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Evaluation of yield, some growth features, economic index and competitive indices of Cumin (*Cuminum cyminum*) and Chickpea (*Cicer arietinum*) in delayed intercropping

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Key words: Aggressivity, Sustainable agriculture, Medicinal plants, Land equivalent ratio, Productivity index

Abstract

An experiment was conducted in the form of complete randomized blocks design (RCBD) with 3 replications and 7 treatments in growing season of 2012-2013 to evaluate Cumin (*Cuminum cyminum*) and Chickpea (*Cicer arietinum*) intercropping indices in delayed intercropping under Mash had weather condition. Treatments include Cumin pure cultivation (February 13), Chickpea pure cultivation (February 13), Cumin and Chickpea intercropping (February 13), Chickpea pure cultivation (February 28), replaced delayed intercropping (February 13), Chickpea pure cultivation (March 16), and replaced delayed intercropping (March 16). Evaluation of Cumin yield and its components indicated that biological and economic yields, bush height and the number of umbelet per bush were significantly affected by various treatments. Moreover, biological and economic yields, bush height, the ratio of stem and root and the weight of one thousands grains of Chickpea were affected by various treatments. The value of System Productivity Iindex (SPI) and total Actual Yield Loss (AYL_t) indices as well as Relative Value Total (RVT) and Intercropping Advantage (IA) economic indices turned positive for all intercropped ratios. The evaluation of Land Equivalent Ratio (LER) indicated that the most LER was related to delayed intercropping treatment in March 16 and the least one was related to intercropped treatment in February 13. Totally, LER was achieved more than 1 for all intercropped ratios indicated the superiority of intercropping than mono cropping.

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Introduction

The excessive utilization of land resources during last Century and lack of attention to consequences of such utilizations have been manifested in stability and sustainability of ecosystems more than ever. In this direction, the agricultural department has also been confronted with such challenges in addition to playing its role to provide the food with growing population. Managements based on simple insights and lack of incorporated dimensions related to agricultural products have brought numerous complications including soil erosion, biodiversity depletion, environment pollution, etc. That's why in the past decade the new attitudes have been formed in sustainable resources utilization, which all of them may be presented in the form of sustainable development, and undoubtedly sustainable development in agriculture is also highly regarded by its own structure (Koocheki & Khaje-Hosseini, 2008). Diversification of management methods and various forms of resources exploitation, or in other words increasing the diversity of agriculture are the best and most effective strategies to achieve the sustainability of production (Pinedo-Vasquez *et al*., 2000). Many researchers consider the presence of intercropping as the most important factor in increasing the diversity of agricultural ecosystems (Vandermeer, 1992). The amount of arable lands has been decreased in recent years due to urbanization and high speed of industrialization. In this condition, the production of more products in these small lands may be considered more than increasing the production of one product and there is very appropriate context for using multicultural methods. In most parts of the worlds, intercropped agriculture is of priority to mono cropping due to the maximum usage of environmental resources reducing the production risk, balancing in nutrition, soil fertility and increasing of production per area as well as better using of environmental resources such as light, water and nutrients available in the soil (Rezaei-Chianeh *et al*., 2011). Intercropping is playing an important role in producing the food and livelihood of the people in developing countries (Walker & Ogindo, 2003). In arid and semi-arid areas like Iran, intercropping may be used as a strategy to maximize high radiation of the sun and water resources. Intercropping system is useful when the environmental resources required by two species are separated appropriately so that the species can use optimally from environmental factors besides each other (Pinedo-Vasquez, 2000). The legume family plants such Bean (*Phaseolus vulgaris* L.), Chickpea and Soybean (*Glycine max*) are used often in intercropping due to their nitrogen fixation capability (Francis & Decoteau, 1993). Those intercropping systems in which one of the species can fix the nitrogen biologically are called classic intercropping (Gao *et al.,* 2009).

Most of the results distributed in the field of intercropping associated with yield superiority have been the mixture of legume and non-legume (Moris & Garrity, 1993). The role of legume has been known as an important source in human food rations, animal nutrition and increasing the soil fertility (Bhatti *et al*., 2006). Chickpea is the second world product between legumes which is cultivated in 48 countries of world with an area more than 11 million hectares and the production more than 8 million tons with high protein percentage (22-24 %) (FAO, 2004). This plant is normally cultivated in agricultural systems of arid and semi-arid areas and requires a few inputs. About 95% of area under cultivation and consumption of Chickpea is related to developing countries (FAO, 2006). Features like the ability of nitrogen fixation, deep rooting and effective use of the atmospheric precipitations has caused this plant play an important role in fixation of agricultural systems production. Among the Psychrophilic cereals in Iran, the most area under cultivation and production has been allocated to Chickpea (FAO, 2010). Cumin has been known in our country as a domesticated spicy and medical plant, the area under cultivation of which has been more than 5000 hectares (Kafi, 2002). Nowadays, Cumin is considered as the second famous spice of the world after Pepper (*Piper nigrum*) (Daniel & Maria, 2000). Short growth period (100-120 days), low water requirement and high economic value of the plant have caused economic justification of its cultivation in most arid and semi-arid areas (Kafi, 2002).

Further researches on these two plants, whether in mixture or in pure form, are important due to their economic importance and the area under cultivation in world and state level, medicinal property of Cumin, low expectation of both plants and their appropriate effectiveness in environmental resources utilization. Therefore, the purpose of this project is to study the delayed intercropping of tow Cumin and Chickpea plants to achieve the best cultivation time of Chickpea as a by-product of its intercropping with Cumin with the best economic output.

Materials and methods

Experimental site and treatments

This experiment was conducted in Agricultural College Research Farm of Ferdowsi University of Mashhad (Iran) located in the distance of 10 kilometer from Mashhad East, at longitude of 59 degrees and 28 minutes of east and latitude of 36 degrees and 15 minutes of the north and the height of 985 meters above sea level, in the growing season of 2012-2013. The area mean precipitation is 286 millimeter, and the area maximum and minimum absolute temperatures are 42 and -27.7° C, respectively. The experiment was performed in the form of complete randomized blocks with 3 replications. Experimental treatments include Cumin pure cultivation (February 13), Chickpea pure cultivation (February 13), intercropping of Chickpea and Cumin (February 13), Chickpea pure cultivation (February 28), Chickpea delayed replaced intercropping among the Cumin rows (February 28), Chickpea pure cultivation (March 16) and Chickpea delayed replaced intercropping among the Cumin rows (March 16).

Soil characteristics, land preparation and experiment designing

The soil sampling was done before conducting the experiment to determine the physical and chemical properties of the soil. The results have been shown on Table 1. After selecting the experiment land, a part with the dimension of 27×19 square meter was selected and the plowing and leveling operations were conducted in the middle of February to prepare the land, and then furrows with the width of 60 cm were created, and the land blocking included experimental plot with size of 5×3 m in 3 blocks was done to implement the project. Cumin was cultivated as the main plant on February 13, 2013 at once by hand and in one side of the furrow with the width of 60 cm in intercropping, and in its both sides in pure cultivation to create the distance of 30 cm between rows, with the depth less than 1 cm in the form of dry farming. Also the Chickpea cultivated as the second plant on 3th of February, 13 February 28 and March 16 at a predetermined location in the depth less than 3 cm. Irrigation was done immediately after culturing, and thinning operation was done after germinating and complete establishment of two species simultaneously with the first stage of 3 wedding stages were done. After thinning, the optimal density of Cumin reached 70 bushes per square meter and the density of Chickpea reached 27 bushes per square meter, and the ratio was 50:50 in intercropping.

Table 1. Soil physical and chemical characteristics of experimental field.

PH	EC ($ds.m^{-1}$)	Potassium (ppm)	Phosphorus (ppm)	Nitrogen (%)	Organic carbon (%)	Soil texture
8.20	1.8	305	18	0.08	0.39	Loam-clam

Irrigation, sampling, and statistical analysis

Different phases of irrigation were performed in 2 weeks period, which the delay of irrigation was applied for all treatments equally to confront with *Fusarium* (*Fusarium moniliforme*) in case of changing in humidity. The irrigation was done continuously up to early flowering of Cumin, and an irrigation period was done during granularity until ripening of Cumin due to increasing of temperature. Also, no kind of fertilizer was used during plant growth period. The harvest was done in fourth stages to determine the final yield. Cumin was harvested on June 03, 2013, and was exposed to open air condition for one week until it was completely dried and then the threshing and separation process were carried out. Chickpeas cultivated in mixture and pure forms simultaneously with Cumin were harvested on June 22, 2013, the cultivation on March 01, 2013 was harvested on July 01, 2013, and the last cultivation of

Chickpeas on March 17, 2014 was harvested on July 07, 2013. At the end of growth season, 5 bushes from each plot were selected randomly and then the yield components of Chickpeas and Cumin per unit area were measured. The essence of Cumin samples was extracted by Clevenger apparatus by steam distillation of 30g samples of grains. Then the essence percentage and yield per unit area were calculated. Land equivalent ratio (LER) (Mead & Willey, 1980), Aggressivity (A) (Agegnehu *et al.*, 2006), competition ratio (CR) (Dhima *et al.*, 2007), System productivity index (SPI) (Agegnehu *et al.*, 2006), Actual yield loss (AYL) (Banik *et al.*, 2000), Relative Value Total (RVT) (Schultz *et al.*, 1982), and Intercropping advantage (IA) (Banik *et al.*, 2000; Ghosh, 2004) were measured to assess the effectiveness and efficiency of intercropping, and (1)-(15) equations were used.

(1)	Total LER	$LER = LER_c + LER_p$
(2)	Relative yield or LER of Cumin	$LER_c = \frac{Y_{ci}}{Y_c}$
(3)	Relative yield or LER of Chickpea	$LER_p = \frac{Y_{pi}}{Y_p}$
(4)	Competition ratio of Cumin	$CR_c = (LER_c/LER_p)(Z_{pi}/Z_{ci})$
(5)	Competition ratio of Chickpea	$CR_p = (LER_p/LER_c)(Z_{ci}/Z_{pi})$
(6)	Aggressivity index of Cumin	$A_c = (Y_{ci}/Y_c * Z_{ci}) - (Y_{pi}/Y_p \times Z_{pi})$
(7)	Aggressivity index of Chickpea	$A_p = (Y_{pi}/Y_p * Z_{pi}) - (Y_{ci}/Y_c \times Z_{ci})$
(8)	System productivity index	$SPI = (Y_p/Y_c) \times Y_{ci} + Y_{pi}$
(9)	Total Actual yield loss	$AYL = AYL_p + AYL_c$
(10)	Actual yield loss of Cumin	$AYL_c = \{[(Y_{ci}/Z_{ci}) \div (Y_c/Z_c)] - 1\}$
(11)	Actual yield loss of Chickpea	$AYL_c = \{[(Y_{pi}/Z_{pi}) \div (Y_p/Z_p)] - 1\}$
(12)	Total Intercropping advantage	$IA = IA_c + IA_p$
(13)	Intercropping advantage of Cumin	$IA_c = AYL_c P_c$
(14)	Intercropping advantage of Chickpea	$IA_p = AYL_p P_p$
(15)	Relative Value Total	$RVT = (P_c Y_{ci} + P_p Y_{pi})/P_c Y_c$

Y_{ci} is the yield of Cumin grain in the condition of intercropping with Chickpea, Y_c is the yield of Cumin in mono cropping condition, Y_{pi} is the yield of Chickpea grain in the condition of intercropping with Cumin, Y_p is the yield of Chickpea in mono cropping condition, Z_{ci} is the abundance of Cumin species in intercropping with Chickpea, Z_c is the abundance of Cumin specie in mono cropping condition, Z_{pi} is the abundance of Chickpea in intercropping with Cumin, Z_p is the abundance of Chickpea in mono cropping condition, P_P is the price of one kilogram Chickpea=3000 Rials[1] and P_C is the price of one kilogram of Cumin=160000Rials. Statistical analysis of experimental data was done using SAS ver. 9.1 and Minitab ver.16 Softwares. MS-EXCEL ver.13 software was used to draw shapes and diagrams. Mean comparison was performed with Duncan's multiple range test at 5% probability level.

RESULT

The effect of different treatments on yield and its component of Cumin.

Dry matter yield

As you can see (Table 2) a significant difference was observed at 5% probability level among various treatments of delayed intercropping and the pure one in terms of dry matter yield. The highest biological yield of Cumin (1315 kg.ha-1) among various treatments is belonged to its pure cultivation (Fig. 1). Also, the least biological yield of Cumin (737 kg.ha-1)

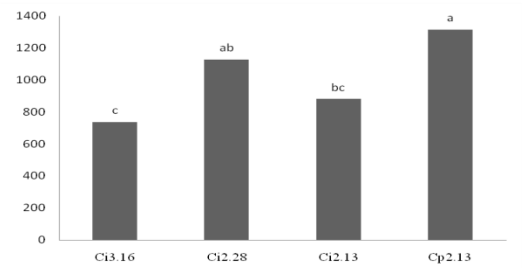
[1]Iran's currency

was achieved from its Simultaneous intercropping with Chickpea in treatment dated February 13, the reason of which may be the less competitive power of Cumin in comparison with Chickpea.

Table 2. Analyze of Variance of yield and yield components of Cumin.

S.O.V	df	Mean square: Dry matter yield	Seed yield	Essence percentage	Plant Height	number of umbelets per bush	1000-Grain Weight
Treatment (T)	3	198293*	17341.86*	0.0477ns	9.605*	21.14*	0.126ns
Replication (R)	2	3822ns	557.58ns	0.0723ns	0.288ns	1.44ns	0.019ns
Error (E)	6	20801	2200	0.572	1.633	2.46	0.044
CV (%)		14.21	13.92	15.37	6.34	9.37	6.34

ns: Non significant, * and ** significant at α=0/05 & α=0/01, respectively.

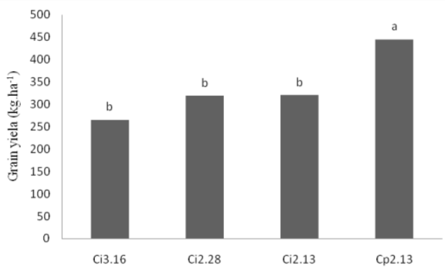


C_p2.13: Cumin pure cultivation (February 13)
C_i2.13: Cumin intercropping (February 13)
C_i2.28: Cumin intercropping (February 28)
C_i3.16: Cumin intercropping (March 16)
means with similar letter, are not significantly different.

Fig. 1. Effect of different intercropping treatments and planting dates on Dry Matter Yield of Cumin.

The Grain yield

The results (Table 2) showed that the effect of various treatments on Cumin grain yield was significant at 5% probability level.



C_p2.13: Cumin pure cultivation (February 13)
C_i2.13: Cumin intercropping (February 13)
C_i2.28: Cumin intercropping (February 28) C_i3.16: Cumin intercropping (March 16)
means with similar letter, are not significantly different.

Fig. 2. Effect of different intercropping treatments and planting dates on Grain Yield of Cumin.

The grain highest yield (444.4 kg.ha-1) between treatments was achieved from pure cultivation treatment (Fig. 2), delayed treatments dated February 28 and March 16 respectively. The grain least yield (265 kg.ha-1) also belonged to intercropping treatment simultaneous with Chickpea on February 13.

Essence percentage

No significant difference was observed among various treatments of delayed intercropping and pure cultivation in terms of essence percentage (Table 2). However, the highest percentage of essence (5.09) among the studied treatments was achieved from delayed intercropping treatment dated February 28, and the lowest percentage of essence (4.79) was observed in delayed intercropping simultaneous with Chickpea on March 15 (Table 3).

Bush height

The effect of various treatments on Cumin bush height was significant at 5% probability level (Table 2). The maximum height of Cumin (22.4 cm) among various treatments was achieved from intercropping simultaneous with Chickpea treatment. The minimum height (18.7 cm) was also related to delayed intercropping treatment dated February 28, which in means comparison was in the same group with delayed intercropping dated March 16 (Table 3).

The number of umbelets per bush

The experiment results (Tables 2 and 3) showed that there is a significant difference, at 5% probability level, among various treatments in terms of effect on the number of umbelets per bush, and among various treatments, the most number of umbelets per bush belonged to pure cultivation. Moreover, as it is evident in mean comparison table, there is no difference among various treatment of intercropping in terms of grouping, and all 3 treatments are in the same group; however, the least number of umbelet per bush (14.4) was also belonged to delayed intercropping treatment dated February 28.

Table 3. The mean comparison of different intercropping treatments and planting dates of Cumin.

	Treatments				Mean
	C_1	C_2	C_3	C_4	
Essence percentage	4.79^a	4.91^a	5.09^a	4.88^a	4.92
Plant Height	22.4^a	18.8^b	18.7^b	20.7^{ab}	20.14
number of umbelets per bush	15.7^b	16.3^b	14.4^b	20.6^a	16.75
1000-Grain Weight	3.42^a	3.44^a	3.43^a	3.02^a	3.331

C_1 : intercropping of Cumin and Chickpea (February 13)

C_2 : intercropping of Cumin and Chickpea (February 28)

C_3 : intercropping of Cumin and Chickpea (March 16)

C_4 : pure cultivation of Cumin

Means with similar letter, are not significantly different ($p \leq 0.05$)

The weight of one thousand Grains

Results of variance analysis (Table 2) showed that there is no significant difference among various treatments in terms of effect on the weight of one thousand grains of Cumin in the experiment. However, the maximum (3.44 gr) and minimum (3.02) weight of one thousand grains of Cumin among treatments belonged to delayed mixture dated March16, and Cumin respectively. Results show very trivial difference between intercropped treatments (Table 5-4). The effect of various treatments on Chickpea yield and its components

Dry Matter Yield

According to Chickpe avariance analysis (Table 4-a), there was a significant difference among treatments at 1% probability level in terms of the effect on dry matter yield.

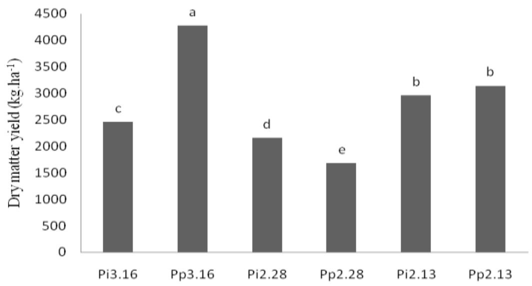
The maximum yield among all treatments (2469 $kg.ha^{-1}$) belonged to pure cultivation dated February 13, and the minimum one (1675 $kg.ha^{-1}$) belonged to pure cultivation dated March 16. The reason of this low yield may be short growth period compared to primary pure treatment.

The maximum yield (2954 $kg.ha^{-1}$) among intercropped treatments was observed in mixture dated February 28, which is ranked second among all treatments, and this indicated the priority of delayed intercropping compared to tow pure treatments dated February 28 and March 16 (Fig. 3).

Table 4-a. Analyze of Variance of yield and yield components of Chickpea.

S.O.V	Mean square					
	df	Dry matter yield	Seed yield	Plant Height	1000-Grain Weight	Number of sub Branch
Treatment(T)	3	2455335^{**}	495467^{**}	$^{**}51.86$	6548^{**}	3.28^{**}
Replication (R)	2	143896^{ns}	143896^{ns}	2.16^{ns}	146.72^{ns}	0.22^{ns}
Error(E)	6	143890	3982	0.63	679.12	0.288
CV(%)		4.33	7	2.57	8.5	14

ns: Non significant, * and ** significant at α=0/05 & α=0/01, respectively.

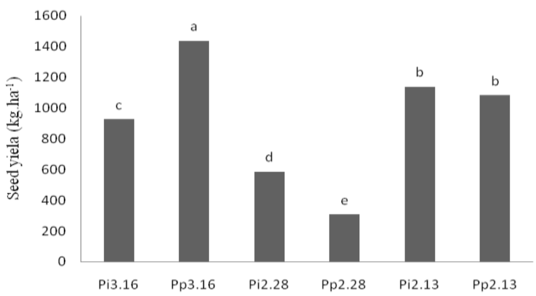


p_p2.13: Chickpea pure cultivation (February 13)p_i2.13: Chickpea intercropping (February 13)
p_p2.28: Chickpea pure cultivation (February 13)p_i2.28: Chickpea intercropping (February 28)
p_p3.16: Chickpea pure cultivation (February 13)p_i3.16: Chickpea intercropping (March 16)
means with similar letter, are not significantly different.

Fig. 3. Effect of different intercropping treatments and planting dates on Dry Matter Yield of Chickpea.

Grain yield

Table 4-a shows that there is a significant difference among the grain yields of various treatments at 1% probability level. According to the results of means comparison (Fig. 4) the grain yield in delayed intercropped treatment dated March 16 was place in the same group with its pure cultivation, but there is a significant difference between pure and intercropping in other treatments. The maximum grain yield among treatments, (1435 $kg.ha^{-1}$) was observed in Chickpea pure treatment, and the minimum one(307 $kg.ha^{-1}$) was achieved from pure cultivation dated March 16.



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p_p3.16: Chickpea pure cultivation (February 13) p_i3.16: Chickpea intercropping (March 16)
means with similar letter, are not significantly different

Fig. 4. Effect of different intercropping treatments and planting dates on Seed Yield of Chickpea.

Plant Height

As you can see in (Table 4-a), a significant difference can be seen among treatments in terms of the effect on bush height at 1% probability level. The bush maximum height (38.7 cm) was related to pure treatment. The maximum bush height (31.3 cm) among intercropped treatments is related to intercrop treatment dated February 13, which has no significant difference with its intercropped treatments dated February 28, and its pure treatment. The minimum bush height (27 cm) is related to intercrop treatment dated March 16, which has no sensible difference with its simultaneous pure treatment (Table 5).

The weight of one thousand grains

The results of variance analysis shows that the effect of various treatments on the weight of on thousand grains of Chickpea was significant at 1% probability level (Table 4-a). As you can see (table 5), the maximum weight of one thousand grains among various treatments belonged to Chickpea pure cultivation dated February 13, and the maximum weight of one thousand grains among intercropping (342 gr) on different dates of cultivation, belonged to delayed intercropping dated February 28. Moreover, the least weight of one thousand grains (242.7 gr) among various treatments was achieved from pure treatments dated March 16.

The number of lateral branches per bush

As we can see (Table 4-a) a significant difference can be seen among various treatments in terms of effect on the number of lateral branches per bush at 1% probability level. Moreover, the treatment means table of comparison (Table 5) shows that there were 3 statistical groups exist among the treatments. The maximum number of lateral branches (5.7 branches) is belonged to pure cultivation treatment dated February 13, and the minimum one (3 branches) is observed in pure cultivation dated March 16.

The percentage of empty pod per bush

According to the results of variance analysis (Table 4-b), there is a significant difference among treatments at 1% probability level in terms of the effect on the percentage of empty pod Moreover, the data of mean comparison table (Table 5) indicates that the maximum percentage of empty pod (47.3%) among various treatments (47.3%), which caused to severe decrease of economic yield. Also, the least percentage of empty pod per bush (17.3%) in Cumin intercropped treatment was observed in delayed treatment dated February 28. The effect of various treatments on some features of Chickpea root

The root dry weight

As you can see in variance analysis table (Table 4-b), there was a significant difference among various treatment at 1% probability level in terms of the effect on the root dry weight. Means comparison table of root dry weight (Table 5) shows that the maximum root dry weight (1.71 gr) is observed in delayed intercropped treatment dated February 28, and it is not different statistically with its simultaneous pure cultivation. Also the minimum root dry weight (0.706 gr) among all treatments belongs to pure treatment dated March 16.

The root length

Table 4-b shows that there is a significant difference among various pure and intercropped treatments of Chickpea at 1% probability level in terms of effect on the root length. According to Table 5 it is observed that the maximum root length (16.2 cm) among various treatments belongs to pure cultivation dated February 28 and the minimum one was observed in pure cultivation treatment dated March 16. As you can see (Table 5) no statistical grouping difference is observed between pure and intercropping in terms of root length among cultivations dated February 13 and February 28.

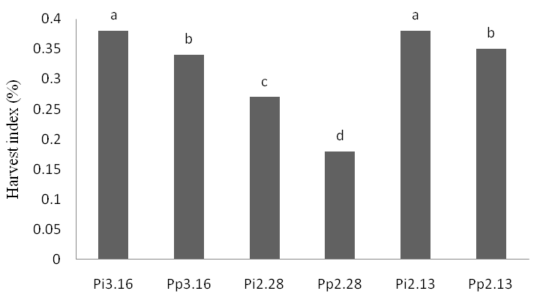
S.R^{-1}[2] ratio

According to table 4-b it is observed that there is a significant difference at 1% probability level between tow statistical groups. Mean comparison table (Table 5) shows that the maximum S.R^{-1} (3/166) between tow established statistical groups, is observed in pure cultivation treatment dated February 13, and the pure and delayed intercropping dated February 28 are in the same group with this treatment. Also the minimum S.R^{-1} (2/01) belongs to delayed intercropped treatment simultaneous with Cumin on February 13.

Harvest Index

According to Table 4-b it can be seen that the harvest indices of different treatments have a significant difference at 1% probability level. Also mean comparison of this index (Fig. 5) shows that the maximum harvest index (385) among various treatments is seen in delayed pure and intercropping dated February 28, and this result shows that February 28, is a suitable time for culturing the Chickpea compared to tow other times. Also the minimum harvest index (18%) was achieved from Chickpeapure cultivation on March 16.

Economic and competitive indices



p_p2.13: Chickpea pure cultivation (February 13)
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p_p3.16: Chickpea pure cultivation (February 13)
p_i3.16: Chickpea intercropping (March 16)
means with similar letter, are not significantly different.

Fig. 5. Effect of different intercropping treatments and planting dates on Harvest index of Chickpea.

Land equivalent ratio (LER)

As it can be observed (Table 6-a) the maximum land equivalent ratio (2.63) was related to total land equivalent ratio from delayed intercropped treatment dated March 16, and the minimum one (0.6) was related to land equivalent ratio from treatment dated February 13.

[2]Shoot. Root^{-1}

Table 4-b. Analyze of Variance of yield and yield components of Chickpea.

S.O.V	Mean square					
	df	Percent of empty pods	root dry weight	root length	$S.R^{-1}$	Harvest index
Treatment (T)	3	458.13**	0.5**	9.53**	0.7817**	0.0184**
Replication(R)	2	4.66ns	0.00017ns	1.166ns	0.0261ns	0.0004ns
Error (T)	6	12.4	0.000819	0.3	0.0914	0.000143
CV(%)		12.3	2.1	3.7	11.4	3.8

ns: non significant, * and ** significant at α=0/05 & α=0/01, respectively.

Table 5. The mean comparison of different intercropping treatments and planting dates of Chickpea.

	Treatments						Mean
	P_1	P_2	P_3	P_4	P_5	P_6	
Plant Height	38.7^{a}	31.3^{b}	27.7^{c}	27^{c}	30.3^{b}	31^{b}	31
1000-Grain Weight	377^{a}	286^{cd}	246.7^{d}	281.3^{cd}	342.7^{ab}	308.7^{bc}	307
Number of sub Branch	5.7^{a}	3.3^{c}	3^{c}	3.3^{c}	4.7^{b}	3.3^{c}	3.9
Percent of empty pods	36.7^{b}	18^{c}	47.3^{a}	19.3^{c}	17.3^{c}	33.3^{b}	28.7
root dry weight	1.526^{c}	1.586^{b}	$.706^{e}$	1.063^{d}	1.71^{a}	1.703^{a}	1.382
root length	15.7^{ab}	14.7^{b}	11.3^{c}	15.5^{ab}	15.7^{ab}	16.2^{a}	14.8
$S.R^{-1}$	3.166^{a}	2.01^{b}	2.056^{b}	2.713^{b}	3.11^{a}	2.893^{a}	2.893

P_1 : pure cultivation of Chickpea (February 13)

P_2 :intercropping of Chickpea and Cumin (February 13)

P_3 : pure cultivation of Chickpea (March 16)

P_4 :intercropping of Chickpea and Cumin (March 16)

P_5 :intercropping of Chickpea and Cumin (February 28)

P_6 : pure cultivation of Chickpea (February 28)

Means with similar letter, are not significantly different ($p \leq 0.05$).

Table 6-a. Quantities of economic and competitive indices under different intercropping dates of Chickpea and Cumin.

Treatments (T)	Land equivalent ratio			Competition ratio		Actual yield loss		
	LER_T total	LER_C Cumin	LER_P Chickpe	CR_C Cumin	CR_P Chickpe	AYL_T total	AYL_C Cumin	AYL_P Chickpea
February 13	1.24	0.6	0.64	0.38	2.73	0.44	0.2	0.24
February 28	1.79	0.74	1.05	0.29	3.81	1.51	0.48	1.03
March 16	2.63	0.73	1.9	0.15	6.69	3.12	0.45	2.67

Competition Ratio (CR)

Mean competition ratio (Table 6-a) indicates that CR for Chickpea is greater than Cumin, while this index is less than 1 for Cumin. The maximum CR for Chickpea and the minimum one for Cumin in March 16 were achieved 1.69 and 0.15 respectively.

Intercropping advantage

The comparison of mean profitability has been presented and indicates that Chickpea plant mean IA was less than Cumin in February 13 and February 28 cultivation dates, but it was more in Chickpea than Cumin on March 16 cultivation date. Total intercropped advantage of both plants was positive in all cultivation dates (Table 6-b).

Aggressivity

The results of Aggressively calculation on February 13 and February 28 cultivation date shows that Cumin plant was dominant and Chickpea has been recessive. As a result, the Cumin dominance sign has been positive (Table 6-b).

System productivity index

In mean comparison it was seen that the date of February 13 is of high production index and it was more than two other treatments (Table 6-b).

This indicates that both plants have made the most use of available resources on this date and have caused increasing production index.

Relative Value Total

The sum of relative indices among various treatments has been shown in Table 6-b. The maximum relative value Total (1.22). Belongs to intercropping treatment dated February 28. Also the minimum sum of relative value Total (0.97) was observed in delayed intercropping treatment dated March 16.

Table 6-b. Quantities of economic and competitive indices under different intercropping dates of Chickpea and Cumin.

Treatment (T)	Intercropping advantage			Aggressively	System productivity index		Relative Value Total
	IA_P Chickpea	IA_C Cumin	IA_T total	A_P Chickpea	A_C Cumin	RVT	SPI
February 13	7269	32197	39466	-12	12	0.99	3873.68
February 28	30935	76128	107063	-11.08	11.08	1.22	3579.3
March 16	80068	72421	152489	1.21	-1.21	0.97	628.62

Discussion

Our study showed the highest biological yield and grain Yield of Cumin is belonged to its pure cultivation. The biological and grain yield of Cumin pure cultivation was higher in comparison to its intercropping with Chickpea (Zarifpour *et al.*, 2014). Also, the least biological and grain yield of Cumin was achieved from its Simultaneous intercropping with Chickpeain treatment dated February 13, the reason of which may be the less competitive power of Cumin in comparison with Chickpea. Koocheki *et al.*, (2010) reported the highest yield of dry matter in pure cultivation. Nasrollah-zadeh Asl *et al.*, (2012) reported that the Sunflower (*Helianthus anus* L.) highest lead in intercropping of Sunflower and Kidney Bean (*Phaseolus vulgaris Pinto*), was achieved in its pure cultivation. Intercropping had a positive effect on cumin height; The reason maybe more adjacency of Chickpea with Cumin and providing the plant required nitrogen during growth period. The Sunflower maximum height was achieved from its intercropping with Chickpea (Rashid *et al.*, 2002). The most number of umbelets per bush belonged to pure cultivation. Jahani *et al.*,(2008) reported that there is no significant difference among various treatments of Cumin and Lentil (*Lens culinaris*) intercropping and its pure cultivation. The weight of one thousand grains of Cumin not affected by treatments. Manjith Kumar *et al.*, (2009) stated also that different ratios of intercropping has no significant effect on the one thousands grains of Chickpea. In Sunflower and Bean intercropping stated that the weight of one thousand grains of Sunflower was not affected by intercropping (Morales *et al.*, 2009).

The maximum Dry matter yield belonged to pure cultivation dated February 13, and the minimum one belonged to pure cultivation dated March 16. The reason of this low yield may be short growth period compared to primary pure treatment. Mirhashemi *et al.*, (2009) reported the maximum Biological yield of Ajowanin its pure cultivation. Rajeswara-Rao (2002) studied and compared Pepermint (*Mentha arvensis* L.) and Rosa geranium (*Pelargonium graveolens*) and concluded that biological yield of Pepermint was led than Rosa geranium in intercropping. The results showed that planting date, most of the crop pattern affected grains yield. One of the reasons of low yield of pure and intercropped treatments dated March 16, we can point to short growth period and Agrotis (*Agrotis segetum*) pest attack. The yield of 3 plants of Chickpea, Bean and Black Cumin (*Nigella sativa*) in pure cultivation was more than intercropping (Koocheki *et al.*, 2014). Moreover, the Soybean (*Glycine max*) and Split Dill (*Lentil dahl*) pure cultivation was superior to their intercropping (Ghosh *et al.*, 2006). Plant height was affected by planting pattern and the maximum value is obtained from pure stands. Sesame height was decreased in intercropping (Koocheki *et al.*, 2010). The maximum weight of one thousand grains and the number of lateral branches per bush among various treatments belonged to Chickpea pure cultivation dated February 13.

One reason for low weight of one thousand grains in pure cultivation dated March 16 was Agrotis pest attack, which caused the grains shrinkage. Our results showed that intercropping decreased the percentage of empty pods. Jahani *et al.*, (2008) reported a significant difference in the number of seeds per umbel of Cumin, and stated that the maximum number of seeds per umbel was achieved in intercropped row cultivation treatment of Cumin and Lentil. The maximum harvest index among various treatments is seen in pure and delayed intercropping dated February 28, and this result shows that February 28, is a suitable time for culturing the Chickpea compared to tow other times. Rezvani-Moghaddam *et al.*, (2009) reported that the Vetch (*Vigna radiata*) harvest index was increased in its intercropping with Black Cumin than its pure cultivation. Moreover, Zarifpour *et al.*, (2014) showed high harvest index of Cumin and Chickpea intercropping compared to its pure cultivation.

Land equivalent ratio of all various dates of cultivation is greater than 1, which is a reason for superiority of intercropping to mono cropping in this cultivation system. When then land equivalent ratio is greater than 1, it means that there is positive profit in multi cultivation, and this indicates that the facility between species is greater than competition between species (Vandermeer, 1989). In a study conducted on Sesame and Bean, LER was observed greater than 1 in all intercropped treatments (Nurbakhsh *et al.*, 2013). In Basil (*Ocimum basilicum* L.) and Bean intercropping, Alizadeh *et al.*, (2010) reported that nearly all intercropping treatments were superior to their pure cultivation. The CR for Chickpea is greater than Cumin. As the growth period, cultivation density, difference in development depth and root density are the factors effect on competition between intercropping components in consumption of nutrients, it seems that Chickpea could use this features properly, and have more competitive power in absorbing some elements (Eskandar & Ghanbari., 2011). The study conducted on Fennel (*Foeniculum vulgare* L.) and Dill (*Anethum graveolenss*) sustainable production indicates that the most effective used agricultural ecosystem was intercropping with higher ratio of Fennel, in which accounted CR reached to 1.9 for Dill (Carruba *et al.*, 2008). According to positive AYL_t in all intercropping (table 6-a), intercropping is beneficial rather than mono cropping in both plants, and is of supporting production principle observance. The researchers also observed that hard Durum Wheat (*Triticum durum*) and Chickpea intercropping in minimum fertilizer treatment caused to more stability of air molecular nitrogen rather than its mono cropping and increased the yield more steeper (Bedoussac *et al.*, 2010). Total intercropped advantage of both plants was positive in all cultivation dates. Some researchers have introduced the better use of the resources such as light, water and nutrition as the reason for increasing the Intercropping advantage (Litourgidis *et al.*, 2011). Due to the fact that nitrogen is one of the major sources of plant growth, it seems that transferring the fixed nitrogen by Chickpea to Cumin has done better in intercropping and has caused increasing of product profitability in intercropping rather than mono cropping (Ahmadi *et al.*, 2010). Fast primarily growth of Cumin compared to Chickpea caused its Aggressively than Chickpea. However, this ratio became reversed and Cumin Aggressively became negative on March 16 cultivation date, but it is negligible due to its low numerical value. In Banik *et al.*, (2006) study, Barley (*Hordeum vulgare*) was dominant plant and Chickpea was recessive one. Wahla *et al.*, (2009) have also reported dominancy of Barley in intercropping treatments of Chickpea and Lentil. Our results showed that, during the growing season has a direct Relationship with System productivity index**.** The highest productivity index of system (2.92) belongs to intercropping treatment replaced with 75% Forage Chickpea (*Pisum sativum* L.) and 25% Barley (Lamei Hervani, 2013). In cultivation dates, which relative value total was greater than 1, intercropping is prior to mono cropping, and in dates which relative value total was less than 1, mono cropping is preferred and prior to intercropping. Relative value total less than 1 in other cultivation dates indicates the lack of economic advantage of these dates for intercropping Cumin and

Chickpea may be due to yield and higher price of Cumin than Chickpea as well as more yield of Cumin in pure cultivation compared to intercropping. The results of research by Bohra *et al*., (1999) and Samsuzzaman *et al*., (1995) on intercropping of Chickpea and Mustard (*Brassica juncea*), Santalla *et al*. (2001) on intercropping the Bean and Corn, Sarker *et al*., (2007) on intercropping Mustard with Garlic (*Allium sativum*) and Onion (*Allium cepa*), indicate more economic advantage of intercropping compared to pure cultivations.

Conclusion

Totally, the result showed that economic yield, biologic yield, bush height, and the number of umbel per bush of Cumin were significantly affected by experiment treatment. Also biologic yield, economic yield, bush height, the number of lateral branches, the percentage of empty pod, root length, root dry weight, S.R^{-1}, and the weight of one thousand grains of Chickpea in intercropping treatments were affected by experiment treatments. Increasing the Chickpea yield in intercropping treatments caused that land equivalent ratio becomes more than 1, and so intercropping be appropriate compared to mono cropping. The dominancy of Cumin to Chickpea affected on other indices so that Aggressively and productivity index indices of Chickpea were more than Chickpea. Relative value total in treatment dated February 28 was more than two other treatments. Therefore, the Evaluation of economic and competitive indices Explain the intercropping advantage of Cumin and Chickpea, and as a result the realization of sustainable agriculture goals as well.

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