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Effect of sowing date and different intercropping patterns on yield and yield components of rapeseed (*Brassica napus* L.) and chickpea (*Cicer arietinum* L.)

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ABSTRACT

In order to evaluate the effect of sowing date and planting pattern on yield and qualitative parameters of rapeseed (*Brassica napus* L.) and chickpea (*Cicer arietinum* L.) in intercropping, a split plot experiment was conducted based on randomized complete block design with four replications, in Hamedan, Iran, during 2014-15. The rapeseed seeds were sown on 21st September. Chickpea was sown on four sowing dates as the main factor (21 September, 10 October, 30 October and 20 November) with 20 days interval. The sub-factor was the planting pattern by replacement series including 100:0, 75:25, 50:50, 25:75 and 0:100 chickpea-rapeseed mixtures, respectively. Based on the results obtained, among chickpea sowing dates, the first and the last dates had the lowest and highest above-ground biomass and grain yield, respectively. During the late sowing date of chickpea (20 November) the field temperature was colder than the earlier dates, and therefore the freezing temperatures did not allow the seeds to germinate. However, no damage happened to seedlings with the earlier sowing dates. The highest yield was observed in sole cropping for both crops. In contrast, the highest values of land equivalent ratio were obtained in intercropping system. The highest value for land equivalent ratio was calculated as 1.23 in intercropping of 50% chickpea + 50% rapeseed.

Key words: Chickpea, Intercropping, Rapeseed, Yield components.

INTRODUCTION

Intercropping is a cropping technology that could be useful for more efficient use of resources, for stable yields particularly in problematic environments and also a method to reduce problems with weeds, plant pathogens and nitrogen losses after grain or legume harvest (Jansen, 2004). Intercropping systems has the potential to produce better yields than monocultures. It is a common practice among small landholders using traditional farming systems. It provides farmers with a variety of returns from land and labor, and often increases the efficiency with which scarce resources are used and reduces the risk associated with a single crop that is susceptible to environmental and economic fluctuation (Khan *et al.*, 2005). Intercropping is also known to intercept more solar energy and provide comparatively higher yield stability (Tsubo *et al.*, 2013) and yield insurance during aberrant weather conditions compared with sole cropping (Mandal *et al.*, 1991).

Several research works indicated the particular importance of plant density and planting pattern upon intercrop viability. Many studies have shown that intercrop components might utilize different edaphic and climatic growth resources more efficiently and potentially supporting a great number of plants which may result in more optimum plant density than those of sole cropping (Ofori and Stern, 1987; Ghosh, 2004, Banik *et al.*, 2006; Ghosh *et al.*, 2009). Choosing an optimum sowing time can also be a compromise between maximum yield potential and minimum disease levels. Earlier sowings can expose the crop to more rain events which can increase the risk of diseases (Matthews and McCaffery, 2011). One method to enhance grain yield in chickpea would be to change the sowing time using improved varieties which are resistant to biotic and abiotic disorders (Janneli and Bozzini, 2001). Winter/autumn sown chickpea produced higher grain yield than spring sown crop (Iliadis, 2001). Increased crop production, contributed by plant height, higher number of branches and pods per plant which was positively correlated with yield (Singh *et al.*, 1990). Optimum sowing time of chickpea varies among cultivars and also from one region to another due to variation of agro-ecological conditions.

Chickpea and rapeseed are among the most important crops in the world as they play vital roles in global agricultural economy. Therefore, the main objective of this study was to evaluation of the changes in the chickpea yield components as influenced by intercropping of rapeseed following different sowing dates of chickpea.

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MATERIALS AND METHODS

A two years experiment was conducted at the Agricultural Research Center of Hamedan, Iran (latitude 34°472 573 N, longitude 48°302 523 E, Altitude 1820m above sea level) in 2015 and 2016. The climate is semi-arid and cold with mean annual precipitation of 326 mm and mean annual temperature of 12°C. The soil texture was clay-loam. The experimental design used was randomized complete block (RCB) with four replicates for rapeseed in single sowing date and split plot design based on RCB with four replications for chickpea. In split plot design, the sowing date were considered as a main factor and intercropping ratio as a sub-factor. Intercropping ratios were 100:0, 75:25, 50:50, 25:75 and 0:100 as chickpea-rapeseed mixtures, respectively. Sowing dates for chickpea were 21 September, 10 October, 30 October and 20 November in both years tested. Each year, the experimental area was ploughed in the spring and manured with 10 t ha^{-1}. Fields were disked, furrowed and then plotted before sowing the seeds. After the bed preparation, seeds were sown based on different sowing dates. Each experimental plot was 5×4 m containing 8 rows of 4 m length. All plots were irrigated immediately after sowing and subsequent irrigations were carried out when 80 mm evaporation was recorded from class A pan-evaporimeter. Weeds were hand controlled. At maturity stage, 10 plants were randomly harvested from each plot and plant height (cm), number of pods per plant, 1000 seed weight (g) of both crops, oil percentage of rapeseed and protein percentage of chickpea were extracted and recorded. Finally, plants from 1 m^2 area in the middle of each plot were harvested and different yield parameters were determined.

Land equivalent ratio (LER) was calculated as follows (Willey, 1979):

$$LER = LER_a + LER_b = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where, LER_a and LER_b are the partial LER of chickpea and rapeseed, respectively.

Relative crowding coefficient (RCC) was calculated by the following formula (de Wit, 1961):

$$RCC_{ij} = \frac{(Y_{ij}/Y_{ii})}{(Y_{ji}/Y_{jj})}$$

Where, Y_{ii} and Y_{jj} are the yields of chickpea and rapeseed pure stand, respectively. Whereas, Y_{ij} and Y_{ji} are the yields of chickpea and rapeseed in intercropping system, respectively.

System Productivity Index (SPI) was calculated as described by Odo (1991):

$$SPI = \frac{S_a}{S_b} \times (Yb + Ya)$$

Where, Y_a and Y_b mean the chickpea and rapeseed yields in pure stand, respectively. Whereas, S_a and S_b mean the chickpea and rapeseed yield in intercropping system, respectively.

Analysis of variance and means comparison were performed by the Least Significant Difference Test (LSD) at p≤0.05 using SAS software.

RESULTS AND DISCUSSION

A. Effect of intercropping on rapeseed yield parameters: Based on the variance analysis results, grain and biological yields of rapeseed in 2015 were greater than 2014 (Tables 1, 2). Because of higher precipitations in 2015 it was not un-expected. Effect of intercropping ratio was significant on all of studied traits (P<0.01). The interaction of year×intercropping ratio was not significant for any of the measured traits (Table 1).

The highest and the lowest values for plant height, weight of 1000 seeds, grain and biological yields of rapeseed were obtained in sole cropping of rapeseed and 25% rapeseed+75% chickpea mixture, respectively (Table 2). In contrast, the highest values of number of pods per plant and oil percentage were obtained in 25% rapeseed+75% chickpea. It seems that lower seed rates of rapeseed in the mixture led to higher pod set per plant and oil percentage (Table 2).

Lower values for 1000 seed weight of crops in intercropping compared to sole cropping is due to stronger competition on resources such as light, water and nutrition in intercropping which indirectly influences seed weight and further reduces these components in intercropping (Shehata *et al.*, 2007). In an investigation carried out by Zolfaghar *et al.* (2000) on soybean-sorghum intercropping, it was observed that sorghum height had no significant influence

Table 1: Combined analysis of variance of the effects of intercropping ratio on field performance of rapeseed.

S.O.V	df	MS					
		Plant height	Pod number per plant	1000 seed weight	Grainyield	Biological yield	Oilpercentage
Year (Y)	1	3.425	159.579	0.029	313919.21*	2208902.50**	1.753
R (Year)	6	1.862	0.311	0.085	35720.163	82865.70	0.372
Intercropping ratio (R)	3	68.91*	989.22**	3.613**	9076604.5**	62236410.8**	**24.62
Y x R	3	9.646	2.478	0.002	275.814	1250.90	0.084
Error	18	17.037	137.046	0.094	71480.584	771002.30	4.041
CV (%)	-	3.23	8.30	7.54	11.28	14.38	5.37

*, ** mean statistical significant at p≤0.05 and p≤0.01, respectively.

Table 2: Mean comparison for yield and yield components of rapeseed mixed with chickpea.

Treatments	Plant height(cm)	Pod number per plant	1000 seed weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Oil(%)
Year 1	126.52a	162.31a	3.91a	2253.67b	5862.14b	38.37a
Year 2	127.25a	166.13a	4.06a	2407.59a	6170.35a	38.46a
Rapeseed (sole)	129.10a	146.40d	4.854a	3382.54a	8749.00a	36.55c
75% Rapeseed/25% Chickpea	127.94a	153.50c	4.177b	2916.97b	7546.25b	36.99c
50% Rapeseed/50% Chickpea	127.82a	171.50b	3.655c	2029.76c	5249.87c	39.43b
25% Rapeseed/75% Chickpea	123.00b	185.90a	3.282d	973.77d	2515.79d	40.53a

Means with similar letters have not significant different at p≤0.05 in LSD test.

on soybean grain size but had significant effect on grain number per unit area; so that the grain number in soybeans intercropped with taller sorghum plants were higher than short sorghum cultivars. The authors reported that this increased grain number was due to increase in pod number per plant and grain number per pod.

The reduction in grain yield of rapeseed has also been demonstrated by other researchers in other crops. For example, Nnoko and Doto (1980) intercropped maize-soybean at four planting patterns. The results indicated that in all cases, grain yield of maize component declined. In a study conducted on sorghum-cowpea intercropping, sole crops of sorghum and cowpea also recorded higher values for both biological yield (Oseni and Aliyu, 2010).

In contrast, for pod per plant and oil percentage, the highest and lowest values were obtained in 25% rapeseed+75% chickpea mixture and sole cropping of Rapeseed, respectively. The highest and lowest values of pod per plant (146.4 and 185.9) and oil percentage (36.5 and 40.5%) was observed in treatment of 25% rapeseed+75% chickpea mixture and sole cropping, respectively (Table 2). These results were in agreement with those reported by Ahmadi (2010).

B. Effect of intercropping on chickpea yield parameters: Based on the variance analysis results, grain and biological yields of chickpea in 2015 were greater than 2014 (Tables 3, 4). Sowing date influenced significantly all traits measured except weight of 1000 seeds (P<0.01), whereas, the effect of intercropping ratio were significant for all of traits (P<0.01). Interaction of sowing date×intercropping ratio was significant for pod per plant and grain yield (P<0.01) (Table 3 and Fig. 1).

The highest and lowest values for plant height (46.53 and 13.20 cm, respectively) were obtained in 21 September and 20 November, respectively. In contrast, the lowest and highest values for pod per plant (14.7 and 19.14), grain yield (865.9 and 1171.1 kg ha^{-1}), biological yield (2316.17 and 2614.1 kg ha^{-1}) and protein content (21.66% and 23.46%) were obtained in 21 September and 20 November, respectively. On the other hand, later sowings led to greater yield quantity and quality in the plants intercropped (Table 4). In the late sowing date of chickpea (20 November) the weather changed to colder and therefore the freezing not allowed to seed germinated and therefore no damage happened to seedling in compare to earlier sowing date.

The highest and lowest values of plant height (53.5 and 35.1cm) and weight of 1000 seeds (28.6 and 24.4g) were obtained in 25% chickpea+75% rapeseed and sole cropping of chickpea, respectively. This reason is due to increased competition of chickpea plants to absorb light in mixed crops (Mahfouz and Migawer, 2014). In contrast, these values for pod per plant (20.6 and 13.2), grain yield (1481.9 and 406.1 kg ha^{-1}), biological yield (3574.3 and 1028.1 kg ha^{-1}) and protein content (25.01% and 20.24%) were observed in sole cropping of chickpea and 25% chickpea+75% rapeseed, respectively (Table 4).

Table 3. Combined analysis of variance of the effects of sowing date and intercropping ratio on field performance of chickpea.

S.O.V	df	MS					
		Plant height	Pod number per plant	1000 seed weight	Grainyield	Biological yield	Oilpercentage
Year (Y)	1	3.43	10.79	4.53	**683154.8	**1355592.6	8.35
R (Year)	6	0.18	15.74	0.43	1924.67	82677.06	5.06
Sowing date (A)	3	**415.15	**136.72	10.84	**542494.9	537902.5**	**23.24
Y × A	3	0.39	1.76	0.43	42.70	77.06	0.14
Error 1	18	1.08	4.79	0.54	950.17	65406.03	4.14
Intercropping ratio (B)	3	**2025.13	**394.62	**123.81	**7405331.6	**40299561.5	**145.04
B × Y	3	0.18	1.21	0.28	23339.87	71277.95	0.08
B × A	9	0.36	*6.43	2.83	*34962.68	28054.71	0.61
B × A × Y	9	0.24	0.93	1.57	285.79	43.43	0.22
Error 2	72	3.22	3.88	4.76	13653.50	539875.73	2.36
CV (%)	-	4.21	11.61	8.21	11.22	29.90	6.71

*, ** mean statistical significant at p≤0.05 and p≤0.01, respectively.

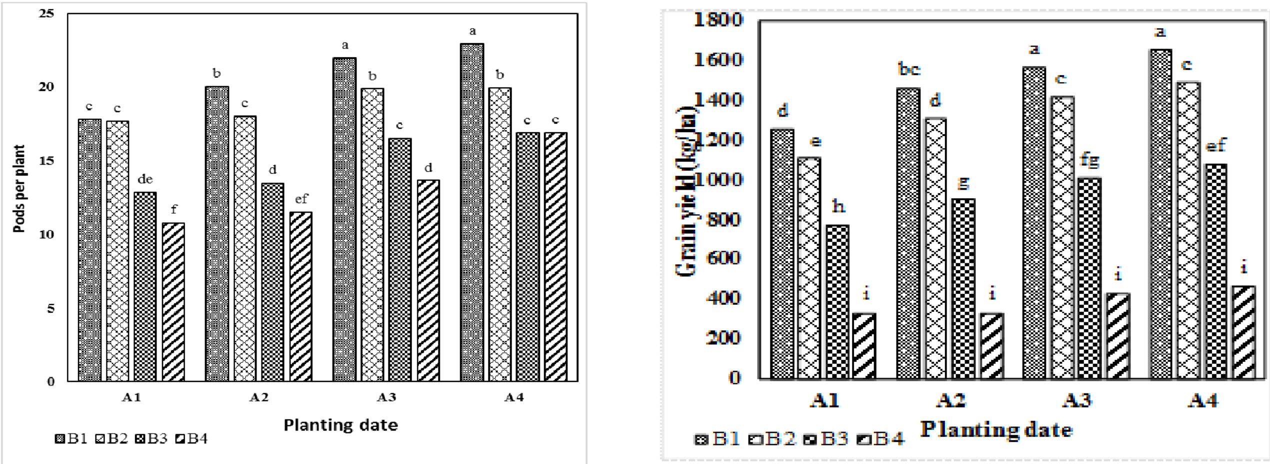

Fig 1: Mean grain yield and pods per plant of chickpea affected by sowing date × intercropping ratio
Means with similar letters have not significant different at p≤0.05 in LSD test.
A_1, A_2, A_3 and A_4: 21 Sept, 10 Oct, 30 Oct and 20 Nov, respectively
B_1, B_2, B_3 and B_4: Chickpea (sole), 75% Chickpea /25%Rapeseed, 50% Chickpea /50%Rapeseed and 25% Chickpea /75%Rapeseed

Interaction of sowing date×intercropping ratio on number of pods per plant and grain yield in chickpea was significant (Fig 1). For both traits the higher values were obtained in sole planting of chickpea in late dates of 30 October and 20 November followed by the treatment of 75% chickpea+25% rapeseed in the same sowing dates. Decreasing the number of chickpea pods per plant in intercropping than to the sole cropping can be contributed to higher interspecific competition. Also increase in the competition for light and minerals and consequently enhance shading in intercropping lead to decrease in photosynthesis rate and so more abscission and lower pod set per plant. Based on the results obtained from Carruthers *et al.* (2009) the number of soybean pod per plant when intercropped with maize decreased compared to the sole cropping. Also, Getachew *et al.* (2006) reported more faba bean (*Vicia faba* L.) pod per plant in mono culture compared to it's intercropping with barley.

The highest grain and biological yields of chickpea were observed in the sole cropping (Table 4 and Fig 1). It seems the higher values of both traits are related to higher number of pods per plant in sole cropping of chickpea. The findings of this study revealed that the improvement of grain yield in chickpea crop is a result of the higher number of pod set per plant. Banik *et al.* (2006) reported that the grain yield of lentil (*Lens culinaris* L.) was significantly decreased when intercropped with wheat. Also, Getachew *et al.* (2006) reported that the biologic yield of faba bean in intercropping with barley decreased compared to the sole planting treatment as a result of increasing interspecific competition.

Land equivalent ratio (LER): The land equivalent ratio (LER) is used to calculate economic advantage of the two component crops. LER indicates the efficiency of intercropping for using the environmental resources

Table 4. Mean comparison for yield and yield components of chickpea mixed with rapeseed at different sowing dates.

Treatments	Plant height(cm)	Pod number per plant	1000 seed weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Protein(%)
Years						
Year 1	42.12 a	16.77 a	26.54 a	967.536 b	2354.22 b	22.44 a
Year 2	42.33 a	16.89 a	26.11 a	1113.64 a	2560.18 a	22.57 a
Sowing Date						
21 Sept	46.53 a	14.77 d	26.13 a	865.97 d	2316.17 b	21.66 b
10 Oct	44.28 b	15.74 c	26.20 a	1017.17 c	2395.26 b	22.94 a
30 Oct	41.54 c	17.98 b	26.33 a	1106.06 b	2504.04 a	23.47 a
20 Nov	38.18 d	19.14 a	26.48 a	1171.13 a	2614.19 a	23.46 a
Intercropping treatments						
Chickpea (sole)	35.11 d	20.67 a	24.46 b	1481.98 a	3574.36 a	25.01 a
75% Chickpea /25%Rapeseed	38.99 c	18.85 b	25.38 b	1331.44 b	3083.20 b	24.10 b
50% Chickpea /50%Rapeseed	42.84 b	14.91 c	27.67 a	940.79 c	2145.56 c	22.19 c
25% Chickpea /75%Rapeseed	53.59 a	13.20 d	28.68 a	406.11 d	1028.11 d	20.24 d

Means with similar letters have not significant different at p≤0.05 in LSD test.

compared with sole culture. It gives an accurate assessment of the greater biological efficiency of the intercropping situation. When LER value is >1, the intercropping favors growth and yield of species (Willey, 1979). LER calculations in two years of experiment showed that all intercropping ratios were superior to pure crop at all sowing dates, the highest and lowest LER with average values of 1.23 and 1.13 were observed in 50:50% and 25:75% chickpea+ rapeseed intercroppings, respectively (Table 5). Similar to our results obtained Yadav *et al.* (2015) in intercropping of green gram (*Vigna radiata*) and pearl millet (*Pennisetum glaucum* L.) found that higher densities of legume crops were always superior to their sole crops. The higher value of LER in intercropping treatments compared to sole cropping might be due to better utilization of land, light, nutrients and water. When the legumes are grown with other plants, the nitrogen fixed by legumes in the soil can be transferred to the other plant in the mixed crop, resulted in increased yield crop. These results were similar to findings from those studies conducted by Banik *et al*. (2006) and Shehata *et al.* (2007).

Relative crowding coefficient (RCC): Relative Crowding Coefficient indicates the relative dominance of a species in mix cropping (Goshe, 2004). RCC in 2 years revealed the superiority of 75:25 pattern of chickpea/rapeseed intercropping, followed by those of 50:50 one, in all sowing date. While chickpea /rapeseed of 25:75 ratio resulted in the lowest value (Table 5).

System productivity index (SPI): The system productivity Index (SPI) is used for assessing intercrops that standardizes the yield of the secondary crop, in terms of the primary crop (Odo, 1991). The SPI was positive for two plants in all mixed cropping ratios and in all chickpea sowing dates in two years of study (Table 5). The index had higher values when the seed rate of chickpea in the mixture was increased to 75 %. The relatively higher SPI values indicated yield advantages from mixed cropping of the two species. The highest values of SPI were obtained when chickpea was mixed at a rate of 75% coupled with 20 November date of sowing. Some researchers have understood that the rise in the SPI value in mixed cropping systems is due to existing growth sources such as light, water and nutrients (Lithourgidis *et al.*, 2011). Nitrogen is one of the main sources for plant growth, it seems that in the late sowing date (20 November), the transfer of nitrogen from chickpea to rapeseed was efficient and increased the usefulness of the mixture compared to single-ship (Ahmadi *et al.*, 2010)

CONCLUSION

This study was conducted to study of effect of sowing date and intercropping patterns on yield and yield components of rapeseed and chickpea. According to the results obtained, the highest plant height, 1000 seed weight, grain and biological yields of rapeseed were observed in pure stand of rapeseed. Sole cropping patterns had high ratios of pod set per plant, grain and biological yields in chickpea. In this experiment LER in all intercropping ratios were superior to pure cropping at all sowing dates, and the highest LER was observed as 1.23 in intercropping of 50% chickpea+50% rapeseed. In sole culture, the grain yields exceeded intercropped yields but nonetheless, results showed that mixed cropping increased both LER and SPI. However, farmers in Iran not be interested in the LER or SPI of intercropping but rather in the profitability of intercropping one crop with the other (that is, which of the intercropping

Table 5: Mean LER, RCC and SPI of chickpea mixed with rapeseed in different sowing dates.

Date of sowing	Treatments	LER (Y1)	LER (Y2)	RCC (Y1)	RCC (Y2)	SPI (Y1)	SPI (Y2)
A1 (21 September)	**75% Chickpea 25%Rapeseed**	1.17	1.17	3.14	3.25	4686.00	5519.49
	50% Chickpea 50%Rapeseed	1.21	1.22	1.01	1.00	2327.49	2756.63
	25% Chickpea 75%Rapeseed	1.13	1.12	0.30	0.29	1501.11	1769.66
A2 (10 October)	**75% Chickpea 25%Rapeseed**	1.18	1.18	3.17	3.21	5565.90	6447.42
	50% Chickpea 50%Rapeseed	1.22	1.22	1.00	1.01	2759.72	3173.18
	25% Chickpea 75%Rapeseed	1.13	1.13	0.30	0.31	1781.59	2056.92
A3 (30 October)	**75% Chickpea 25%Rapeseed**	1.18	1.19	3.21	3.10	6062.98	6940.06
	50% Chickpea 50%Rapeseed	1.24	1.24	1.04	1.06	3031.20	3464.30
	25% Chickpea 75%Rapeseed	1.14	1.14	0.31	0.31	1930.76	2202.74
A4 (20 November)	**75% Chickpea 25%Rapeseed**	1.19	1.19	3.10	3.21	6385.50	7289.01
	50% Chickpea 50%Rapeseed	1.25	1.25	1.08	1.06	3225.75	3667.62
	25% Chickpea 75%Rapeseed	1.14	1.15	0.31	0.32	2039.89	2336.61
Average	**75% Chickpea 25%Rapeseed**	1.18	1.18	3.15	3.19	5675.09	6548.99
	50% Chickpea 50%Rapeseed	1.23	1.23	1.03	1.03	2836.04	3265.43
	25% Chickpea 75%Rapeseed	1.13	1.13	0.30	0.31	1813.08	2091.48

combinations would generate higher income than the other). In conclusion, therefore, for optimum and sustainable productivity and profitability of rapeseed and chickpea intercrop combinations, a planting pattern comprising of two rows of each should be adopted in to increase land use efficiency. These mixtures seem promising in the development of sustainable crop production with a limited use of external inputs. The farmers in Iran can use them, as they are the most profitable systems with the greatest economic return.

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