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Effect of row ratio and fertility levels on chickpea (*Cicer arietinum*) and linseed (*Linum usitatissimum*) intercropping system

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ABSTRACT

A field experiment was conducted during 2005-07 at Kota, Rajasthan to study the effect of intercrop row ratio and fertility levels on chickpea (*Cicer arietinum* L.) and linseed (*Linum usitatissimum* L.) intercropping system. The experiment was laid out in 4 times replicated split plot design, where main-plots received 4 cropping systems, *viz*. sole chickpea, sole linseed, chickpea + linseed (4:2) and chickpea + linseed (5:1) and sub-plots got 3 fertility levels for chickpea and linseed, *viz.* 100 % recommended dose of fertilizer (RDF) (N_{20} $P_{17.2}$ and N_{30} $P_{6.5}$), 75% RDF ($N_{15}P_{12.9}$ and $N_{22.5}P_{4.8}$) and 50% RDF ($N_{10}P_{8.6}$ and $N_{15}P_{3.2}$) applied on area basis. Seed and biological yields of both chickpea and linseed were higher in sole cropping than in intercropping systems. However, the system productivity (chickpea equivalent yield), total LER, net returns and B:C ratio of chickpea+linseed intercropping under both the row arrangements (5:1 and 4:2) were at par with sole chickpea and significantly higher over sole linseed. The highest N and P uptake was recorded under sole chickpea. Reduction in fertilizer dose by 25 and 50% of RDF decreased the seed yield of chickpea by 6.6 and 16.8% during 2005-06 and by 10.1 and 23% during 2006-07, respectively, while reduction in linseed yield was observed only at 50% RDF. Net returns and B:C ratio decreased significantly with the decreasing fertilizer doses. Total LER and LER of component crops recorded improvement with the reduction in fertility level. Competition functions *viz*. relative crowding coefficient, competition ratio and aggressivity indicated that linseed was dominant over chickpea. Intercropping systems were found more advantageous than sole cropping under reduced fertilizer application.

***Key words**:* Bivariate analysis, Chickpea, Competition indices, Fertility, Intercropping, Linseed

Chickpea is the premier pulse crop of India, grown over 7.54 Mha area with an annual production of 5.7 Mt (FAO, 2008). It is mainly grown under rainfed situations and hence, crop often experience moisture stress at critical growth stages. To improve the overall productivity and stability, farmers often grow chickpea in association with other rainfed crops, like barley, mustard, linseed and safflower. Amongst them, chickpea + linseed is one of the most important cropping systems of Central India. Intercropping with linseed had also been found to reduce the incidences of pod borer in chickpea (Ahmed, 2003). Several planting patterns in this system are in vogue like mixed sowing or in replacement series with row proportion varying from 2:1 to 6:2. Spatial arrangements in an intercropping system have important effect on the competition between component crops and their overall productivity. Little information are available regarding the competition behaviour in chickpea+linseed system. Magnitude of competition also varies with the agro-climatic conditions. Further, both the crops differ in their nutrient absorption behaviour and chickpea being a pulse crop may supplement nitrogen requirement of the component crops. Keeping these aspects in view, the present investigation was planned to find out the appropriate row ratio and nutrient management strategy for chickpea–linseed intercropping system.

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MATERIALS AND METHODS

A field experiment was conducted during the winter seasons of 2005-06 and 2006-07 to study the effect of chickpea + linseed intercropping system and fertility levels at the Agriculture Research Station, Kota, Rajasthan. The soil was clayey in texture having pH 7.85, organic carbon (0.56%) and medium in available nitrogen (278 kg N/ha), phosphorus (10.3 kg P/ha) and potassium (295 kg K/ha). The experiment was laid out in split plot design with 4 replications. Main-plots treatments consisted of 4 cropping systems, *viz.* sole chickpea, sole linseed, chickpea + linseed (4:2 ratio) and chickpea + linseed (5:1 ratio). Sub-plots treatments comprised of 3 N + P fertility

levels for chickpea and linseed, *viz.* 100% RDF (20 kg N + 17.2 kg P/ha for chickpea and 30 kg N + 6.5 kg P/ha for linseed), 75% RDF (15 kg N + 12.9 kg P/ha and 22.5 kg N + 4.8 kg P/ha) and 50% RDF (10 kg N + 8.6 kg P/ha and 15 kg N + 3.2 kg P/ha) applied to individual crop row on area basis. Chickpea 'GNG 469' and linseed 'Meera' were sown in rows 30 cm apart on 2 November during 2005 and on 25 October during 2006. N and P doses through diammonium phosphate and urea were drilled at sowing as per treatments. There was no rainfall during the cropping season of 2005-06, however, during 2006-07 26.2 mm rainfall received in the second and third week of February. One spray of endosulfan 35 EC 1 litre/ha at pod filling stage was applied as prophylactic measure against pod borer. The N and P content were determined using standard procedures and uptake by the crops was obtained as product of nutrient concentration and yield. The competition behaviour of the crops was evaluated by bivariate analysis of variance. It is the joint analysis of a pair of yields for two crops intercropped on a set of experimental plots. The philosophy is that because two yields are measured for each plot, and the yields will be interrelated, they should be analysed together. In order to remove the covariance, yield data were transformed as: $Y_1=X_{11}/Y_{11}^{1/2}$ and $Y_2 = (X_2-V_{12}X_1)/(V_{22}-V_{12}^2/V_{11})^{1/2}$; where X_1 and X_2 were chickpea and linseed yields with error variances, V_{11} and V_{22} and error covariance $V_{12.}$ These data sets were then subjected to bivariate analysis and significance was tested using Wilk's criterion as suggested by Pearce and Gillivar (1978).

Land equivalent ratio (LER), aggressivity (A) and relative crowding coefficient (RCC) were worked out as per procedure given by Mead and Willey (1980), Mc Gilchrist (1965) and De Wit (1960). Crop having positive A value is considered to be a dominant species in the intercropping system. The RCC expresses competitive relations and advantages of intercropping. When the product of these two coefficients is greater than one there is a yield advantage, when the RCC is equal to one there is no yield advantage, and when the RCC is less than one there is a disadvantage. Competition Ratio (CR) indicates the degree with which one species competes with the other in an intercrop. It represents ratio of individual LERs of two intercropped crops taking into account the proportion of crops in which they are initially sown. The CR was calculated as $CR_{chickpea}=(LER_{chickpea}/LER_{linseed})(Z_{ba}/Z_{ab})$ and $CR_{linseed}=(LER_{linseed}/LER_{chickpea})(Z_{ab}/Z_{ba})$ When CR is below one there is a positive benefit and the species can be grown in a mixture, in case that the CR is above one there is a negative effect. All the indices were calculated for each crop/intercrop replicate. In all equations, the replicate seed yield values were used for the numerators; however, the mean of sole crop/intercrop values across all the replicates at same fertility levels were used for denominator to improve the normality and homogeneity of variance of data as suggested by Oyejola and Mead (1982).

RESULTS AND DISCUSSION

Productivity

Intercropping did not affect growth and yield attributes of chickpea as well as linseed except 1000 seed weight of linseed that was significantly higher under intercropping (Table 1). The highest seed as well as biological yields of both the crops were observed under their sole stands (Table 1 and 4). Compared to its sole stand, yield reduction in chickpea was to the tune of 24.2 and 33.0% under 4:2 row arrangement and 10 and 15.1% under 5:1 row arrangement during 2005-06 and 2006-07, respectively. This reduction in yield was mainly due to the replacement of area to linseed by 33.3 and 16.6% under 4:2 and 5:1 row arrangements, respectively. The loss in chickpea yield was compensated by additional yield of linseed which was to the tune of 41.1 and 35.0% under 4:2 row arrangement and 27.0 and 22.2% of sole stand (1.10 and 1.64 t/ha) under 5:1 row arrangement during 2005-06 and 2006-07, respectively. Hence, the system productivity (chickpea equivalent yield) of chickpea + linseed intercropping, irrespective of row arrangements did not differ significantly from chickpea sole. However, chickpea equivalent yield for sole linseed was significantly lowest. Singh and Pandey (2002) and Ahalawat and Gangaiah (2010) reported even better performance of chickpea + linseed intercropping over sole chickpea.

With the progressive decrease in fertilizer doses in both the crops from RDF (20 kg N + 17.2 kg P/ha and 30 kg N + 6.5 kg P/ha) to 50% RDF (10 kg N + 8.6 kg P and 15 kg N + 3.21 kg P/ha), yield attributes *viz.* pods/plant and 1000 seed weight of chickpea and capsules/plant and 1000 seed weight of linseed decreased significantly. The seed and biological yields of component crops also decreased accordingly. The percentage decrease in seed yield of chickpea was 6.6 and 10.1% under 75% RDF and by 16.8 and 23% under 50% RDF compared to 100% RDF during 2005-06 and 2006-07, respectively. However, the decrease in seed and biological yields of linseed were not significant between 100% and 75%. The system productivity in terms of chickpea equivalent yield (CEY) also decreased by 7.0 and 7.1 % under 75% RDF and by 21.3 and 15.2% under 50% RDF.

Interaction effect

Significant interaction was observed between the intercropping systems and fertility levels on seed yield of linseed during both the years (Table 2). Although, the reduc-

Table 1. Growth, yield attributes and yield of chickpea and linseed as influenced by cropping systems and fertility levels (pooled data of 2 years)

Treatment	Chickpea					Linseed				Seed yield (t/ha)				System productivity (CEY, t/ha)	
	Plant height (cm)	Branches/ plant	Pods/ plant	Seeds/ pod	1000 seed weight (g)	Plant Height (cm)	Branches/ plant	Capsules/ plant	1000 seed weight (g)	Chickpea 2005-06	Chickpea 2006-07	Linseed 2005-06	Linseed 2006-07	2005-06	2006-07
Cropping system															
Chickpea sole	71	3.7	55.6	1.56	248					2.08	2.60			2.30	2.84
Linseed sole						81	4.8	46.6	7.96			1.10	1.64	1.31	2.01
Chickpea + linseed (4:2)	70	3.6	59.4	1.59	252	81	4.6	44.0	8.20	1.58	1.74	0.45	0.58	2.28	2.61
Chickpea + linseed (5:1)	71	3.8	58.0	1.57	250	83	4.9	45.4	8.22	1.88	2.20	0.30	0.37	2.42	2.87
SEm±	1.1	0.1	1.21	0.03	3.3	1.1	0.1	1.3	0.07	0.04	0.08	0.01	0.04	0.04	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.21	0.13	0.28	0.03	0.13	0.13	0.30
Fertility level (Chickpea : linseed)															
RDF (N_{20} $P_{17.2}$: N_{30} $P_{6.5}$)	72	3.7	62.3	1.56	257	83	4.9	49.9	8.33	2.04	2.37	0.67	0.90	2.29	2.78
75% RDF ($N_{15}P_{12.9}$: $N_{22.5}P_{4.8}$)	71	3.8	57.0	1.58	249	81	4.8	45.3	8.07	1.91	2.19	0.62	0.86	2.13	2.59
50% RDF ($N_{10}P_{8.6}$: $N_{15}P_{3.2}$)	69	3.6	53.8	1.57	243	81	4.5	40.7	7.99	1.59	1.97	0.55	0.81	1.80	2.37
SEm±	0.7	0.2	1.2	0.02	2.0	0.9	0.2	0.9	0.07	0.02	0.06	0.01	0.02	0.02	0.05
CD (P=0.05)	NS	NS	3.5	NS	5.8	NS	NS	2.5	0.21	0.06	0.18	0.04	0.05	0.06	0.16

CEY= Chickpea equivalent yield, calculated using minimum support price (₹/tonne): Chickpea, 14,250 and 14,350; Linseed, 16,500 and 17,100; Chickpea and linseed stover, ₹ 500 and 200/tonne during both the years.

tion in fertilizer doses reduced seed yield of linseed significantly in its sole stand. However, when grown in association with chickpea under both the row proportions (4:2 and 5:1), reduction in fertilizer dose even up to 50% did not reduce the seed yield of linseed to a significant level. This was further tested by the bivariate analysis technique. When two species are interplant, the yields of two crops in general will not be independent. The bivariate analysis of variance has been considered an effective and sound statistical tool for precise evaluation of intercropping treatments as it considers the interaction between intercrops also. The yield data of both the crops were transformed by removing the underlying covariance. The ANOVA revealed that the intercropping systems significantly affected the yield of both the component crops (Table 3). But the fertility levels affected only the yield of chickpea. Conversely, the yield of linseed was not reduced to significant levels when grown in association with chickpea, thus confirming the earlier observation. This might be an indication of legume effect. The associated legume i.e. chickpea might be fulfilling nitrogen requirement of linseed. Pal and Shehu (2001) reported that nodulating greengram contributed to the yield and N uptake of maize and the direct transfer of N from nodulating green gram to the intercropped maize was in the range of 19.7–22.1kg N/ha.

Nitrogen and phosphorus uptake

Sole chickpea recorded significantly highest total N uptake (Table 4). On system basis amongst the intercropping systems, there was no significant difference for total N uptake. However, P uptake was maximum under chickpea + linseed (5:1) intercropping system which was significantly higher over 4:2 row arrangement and sole linseed but was on par with chickpea sole. The N and P uptake of the system decreased significantly with the progressive decrease in fertilizer dose from 100% to 50% RDF. Since the uptake of nutrient is a function of dry matter and nutrient content, the higher biological yield resulted into higher N and P uptake.

Competitive behaviour

Partial LER of both the crops increased as their proportion increased in the planting patterns (Table 5). The total LER of intercropping systems was 1.10 and 1.12 i.e. greater than unity, indicating a greater biological efficiency in utilizing land, space and nutrients over respective mono-crops. It indicated 10–12% higher yield advantage compared to sole cropping. The positive aggressivity value for linseed and negative for chickpea indicated that linseed is a dominant species in this intercropping system. The competition ratio (CR) which

measures the degree with which one crop competes with the other also showed that linseed having higher values is more competitive than chickpea. The CR value for chickpea is less than unity, indicating that there was a positive benefit of chickpea on the component crop (linseed) and this species can be grown in an intercrop. Further, higher CR values for linseed under 5:1 row ratio than under 4:2 row ratio indicate that linseed had more intra specific competition than inter specific competition. Linseed has relatively rapid initial growth leading to stiff competition for resources particularly nutrients, moisture and space which persists for the whole cropping period as evident from strong correlation obtained between competition ratio and height and branches/plant of linseed (r = 0.86 and 0.88). The intercropped linseed had higher relative crowding coefficient than chickpea indicating it to be more competitive than chickpea, agreeing with the CR values reported earlier. The products of relative crowding coefficients were in both the intercropping systems higher than unity indicating that there was a yield advantage having a complementary relationship. The K value was higher under 5:1 row ratio compared to 4:2 row ratio. Similar results were also reported with respect to LER, CR, A and K values by Ahalawat *et al*. (2005) and Mishra *et al*. (2001). Significantly highest LER value under 50% RDF (1.16) indicate that under reduced fertility conditions intercropping system utilizes the resources more efficiently over sole cropping. This was further supported by significantly higher K values under 50% RDF over 75 and 100% RDF.

Economics

The highest net returns (₹25,018 and 31,681) and B:C ratio (2.64 and 3.35) were obtained under chickpea + linseed at 5:1 row ratio during 2005-06 and 2006-07, respectively (Table 5). However, it was at par with sole chickpea and chickpea + linseed at 4:2 row ratio. The net returns under sole linseed were least. Amongst the fertility levels, there was a steady and significant decrease in net returns and B:C ratio with the decrease in fertilizer doses.

From this study, it is inferred that intercropping of chickpea with linseed in 4:2 and 5:1 row arrangements was equally productive as sole chickpea and 50% economy in fertilizer dose to linseed can be achieved under intercropping system, thus providing an opportunity for diversification and achieving stability under rainfed situations.

Table 2. Seed yield of linseed (t/ha) as influenced by interactive effect of cropping systems and fertility levels

Fertility level (Chickpea : linseed)	2005-06			2006-07		
	Cropping systems			Cropping systems		
	Sole linseed	Chickpea + linseed (4:2)	Chickpea + linseed (5:1)	Sole linseed	Chickpea + linseed (4:2)	Chickpea + linseed (5:1)
RDF (N_{20} $P_{17.2}$: N_{30} $P_{6.5}$)	1.22	0.48	0.32	1.76	0.58	0.37
75% RDF ($N_{15}P_{12.9}$: $N_{22.5}P_{4.8}$)	1.12	0.46	0.30	1.65	0.59	0.36
50% RDF ($N_{10}P_{8.6}$: $N_{15}P_{3.2}$)	0.95	0.42	0.28	1.52	0.56	0.36
SEm±		0.02			0.03	
CD (P=0.05)		0.07			0.08	

Table 3. Bivariate analysis of variance for transformed yields (t/ha) of chickpea and linseed

Source of variance	Degrees of freedom	2005-06			2006-07		
		Sum of squares		Sum of products	Sum of squares		Sum of products
		Chickpea (Y_1)	Linseed (Y_2)	(Y_1 x Y_2)	Chickpea (Y_1)	Linseed (Y_2)	(Y_1 x Y_2)
Replication	3	2.57	1.29	(-)1.34	3.78	2.39	2.81
Intercropping systems (IC)	1	148.08**	108.15**	(-)126.55	28.67**	79.51**	(-)47.75
Error A	3	1.67	2.97	1.90	6.37	11.72	0.75
Fertility levels(F)	2	223.51**	1.64	18.30	5.55**	0.08	0.50
IC X F	2	6.57	0.98	(-)2.01	0.07	0.18	0.10
Error B	12	13.35	11.99	(-)1.91	8.63	3.28	(-)0.75
Total	23	395.75	127.03	(-)111.60	53.07	97.15	(-)44.34

Where, $Y_1 = 6.83X_1$ and $Y_2 = 24.7X_2 - 1.45X_1$ during 2005-06; $Y_1 = 4.68X_1$ and $Y_2 = 15.45X_2 - 0.82X_1$ during 2006-07; X_1 and X_2 are actual yields of chickpea and linseed respectively; ** Significant at (P=0.05) level of confidence

Table 4. Biological yield and nutrient uptake of chickpea and linseed as influenced by cropping systems and fertility levels.

Treatment	Biological yield (t/ha)				N uptake (kg N/ha)						P uptake (kg P/ha)					
	Chickpea		Linseed		Chickpea		Linseed		System		Chickpea		Linseed		System	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Cropping system																
Chickpea sole	8.16	9.74			91.1	117.4	-	-	91.1	117.4	24.9	30.2	-	-	24.9	30.3
Linseed sole			3.78	5.50	-	-	49.0	70.6	49.0	70.6	-	-	14.8	21.2	14.8	21.2
Chickpea + linseed (4:2)	6.09	6.68	1.54	1.96	55.8	62.3	20.5	25.5	76.3	87.7	17.9	19.4	6.0	7.7	23.9	27.1
Chickpea + linseed (5:1)	7.27	8.41	1.01	1.23	58.9	67.5	13.6	16.3	72.5	83.8	22.4	25.9	4.0	4.8	26.4	30.7
SEm±	0.15	0.32	0.03	0.13	1.3	2.5	0.5	1.6	1.3	3.1	0.5	0.9	0.1	0.5	0.5	1.0
CD (P=0.05)	0.53	1.09	0.11	0.44	4.4	8.7	1.7	5.4	4.1	9.9	1.8	3.3	0.4	1.7	1.5	3.1
Fertility level (Chickpea : linseed)																
RDF (N_{20} $P_{17.2}$: N_{30} $P_{6.5}$)	7.87	9.00	2.29	3.04	76.4	90.4	31.0	40.5	80.6	98.1	24.8	28.0	9.1	12.2	25.5	30.1
75% RDF ($N_{15}P_{12.9}$: $N_{22.5}P_{4.8}$)	7.43	8.24	2.15	2.91	70.5	82.4	28.4	38.0	74.2	90.3	22.4	25.1	8.4	11.3	23.1	27.2
50% RDF ($N_{10}P_{8.6}$: $N_{15}P_{3.2}$)	6.22	7.59	1.90	2.75	59.0	74.3	23.7	33.9	62.0	81.2	18.1	22.5	7.3	10.3	19.0	24.6
SEm±	0.08	0.24	0.05	0.06	1.0	1.9	0.6	0.7	1.0	1.5	0.3	0.8	0.2	0.2	0.3	0.6
CD (P=0.05)	0.25	0.70	0.14	0.17	3.0	5.7	1.9	2.01	2.8	4.5	1.0	2.3	0.6	0.6	0.9	1.8

Table 5. Competition indices (Pooled data of 2 years) and economics of chickpea and linseed as influenced by cropping systems and fertility levels.

Treatment	Land equivalent ratio (LER)			Aggressivity (A)		Competition ratio (CR)		Relative crowding coefficient (RCC)			Net returns (× 10^3 ₹/ha)		B:C ratio	
	Chickpea	Linseed	System	Chickpea	Linseed	Chickpea	Linseed	Chickpea (K_C)	Linseed (K_L)	System ($K=K_C \times K_L$)	2005-06	2006-07	2005-06	2006-07
Cropping system														
Chickpea sole*	1.00	0.00	1.00					1.00		1.00	23.56	31.64	2.56	3.19
Linseed sole*	0.00	1.00	1.00						1.00	1.00	10.24	20.47	1.22	2.45
Chickpea+linseed (4:2)	0.72	0.38	1.10	(-) 0.09	0.09	0.95	1.07	1.28	1.36	1.81	23.03	28. 10	2.44	2.99
Chickpea+linseed (5:1)	0.88	0.25	1.12	(-) 0.40	0.40	0.72	1.41	1.62	1.83	3.02	25.02	31.68	2.64	3.35
SEm±	0.02	0.01	0.02	(-) 0.05	0.05	0.04	0.05	0.08	0.10	0.21	0.57	1.35	0.06	0.18
CD (P=0.05)	0.06	0.10	NS	(-) 0.17	0.17	0.13	0.18	0.27	0.33	0.71	1. 82	4.32	0.20	0.59
Fertility level (Chickpea : linseed)														
RDF (N_{20} $P_{17.2}$: N_{30} $P_{6.5}$)	0.77	0.30	1.07	(-) 0.21	0.21	0.85	1.22	1.35	1.50	2.17	23.28	30.64	2.48	3.28
75% RDF ($N_{15}P_{12.9}$: $N_{22.5}P_{4.8}$)	0.79	0.31	1.10	(-) 0.23	0.23	0.84	1.23	1.42	1.42	2.07	21.32	28.12	2.32	3.08
50% RDF ($N_{10}P_{8.6}$: $N_{15}P_{3.2}$)	0.82	0.33	1.16	(-) 0.29	0.29	0.82	1.27	1.58	1.87	3.01	16.79	25.15	1.86	2.62
SEm±	0.01	0.01	0.01	(-) 0.03	0.03	0.02	0.03	0.04	0.14	0.23	0.29	0.76	0.03	0.13
CD (P=0.05)	0.04	0.02	0.04	NS	NS	NS	NS	0.13	0.41	0.67	0.85	2.23	0.09	0.38

*Sole crop values for competition indices not included in mean calculations

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