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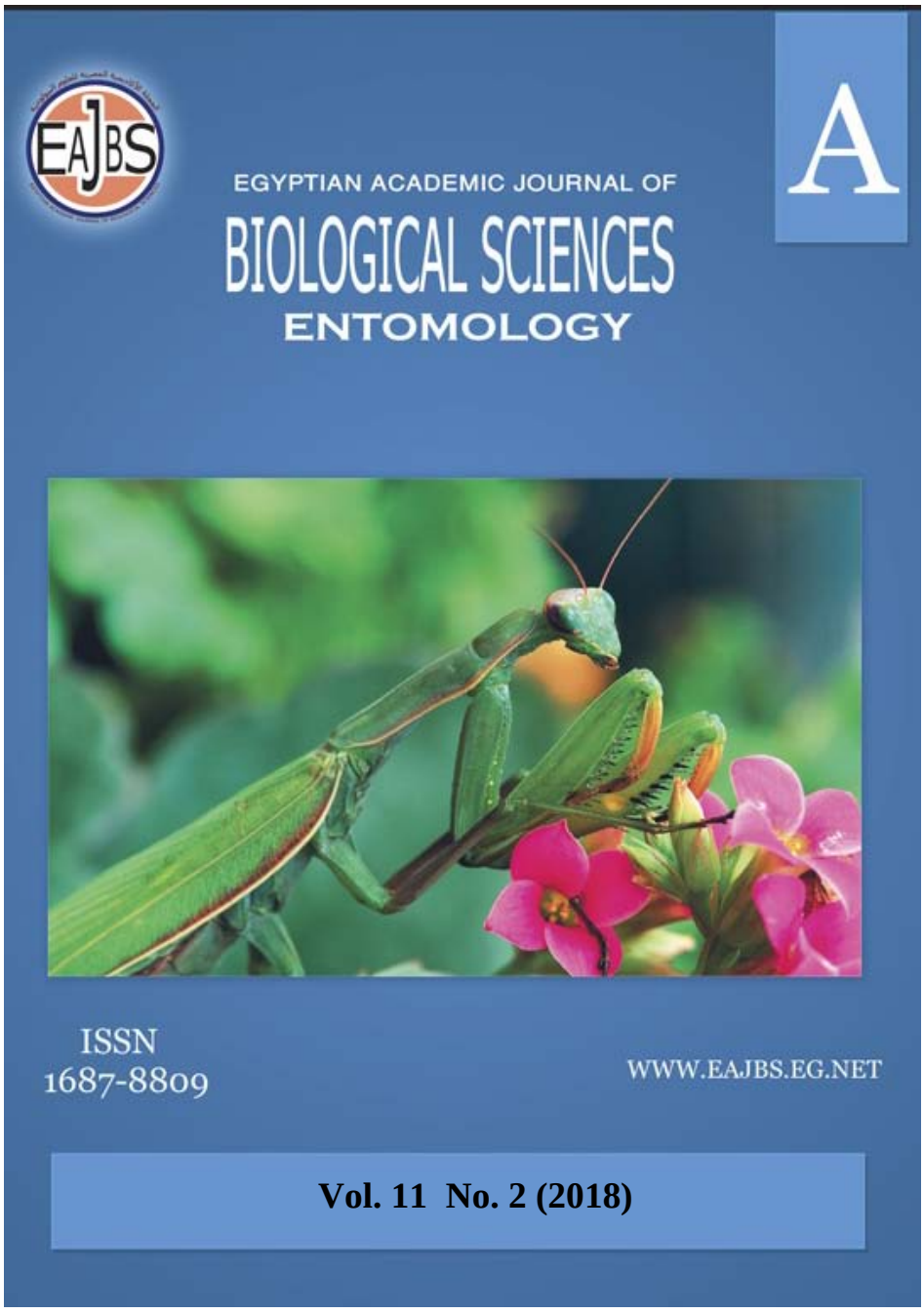

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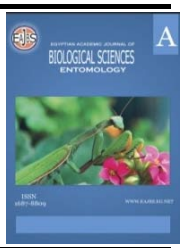

Land Equivalent Ratio (LER), and Competition Indices in Cotton (*Gossypium hirsutum*) – Sesame (*Sesamum indicum*) Intercropping System

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ABSTRACT

Cotton (*Gossypium hirsutum*) and sesame (*Sesamum indicum*) are two major crops in Islamic Republic of IRAN. In the northeast of IRAN, most farmers' landholdings are less than 5 hectares; therefore cotton production cost is high. Agricultural experts suggest that one method for improving productivity is intercropping system. This research was done to study advantages or disadvantages of intercropping of cotton and sesame through investigation of Land Equivalent Ratio (LER) and competition indices. The experiment was conducted during 2015 growing seasons in Cotton Research Institute (C.R.I.). It was included a Randomized Complete Block Design (RCBD) with 3 replications. Treatments were intercropping patterns of cotton (c) and sesame (s) (1c:1c, 1c:2s, 2c:1s, 3c:1s, 1c:3s, sole cotton, sole sesame). Substitution method of intercropping was done. Land Equivalent Ratio (LER), Relative Crowding Coefficient (k), Aggressivity (A), Competitive Ratio (CR), Actual Yield Loss (AYL), and Relative Value Total (RVT) were evaluated. Results revealed that, Land Equivalent Ratio (LER), Relative Crowding coefficient (K), Aggressivity (A), Competitive Ratio (CR) values of cotton generally were more than sesame. Planting cotton in intercropping with sesame had a higher monetary profitability too. In this study the best intercropping pattern for acquiring a highest Land Equivalent Ratio (LER) and monetary profitable was (3:1).

INTRODUCTION

Cotton (*Gossypium hirsutum*) and sesame (*Sesamum Indicum*) are two major crops in IRAN. These crops are used in textile and oil industry and have big effects on the local economy too. In the northeast of the country most of farmers have landholdings less than 5 hectares, and cotton culture has gone to the marginal lands because of high production cost. For these reasons, agricultural experts suggest that a way to improve productivity of cotton is intercropping system. Intercropping of Cotton and sesame is done in the north of IRAN as a conventional practice from years ago. Use of intercropping by smallholders is common in the rain fed areas all over the world (Dhima et al. 2007., Ofuso-Amin 2007). The advantages of intercropping over mono-cropping include soil conservation, lodging resistance, yield increment (Anil.,1998) and weed control (Banik et al, 2006). When two crops are planted together, may occur intra and/or inter specific competition or facilitation between plants (Zhang et al, 2003). A number of indices such as Land Equivalent Ratio (LER), Relative Crowding Coefficient, Competitive Ratio, Actual Yield Loss and monetary advantages, have been proposed to describe competition and economic aspects of intercropping systems (Ghosh,2004; Yilmaz ,2007). Goma (1991) and

Shahid (1997) reported a dominant effect of cotton having positive "A" value when grown in association with mung bean, mash bean and linseed. However, such indices have not been used for cotton and sesame to evaluate the competition among species in IRAN. The objectives of the study were to investigate of competitive indices aspect of cotton-sesame intercropping system in Golestan province to evaluate the advantages of this practice on the lands.

MATERIALS AND METHODS

The experiment was conducted during 2015 growing seasons in a Research Farm of Cotton Research Institute of IRAN. The farm is located at Hashem Abad, Gorgan in ecological zone (54.16 long 36.51 lat) and (13.2 meter) above sea level. Total average 22 years rainfall of the area was (525.1 mm) and average daily temperature was (17.9 ^{0}C). In 2015, total annual rainfall was (493.7 mm) and average daily temperature was (18.4 ^{0}C). The soil was a (silty clay loam) with approximately 10 % sand, 62% silt and 28 % clay, organic matter 1.7% and with pH 7.9. The experiment was a randomized complete block design with 3 replications. Treatments were different patterns of cotton (c) and sesame (s) in an intercropping system (1c:1c, 1c:2s, 2c:1s, 3c:1s, 1c:3s, sole cotton, sole sesame). The experimental plots were (6m × 7m = 42 m2) involving 6 rows. Sole cotton planted at the rate of 50000 plants/ha, and sole sesame planted at 200000 plants/ha. Fertilizers was applied normally correspondence to cotton as ammonium phosphate (150 kg/ha) before planting of both crops and urea (50 kg/ha) in 2 splits after planting of the crops. Controlling of weeds was done by labors with a small shovel. Cotton was harvested at two sequential phase but sesame harvested when the pods were nearly matured because of seed falling. Evaluation of the cropping systems was carried out as the following indices:

I) the first criterion for assessing the effectiveness of intercropping for using the environmental resources compared to sole cropping is Land equivalent ratio (LER) (Mead and Willey, 1980). The LER values were calculated as: $LER=LER_c + LER_s$ where $LER_c= Y_{ic}/Y_c$ and $LERs=Y_{is}/Y_s$ where Y_c and Y_s are the yields of cotton and sesame as sole while Y_{ic} and Y_{is} are the yields of cotton and sesame as intercrops, respectively. The intercropping is advantage when LER is more than 1.00 for the growth and yield of the species (Caballero *et al.*, 1995). In contrast, when it is less than 1.00 there is a disadvantage of intercropping. A LER of 1.0 indicates no differences between intercropping compared to sole cropping of two species (Caballero *et al.*, 1995).

II) The second coefficient was the Relative Crowding Coefficient (*k*) which is a measurement of the relative dominance of one species over the other in a mixture (Banik *et al.*, 2006). The *k* was calculated as:

$k = k_{cotton} \times k_{sesame}$, where

$$k_{cotton} = \frac{Y_{ic} \times Z_{is}}{\left((Y_c - Y_{ic}) \times Z_{ic}\right)}$$

$$k_{sesame} = \frac{Y_{is} \times Z_{ic}}{\left((Y_s - Y_{is}) \times Z_{is}\right)}$$

Where Y_c and Y_s are the yields of cotton and sesame as sole crop, respectively. And Y_{ic} and Y_{is} are the yields of cotton and sesame as intercrops, respectively. Where Z_c and Z_s are the proportions of cotton and sesame in the mixture, respectively. When

the value of *k* is greater than 1.00 there is a yield advantage; when *k* is equal to 1.00 there is no yield advantage; and when it is less than 1.00 there is a disadvantage (Dhima et al. 2007).

III) Aggressivity (A) was used to determine the competitive relationship between two crops in a mixture pattern (Willey, 1979). The aggressivety was calculated as (Dhima *et al.,* 2007).

$$A_{cotton} = \left(\frac{Y_{ic}}{Y_c \times Z_{ic}}\right) - \left(\frac{Y_{is}}{Y_s \times Z_{is}}\right)$$

$$A_{sesame} = \left(\frac{Y_{is}}{Y_s \times Z_{is}}\right) - \left(\frac{Y_{ic}}{Y_c \times Z_{ic}}\right)$$

For cotton example: if A_{cotton} =0. Both crops are equally competitive, if A_{cotton} is positive, then the cotton species is dominant, if A_{cotton} is negative, then the cotton is recessive.

IV) The forth criterion is Competitive Ratio (CR) which evaluate the competitive ability of different species in intercropping. It measures the degree of one crop competition the other crop in an intercropping system, and can be calculated following the formula bellow (Dhima *et al.,* 2007):

$$CR_{cotton} = \left(\frac{LER_{cotton}}{LER_{sesame}}\right) \times \left(\frac{Z_{is}}{Z_{ic}}\right)$$

$$CR_{sesame} = \left(\frac{LER_{sesame}}{LER_{cotton}}\right) \times \left(\frac{Z_{ic}}{Z_{is}}\right)$$

V) Actual Yield Loss (AYL) index is the proportion yield decrease of intercropping of cotton and sesame compared to corresponding yields in sole crops (Dhima *et al.,* 2007). The AYL was calculated as (Banik. 1996).

$AYL = AYL_{cotton} + AYL_{sesame}$, where

$$AYL_{cotton} = \frac{(Y_{ic}/Z_{ic})}{(Y_c/Z_c) - 1}$$

$$AYL_{sesame} = \frac{(Y_{is}/Z_{is})}{(Y_s/Z_s) - 1}$$

The partial AYL can have positive or negative values indicating an advantage (dominant component) or disadvantage (dominated component) in intercrops allowing for the comparison of yields on a per plant basis.

VI) The other indices are Relative Value Total (RVT) which is estimated as bellow (Harper. 1977):

$$RVT_c = \frac{(aP1 + bP2)}{aM1}$$

$$RVT_s = \frac{(aP1 + bP2)}{bM2}$$

Where p1 and p2 are yield in mixed crop of cotton and sesame, respectively. (a) is the price of cotton and (b) is the price of sesame, and (M1 and M2) are the yield of cotton and sesame in monoculture, respectively.

RESULTS

1. Land Equivalent Ratio and Relative Crowding Coefficient:

Mean of partial LER for cotton was greater than sesame (Table 1). It showed that cotton use of land in intercropping was better than sesame. Although mean of total LER was less than 1.00 but LER of 3:1 planting pattern was greater than 1.00. This result indicated that use of land in (3:1) treatment was better than mono-cropping of cotton or sesame. With increase in proportion of cotton in intercropping, total LER increased from 0.56 to 1.06 and in maximum proportion of sesame, LER decreased to 0.65. Mean of partial *k* for cotton was greater than partial *k* for sesame (Table 1). Together with decreasing the proportion of cotton in intercropping, partial *k* of cotton decreased. Partial *k* for cotton and sesame in (3:1) and (2:1) patterns had a maximum value made a highest value of total *k* too. Total *k* had an increasing and decreasing value trend when the proportion of cotton increased and decreased, respectively.

2. **Aggressivity, Competitive Ratio and Actual Yield Loss:**

Mean of Aggressivity of cotton was positive (Table 1). This result showed that in cotton – sesame intercropping, cotton was dominant and sesame was a recessive plant. This result showed that except (1:1) treatment which sesame was a dominant plant, in the other form of intercropping patterns, cotton was dominant. This study showed that mean of Competitive Ratio (CR) of cotton was greater than sesame (Table 2). Greatest value of Competitive Ratio belonged to (1:3) and (1:2, 2:1) intercropping patterns for cotton and sesame, respectively. Except (1:1) pattern which sesame Competitive Ratio was greater than cotton, sesame was a recessive plant on the other treatments. Competitive Ratio on cotton decreased when the cotton proportion in intercropping reduced. Mean of Actual Yield Loss (AYL) in cotton, sesame and total (AYL) were negative but Actual Yield Loss of cotton was greater than sesame (Table 2). Actual yield of cotton in three forms of treatments (2:1, 3:1, and 1:3) were positive but this index was negative for all treatments of sesame. All values of total Actual yield loss were negative but (3:1) treatment value was positive.

3. **Relative Value Total**:

Mean of Relative Value Total for cotton was greater than 1.00 but this value for sesame was less than 1.00 (Table 2). The highest (RVT) values for cotton and sesame were (2:1, 3:1). All values of RVT for cotton were more than 1.00 but in sesame were less than 1.00.

Table 1. Land Equivalent Ratio, relative crowding coefficient (*k*) and Aggressivity (A) in five intercropped planting patterns.

		LER			*k*			A	
Planting patterns	**Intercrop proportion (%)**	**cotton**	**sesame**	**Total**	**cotton**	**sesame**	**Total**	**cotton**	**sesame**
1:1	**50:50**	**0.26**	**0.30**	**0.56**	**0.35**	**0.43**	**0.15**	**-0.07**	**0.07**
2:1	**67:34**	**0.66**	**0.32**	**0.98**	**1.32**	**0.95**	**1.31**	**0.03**	**-0.03**
3:1	**75:25**	**0.82**	**0.24**	**1.06**	**1.97**	**0.97**	**1.91**	**0.11**	**-0.11**
1:2	**34:67**	**0.21**	**0.39**	**0.60**	**0.53**	**0.32**	**0.17**	**0.03**	**-0.03**
1:3	**25:75**	**0.31**	**0.34**	**0.65**	**1.35**	**0.17**	**0.23**	**0.78**	**-0.78**
Mean		**0.45**	**0.31**	**0.77**	**1.10**	**0.56**	**0.75**	**0.17**	**-0.17**
LSD(p=0.05)		**0.15**	**0.05**	**0.155**	**1.17**	**0.05**	**1.23**	**0.19**	**0.19**

Table 2. Competitive Ratio (CR), Actual yield loss (AYL) and Relative value total in five intercropped planting pattern

		CR		AYL			RVT	
Planting pattern	Intercrop proportion(%)	cotton	sesame	cotton	sesame	Total	cotton	sesame
1:1	50:50	0.87	1.15	-0.47	-0.39	-0.87	1.31	0.38
2:1	67:34	1.02	1.00	0.01	-0.02	-0.01	1.78	0.51
3:1	75:25	1.11	0.90	0.09	-0.02	0.07	1.66	0.48
1:2	34:67	1.06	0.96	-0.36	-0.40	-0.76	1.58	0.45
1:3	25:75	2.71	0.37	0.24	-0.54	-0.29	1.50	0.43
Mean		1.34	0.87	-0.09	-0.27	-0.37	1.56	0.45
LSD (p=0.05)		0.25	0.23	0.22	0.05	0.25	0.19	0.05

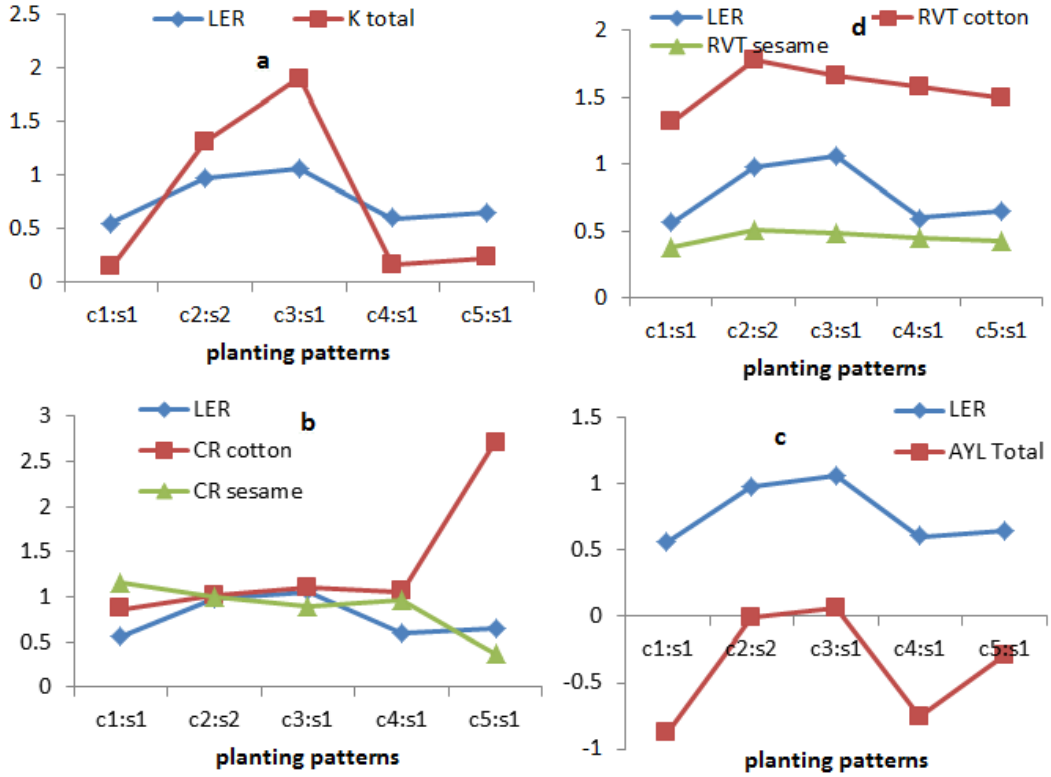

Figure 1. Land Equivalent Ratio (LER), and competition indices in Cotton. a) relationship between LER and *k* total, b) relationship among LER, CR cotton and sesame, c) relationship between LER and AYL total, d) relationship among LER, RVT_{cotton}

DISCUSSION

Mean of partial LER for cotton was greater than sesame. This result showed that cotton generally got more advantages from intercropping system than sesame. Although mean of total LER was less than 1.00 but this LER in (3:1) treatment was greater than 1.00. Thus cotton in this form of intercropping had more advantages over sole crop in regard to the use of environmental resources for plant growth (mead

and willey, 1980). We guessed that a value of total LER up to 1.00 in intercropping compared with mono-cropping of cotton was ascribed from a better utilization of natural (land and light) and added (fertilizer and water) resources too. Aal (1991), Raghuwanshi et al. (1994) and Rao (1991) also reported higher LER in intercropping as compared to sole crops. Mohammad (2001) found that in an intercropping system which cotton intercropped with some crops, intercropping of cotton with sesame had less LER than the others.

Mean of crowding coefficient (k) of cotton was greater than 1.00 but it was less than 1.00 in sesame. This result showed that cotton is more competitive than sesame but effect of this ability merely could observe in total LER in (3:1) intercropping pattern (Fig.1a). The highest partial (k) value of cotton was 1.97 in (3:1) that is 0.49% higher than sesame's. This result corresponds with some researchers who worked on the other crops. For example, Banik et al (2000) in chickpea – wheat intercropping, Dhima et al (2007) in cereal – vetch intercropping similarity reported a yield advantage of one crop over the other. Researches in a groundnut – cereal mixtures, recorded that cereals overcrowded groundnut (k cereal >1) too (Ghosh, 2004). In the present study, we also found that partial *k* values may change when the ratio of crops in intercropping modified. Competitiveness between crops in (1:1) and (1:2) patterns made a less partial *k* value in both crops than (2:1) and (3:1) treatments. This results revealed that crops competition in (1:1) and (1:2) patterns cause a suppressing effects on them, but this competition in (3:1) and (2:1) patterns made a higher partial *k* value for two crops. Sesame in (1:3) didn't need a high compete with cotton which experienced a high competition pressure with sesame. Thus, scrambling of cotton to success the competition made a higher partial *k* value for it.

Mean of aggressivity value for cotton was positive while such value for sesame was negative. This result showed that generally in the intercropping system, cotton was a dominant species. Except (1:1) pattern (partial A for cotton was negative), the mentioned value was positive in the other treatments. This result indicated that in a close sowing of cotton and sesame pattern, cotton didn't have a strong compete with sesame but in the other patterns which they were more far from each other; cotton could have a strong compete with sesame. Thus, this phenomenon made cotton a dominant species in the intercropping system. A high value of Aggrresivity for cotton in (3:1) pattern also made a higher partial LER for cotton than sesame too. This result on the other crops occurred too. For example, in a cereal-legume intercropping system, cereal was a dominant crop than legume (Ghosh, 2004., Dhima *et al.*, 2007). This study demonstrated a relation between Aggrresivity (A) value and Competitive Ratio (CR) too. Both of them had a maximum value in (1:3) pattern in cotton and a minimum value in sesame treatments. Such as (A), mean of Competitive Ratio was higher in cotton than that's indices of sesame. These results showed that cotton was more competitive species than sesame especially in (1:3) in the intercropping. Like (k), sesame in (1:3) didn't need to a high compete with cotton which experienced a high competition pressure with sesame. Thereby, trying of cotton to be a competitive crop made a higher (CR) value for it. In the other word, in a minimum ratio of cotton and maximum ratio of sesame in the intercropping, cotton was a good competitiveness plant (Fig 1b).

According to Banik *et al.*, (2000) findings, AYL index gave more accurate information than the other indices on inter and intraspecific competitions in intercropping system (Fig.1c). Mean of partial AYL for cotton was greater than sesame but both of them were negative. This result indicated that cotton was more

resistant to yield loss than sesame in a cotton-sesame intercropping system. The highest AYL for cotton were (3:1) and (1:3) but for sesame it was (2:1) and (3:1). In AYL total the best treatment was (3:1) with a positive value. This study showed that if all of cotton lines of a cotton – sesame intercropping had a character and value such as (1:3) pattern, yield of cotton can increase 24% compared to the sole crop; but in (1:3) pattern of intercropping the proportion of cotton was lower than it could make such a mentioned yield in the harvest time. Then we guessed that the suitable form of intercropping of cotton and sesame for gaining a balance competition and a maximum yield was (1:3) or (75%:33%) proportions of cotton – sesame in an intercropping system.

Results of Relative Value Total indices indicated that from view of a cotton farmer, intercropping of cotton and sesame had more economic advantages than sole crop of cotton but reverse to it, from view of a sesame farmer, intercropping of sesame with cotton didn't have any economic advantages than sole crop of sesame. On the other hand, the best (RVT) for cotton were from (3:1) and (2:1) form of intercropping that they had the best LER in experiment treatments too (Fig.1d).

CONCLUSION

This study indicated that in the north of Iran intercropping of cotton with sesame, when both crops were planted in the same time, may affect LER, competition between two crops, and economic indices compared to solitary cropping of the same species in different planting patterns. Regardless of planting patterns, Land Equivalent Ratio (LER), Relative Crowding coefficient (*k*), Aggressivity (A), Competitive Ratio (CR) values of cotton were more than sesame. Additionally, planting cotton in intercrop with sesame had a higher monetary profitable than mono-cropping of it. Although mentioned indices in sesame were lower than cotton, but sesame has a higher price than cotton in Iran market which made the intercropping of two crops (cotton and sesame) a profitable practice for farmers. In addition, the patterns or the ratio of proportion of cotton and sesame also seemed to significantly affect the efficiency of intercropping farming system. In this study the best pattern or proportion ratio for acquiring highest Land Equivalent Ratio (LER) and monetary profitable was 3:1 or 75C:25S, respectively. Such a system can be easily practiced especially by small farmers in the north of Iran. Therefore, along with monetary profitable for farmers, use of resources of environment compared to sole cropping may be improved.

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