculture of corn (100 percent); soya monoculture (100%); additive intercropping compose of 100% maize plus 20% soya; and replacement intercropping of corn and soybean with 2:2 mixing ratio (50% soybean +50% corn). The reason for using these intercropping patterns was introduction of this method as the best and most useful intercropping patterns in three separate surveys in Zanjan University Research Farm.
The rows distance for corn and soybean cultivation were 75 and 37.5 cm respectively. The optimum density of maize was considered for additive intercropping and soybeans added as 20% of the desired level. Additive intercropping was carried out by calculating the ratio of the pairwise and crop equivalent units. The planting was performed as follow: monoculture crops were planted using wooden ruler with intervals of 15 cm between plants in the middle of the stack; monoculture of soybean seed 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 soybean with ratio of 20% in another side of watermark. In replacement intercropping, corn seeds were planted in 2 rows with optimal density and 8 row of soybean at its side. There were five rows, six meter long for monoculture and additive intercropping.
In this experiment, the Maxima spices was used for corn which considered as 3V- Cross 524 species from middle ripening corn seed group with few years of cultivation experience in Iran. The seed is produces, sorting, and packing in Hungary with precise care and under controlled conditions and belong to horse teeth type (Qurchiani et al, 1390). The Williams soybean cultivar was used as soybean sample which is a common cultivar in Golestan and Zanjan provinces; belong to unlimited growing and medium ripening species (Rezvani et al, 1389). The seeds were bought from Seed and Plant Improvement Institute, Karaj. 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. No chemical or pesticides were used during the growing season due to the lack of a pest or disease. At the end of the growing season and physiological maturity of corn and soybean, sampling for yield and yield component measurement of both plants were performed on all plots as follow: the side plots and 50 cm of both ends of plots were excluded and sampling done on the remainder plots. In all monoculture and intercropping treatments, 10 bush of corn and 10 bush of soybean were randomly selected

from each plot, and were scooped from ground. The bushes height were measured using metal ruler, mean of height was calculated and recorded for later analysis. Maize and pods were separated from plants and shrubs and counted; then all bushes were placed in the oven (70 °c) separately, then counting, weighting the dry matter, and every thousand seed's weight were measured. To measure the protein content, the grain nitrogen content was measured using crude (FOSS) and the percentage of protein was calculated by multiplying the obtained value of 6.25. Common indices and methods were used for comparing the usefulness of intercropping with monoculture cropping. The land equality ratio is a criteria used by researcher for assessment of intercropping effects (Mead and Willy, 1980). This criterion specifies that how much land is necessary for harvesting same amount of product harvested from one acre intercropping cultivar from a monoculture crop. In other words, it does explain the ratio of land necessary for monoculture compared to intercropping. To determine this index, the relative function of each component is calculated, and the sums of these amounts show the land equality ration.
Equation (1)

$$LER = \sum_{n=1}^{m} \frac{Yi}{Yii}$$

Yi = yield of species (per unit area) in intercropping
Yii = maximum yield of the same species (per unit area) in monoculture farming
Schultz et al (1982) proposed the index of relative value total (RVT). This index is widely used now and has been used by many researchers (Hosseini, 1383).
Equation (2)

$$RVT = \frac{(ap^1 + bp^2)}{ap^1}$$

Where "a" is the key product price, b is a secondary product price, p^1 is the main types yield and p^2 is the secondary species in the mixture. If the RVT is greater than one, it's indicating the intercropping advantage. If this index is smaller than one, it's indicating that monoculture would prefer intercropping. The critical value of RVT is one.
A group of indicators use to compare the ability of a species for the use of limited resources in intercropping with its ability to obtain such resources in mono culture. Among these indicators could be indicating to relative crowding coefficient criteria. This index indicates the degree of competition between plants in intercropping. Equation 3 is used to calculate the RCC.
Equation (3)

$$RCCij= (Yij/Yii)/ (Yji/Yjj)$$

Yii and yjj= Monoculture yield of species i and j
Yij = yield of species i in the intercropping
Yji = yield of species j in the intercropping
If RCC = 1 is, the two species have the same competitive capabilities. If RCC > 1 was, the competitive and use of limited resources Species I is better than Speciesj. If RCC < 1 is, the species j is Top of competitive of the species i. (Hall, 1974)
Statistical analysis has been conducted using the MSTAT-C (version 2.10) software package. Statistical comparison of means was performed throughout Duncan's multiple range tests at the five percent level of probability.

Results

The results showed that the effect of irrigation levels on grain yield was significant at the five percent level. The effect of planting pattern on corn grain yield was significant at the one percent level (Table 1). Comparison of means suggests that an increase in irrigation courses, the corn yield decreases. As shown, the maximum and minimum grain yield was 9446 kg/ha for every seven day irrigation course and 6459 kg/ha for every 11 day irrigation course, respectively. However, the irrigation period of every seven day and nine day was not significantly different regarding to this trait (Table 2).
The effects of different irrigation interval on the every 100 seed's weight were significant at 5% significance level (Table 1). The results of mean comparison (Table 2) shown that maximum 100 seed's weight was 24.83 gram from every 7 day irrigation interval and minimum weight was 21.10 from every 11 day irrigation interval. There were not any significant weight differences between 9 day and 7 day irrigation interval. However, every 100 grain weight of corn was significantly ($p<0.01$) affected by cropping pattern (Table 1).

Table 1 - ANOVA of the effects of irrigation course and cultivation pattern on studying features of corn

Variation resources	Mean of squares (MS)			
	df	Grain protein	Weight of 100 seed	seed yield
Iteration	2	1.369^{ns}	53.511 **	8988418.831 ^{ns}
Irrigation course	2	0.189 ^{ns}	34.228 *	23379262.09 *
First error	4	0.314	1.968	1565386.453
Intercropping	2	5.531*	24.384 **	31660019.85 **
Irrigation × intercropping	4	0.775 ^{ns}	5.180 ^{ns}	1068931.258 ^{ns}
Second error	12	1.169	3.036	3501386.657
Coefficient of variation (percent)		13.56	14.80	7.51

**, * and ^{ns} are significance level at 1%, 5% and non-significant, respectively

Table 2 - Comparison of the effects of irrigation level and cultivation pattern on yield and yield components of corn

Feature / Treatment	Grain protein	Weight of 100 seed (gr)	seed yield (kg/ha)
A1	7.98 ^{a}	24.83 ^{a}	9446 ^{a}
A2	7.83 ^{a}	23.94 ^{a}	8271 ^{a}
A3	8.12 ^{a}	21.1 ^{b}	6459 ^{b}
B1	7.122 ^{b}	22.23 ^{b}	9016 ^{a}
B2	-	-	-
B3	8.662 ^{a}	22.46 ^{b}	9262 ^{a}
B4	8.142 ^{ab}	25.19 ^{a}	5898 ^{b}

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

The results of the analysis of variance showed that soybean grain yield was not affected by irrigation course (Table 3). However, soybean yield was significantly affected by cropping pattern (p> 0.01). The results of comparing means showed that the highest monoculture's yield rate of soybean seed was 1240 kg/ha. But there was not any significant difference with the replacement intercropping pattern. Lowest seed yield of soybean from additive intercropping pattern was 165.8 kg/ha (Table 4).

The results showed that the impact of irrigation levels on soybean plant height is significant at five percent level of significance. The effect of cropping patterns on a plant high was significant too (Table 3). The highest soybean plant height was 70.67 cm which observed in every 9 day irrigation course; and the lowest height was 56.78 cm that observed in every 11 day irrigation course. Moreover, the highest height of the soybean plant in maize and soybean intercropping pattern was 72.6 cm and the lowest amount of soy's height was obtained from soybean monoculture crops (table 4).

Table 3 - ANOVA of the effects of irrigation course and cultivation pattern on studying features of soybean

Variation resources	Mean of squares				
	df	Grain protein	Plant height	Weight of 100 seed	seed yield
Iteration	2	7.659 ^{ns}	1.58 ^{ns}	5.158 ^{ns}	675352.253 ^{ns}
Irrigation course	2	17.623 ^{ns}	495.087 *	4.117 ^{ns}	1045347.642 ^{ns}
First error	4	7.591	60.126	4.301	400357.810
Intercropping	2	53.539 *	541.725 **	8.156 ^{ns}	3275710.533 **
Irrigation × intercropping	4	6.138 ^{ns}	16.381 ^{ns}	1.374 ^{ns}	206561.280 ^{ns}
Second error	12	11.002	16.148	2.709	184966.509
Coefficient of variation (percent)		11, 72	49.92	32.24	16.03

**, * and ^{ns} are significance level at 1%, 5% and non-significant, respectively

Table 4 - Comparison of the effects of irrigation level and cultivation pattern on yield and yield components of soybean

Feature / Treatment	Grain protein	Plant height (cm)	Weight of 100 seed (gr)	Soya seed yield
A1	28.88 ^{a}	68.23 ^{a}	10.54 ^{a}	1043 ^{a}
A2	27.71 ^{a}	70.67 ^{a}	10.77 ^{a}	1074 ^{a}
A3	29.02 ^{a}	56.78 ^{b}	9.50 ^{a}	468.4 ^{a}
B1	-	-	-	-
B2	26.24 ^{b}	57.13 ^{c}	9.20 ^{a}	1240 ^{a}
B3	27.69 ^{ab}	72.6 ^{a}	10.59 ^{a}	165.8 ^{b}
B4	31 ^{a}	65.94 ^{b}	11.02 ^{a}	1179 ^{a}

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

The relative value total (RVT) index was calculated for all different intercropping treatments (Table 5); and in most additive intercropping treatments, the value of RVT was greater than one, which represents the preference of additive intercropping over monoculture; and in treatments with RVT of less than one, the monoculture system has been preferred over intercropping.

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

Treatment	Corn yield (kg/ha)	Soybean yield (kg/ha)	LER	RVT	RCC
a1b1	10753.653	-	-	-	-
a1b2	-	1433.198	-	-	-
a1b3	10350.303	204.908	1.093	1.002	7.005
a1b4	7233.612	1489.908	1.628	0.935	0.665
a2b1	8988.158	-	-	-	-
a2b2	-	1558.462	-	-	-
a2b3	10179.463	179.398	1.061	1.170	9.838
a2b4	5646.757	1482.715	1.476	0.941	0.660
a3b1	7306.800	-	-	-	-
a3b2	-	727.893	-	-	-
a3b3	7257.297	113.077	0.747	-	6.393
a3b4	4812.793	564.251	0.809	-	0.849

a1, Irrigation every seven days; a2, Irrigation every nine days; a3, irrigation every 11 days
b1, maize monoculture; b2, soybean monoculture; b3, additive intercropping (21% soybean + 100% corn);
b4, replacement intercropping with 2 to 2 ratio

Discussion

Essentially, 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 (Tavakoli, 1996). It seems that it's the main reason of insignificant relationship between corn yield and raise of irrigation day from 9 to 11 days. Given that the number of grains per maize and every thousand grain's weight are considered as grain yield components, it seems that the number of grains per maize and grain weight was reduced at every 11 days irrigation treatment, and the yield was reduced consequently. 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 soybean have been contributed with corn yield. Oswald et al (2002) reported 40% increase in corn yield in investigating the intercropping of corn and soy. They attributed this increase to more efficient use of existing resources.

According to results presented in table 2, maximum average weight of 100 corn seeds yielded from replacement intercropping with 2:2 ratios was 25.19 and minimum weight that yielded from monoculture of corn was 22.23

gram. There was not any significant difference between additive intercropping and monoculture of corn regarding every 100 grain weight. Leosiing and Francis (1999) was reported an indirect relationship between every thousand seed weight, grain numbers, and plant yield.
The reduction of soybean yield was due 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 [15].
Replacement intercropping pattern also showed a significant increase in plant height relative to control plants. The raise in plant height in the additive intercropping pattern might be due to lower lighting of soybean canopy as result of increases in the corn crop density, which led to production of auxin and increases the length between nodes and thus increasing the soybean height. This experiment is consistent with report which stated that intercropping increases the plant height due to (Mansoori, 1389).
The results of highest land equality ratio calculation shown that land equality ratio were greater than one except every 11 day 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 7 day irrigation) which was 1.628 (table 5). This LER value indicated that yielding from a hectare of land in intercropping system was 8723.52 kg (sum of corn and soybean crop), and we need 62% more land for producing the same amount of crop in monoculture system.
It seems that additive intercropping system obtain this superiority over monoculture systems through controlling weed growth, reducing between species competition, increasing the efficiency of environmental resources utilization, and also possibility of increasing plant density. As shown in table 5 for the relative crowding coefficient (RCC), the additive intercropping maize with soybean plants were dominant in the competition in all treatments (1> RCC). In the replacement intercropping treatments, the soybean plants were dominant (1> RCC). On the other hand, the value obtained from the RCC represents the intensity of competition and competitive pressure is autosomal dominant plant. For example, in the treatment $a_2b_{3,}$ the RCC rate is a 9.838. So it could be results that the competitive pressure of the corn on the soybean is greater.

Conclusion

The results showed that the highest seed yield and yield components of corn and soybean were obtained from seven days irrigation regimen (control). The second highest seed yield of corn after control group was observed in nine days irrigation regimen, which have not significant differences with control group. Considering the water shortage in the country, the extent of arid and semi-arid regions in Iran, and relative reduction of acceptable seed yield along with effective water-saving in every nine day irrigation intervention; this irrigation system can be recommended as the best method of deficit (low) irrigation system for seed production in intercrop farming. The highest corn seed yield was obtained from the additive intercropping pattern. The highest seed yield of soybean was obtained from monoculture pattern, whereas this rate did not show significant differences with intercropping replacement. According to present results, there were more than one LER in majority of intercropping treatments, positive sign of RVT in most intercropping treatments, the usefulness and advantages of intercropping over monoculture.

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