Indian Journal of Agricultural Sciences **84** (6): 770–3, June 2014/Short communication

Productivity, compatibility and economics of mustard (*Brassica juncea*) and lentil (*Lens esculenta*) intercropping system as influenced by moisture conservation practices and fertility levels under rainfed conditions

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Received: 20 June 2012; Revised accepted: 6 May 2014

Key words: Aggressivity, Area time equivalency ratio, Competitive ratio, Land equivalent ratio, Mustard + lentil intercropping, Relative crowding coefficient, System productivity index

Intercropping in recent years has received great attention of the farming community because of its potential advantages in respect of efficient utilization of natural resources by the crops and sustaining productivity of system without deteriorating the soil health. Farmers are motivated to adopt intercropping system primarily due to its economic gains (Bhatti *et al.* (2006). The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture (Dhima *et al.* (2007), Mucheru-Muna *et al.* (2010). Crop compatibility is the most essential factor for a feasible intercropping system. Thus, the success of any intercropping system depends on the proper selection of crop species where competition between them for light, space, moisture and nutrients is less. Competition in an intercrop mixture can be reduced considerably through judicious selection of crops and also by changing plant population with spatial orientation of either of the crops. Indian mustard (*Brassica juncea* L.) and lentil (*Lens esculenta* M.) are important crops in north-west India during winter season and both can be grown in sole as well as mixed stands because of their diverse morphology, growth rhythm and similar climatic conditions. More than 40% of cropped area is raised under rainfed conditions which resulting poor productivity (800 kg/ha). The yield restrictions under rainfed conditions are due to water stress, rapid loss of soil moisture and development of mechanical impedance to root growth. Thus, its real advantage can be obtained if it is supplemented with adequate fertilizers and suitable moisture conservation practices. The combination of a non-leguminous species with a leguminous one might be expected to generate yield advantages over sole cropping, since their canopy architectures are different; mustard grows with tall where as lentil with short stature canopies and less affected by shade. Research on the compatibility as intercrops between mustard and lentil are quite scanty although these are extensively cultivated throughout the world. Therefore, the present study was undertaken to assess the compatibility, productivity and profitability of mustard and lentil intercropping with suitable moisture conservation practice and fertility levels under rainfed conditions.

A field experiment was carried out at Agronomy Research Farm, Division of Agronomy, Indian Agricultural Research Institute, New Delhi, India during the planting season of winter of 2003-04 and 2004-05 to assess the productivity, compatibility and profitability of mustard paired row (30/90 cm) + lentil intercropping system with suitable moisture conservation practices and fertility levels under rainfed conditions. The experimental site situated at 28°58' N latitude, 77°10' E longitude and altitude of 228.6 m above mean sea level and characterized in the long term by a semi-arid and subtropical type of climate which falls within the Trans-Gangetic plains agro-climatic zone of India. The soil was a sandy loam with slightly alkaline reaction (pH 7.7) and poor in organic carbon (0.37%). The total available N, P and K were analyzed 262.5, 16.4 and 316 kg/ha, respectively. The average annual rainfall is 683 mm of which 84% falls during June to September. The average monthly minimum and maximum temperature ranged from 5.1 to 33 °C and 1.8 to 35 °C while 5.5 and 5.4 hr mean daily radiation throughout the growth period during both the years, respectively. During month of December to January crop received 15.8 and 39.0 mm rainfall in 2003-04 and 2004-05, respectively.

The experiment was carried out in split-split plot design with nine combinations of treatments, viz. three cropping systems (sole mustard, sole lentil and mustard paired row (30/90 cm) + lentil (two rows) intercropping) in main plots; three moisture conservation practices (No mulch, organic mulch + kaolin spray (6%) and farmyard manure + organic mulch + kaolin spray (6%) in sub plots; three fertility levels

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(control, 50% recommended doses of fertilizers (RDF) and 100% RDF) in sub-sub plots. Sole mustard (Pusa Barani) and sole lentil (L 7473) were sown at uniform row spacing, i e 60 and 30 cm apart during winter season on 21 October in 2003 and 20 October in 2004 by using 6 and 35 kg/ha seed rate, respectively. In the mustard and lentil intercropping system, mustard was paired row spacing at 30/90 cm to adjust two rows lentil with using seed rate of 6 and 15 kg/ha for both the crop, respectively. Organic mulch was applied after 25 days of sowing with uniform thickness of 5 cm. The organic mulch comprised of chopped organic on farm waste such as previous crop residue, dry weeds etc. Farmyard manure (0.6% N, 0.2% P and 0.5% K) was incorporated in the soil one month prior to sowing of the crop while kaolin (6% suspension) was sprayed at 90 days after sowing when crop was at full bloom stage. The recommended doses of fertilizers at the rate of 60 kg N/ha and 30 kg P_2O_5/ha to sole mustard while 20 kg N/ha and 40 kg P/ha to sole lentil was applied as 100% RDF and its half doses as 50% RDF at the time of sowing. However, 100% and 50% RDF of sole mustard were applied to the mustard and lentil intercropping system. The plots were manually weeded one time by using hand hoe at 25 days after sowing. The fertilizer doses were applied as per treatments at the time of sowing. Harvesting of crops was done in second fortnight of March during both years when large portion of the leaves were observed dried and falling off which was sign of senescence. Mustard harvested one week earlier than lentil. After threshing seed yield were taken in kg/ha and converted to quintal/ha.

The data were subjected to analysis of variance (ANOVA) in split plot design for various observations (Gomez and Gomez 1984). The results were presented at 5% level of significance (P = 0.05) and critical difference (CD) values were calculated to compare the various treatments mean. The other production potential parameters were calculated as follows:

Harvest Index (HI)

HI = (Economic yield/Biological yield) × 100

where, economic and biological yields respectively represent the seed yield and total dry weight.

Land equivalent ratio (LER)

LER = Li + Lj = (Yij/Yii) + (Yji/Yjj)

where, Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i (mustard) and j (lentil) and Yij and Yji are intercrop yields. The partial LER values Li and Lj, represent the ratios of the yields of crop i and j when grown as intercrops, relative to sole crops.

Area time equivalency ratio (ATER)

ATER = (Li ti + Lj tj)/T

where, ti and tj are the durations (days) for crops i and j and T is the duration of the whole intercropping system.

Competitive ratio (CR): The CR was calculated as suggested by Dhima *et al*. (2007)

$CR = \{(Yij/Yii) \times (Yji/Yjj)^{-1}\} \times (Si/Sj)$

where, Si and Sj are the relative space occupied by species i and j in the intercropping system.

Relative crowding coefficient (RCC)

RCC = (Yield of a component crop of mixture)/Yield of its sole crops

Aggressivity (A): The aggressivity shows the degree of dominance of one crop over other when sown together.

Aij = (Yij/Yii x Zij) – (Yji/Yjj x Zji)

where, Aij is aggressivity value for component crop ‘i’ and Zij and Zji are the proportion of the component crops.

System productivity index (SPI)

SPI = (Yii/Yjj x Yji) + Yij

% Land Saved

% Land Saved = 100 – (1/LER × 100)

Effective gain: Effective gain was calculated as suggested by Yadav *et al.* (2004)

Effective Gain = Additional Return (Ar) – Additional Cost (Ac)

Mustard equivalent yield: Seed yield of lentil was converted to mustard equivalent yield, based on the prevailing market prices of the commodities by the following formula:

$$\text{Mustard equivalent yield} = \frac{\text{Seed yield of lentil (q/ha)} \times \text{Price of lentil (₹/q)}}{\text{Price of mustard (₹/q)}}$$

The collected data on various parameters were compiled and statistically analyzed (Gomez and Gomez 1984). Economic values of seed and straw yield were estimated based on the prevailing minimum support prices for 2005-06 by Government of India.

Seed, straw and biological yield

Seed, straw and biological yield of both mustard and lentil were higher in sole cropping system than that of intercropping system (Table 1), presumably due to the absence of competition. However, reduction in seed and straw yields of mustard under the paired row intercropping system was 6.7 and 3.9%, respectively, which was non-significant than that of the sole mustard cropping system. Thus, based on these findings, it showed the better compatibility of mustard with lentil in the intercropping system (Premi *et al.* (2002). The reduction in the seed, straw and biological yields of lentil under intercropping system was significantly higher than mustard which showed the more competition and shading effect of tall mustard. Similar results were also reported by Singh *et al.* (1998).

Seed, straw and total biological yields of mustard and lentil were enhanced by moisture conservation practices (Table 1). Farmyard manure + organic mulch + kaolin spray (6%) recorded the significantly highest seed, straw, mustard equivalent and total biological yield over non mulch but remained statistically at par with organic mulch + kaolin spray (6%). Among the fertility levels, 100% RDF fertility level recorded significantly higher seed, straw, mustard equivalent yield and total biological yields of mustard and lentil over control but remained at par with 50% RDF. Katiyar *et al.* (2003) reported that fertility level increase the

Table 1 Absolute and total productivity of mustard and lentil as influenced by moisture conservation practices and fertility levels under intercropping system in rainfed situations (Two year data pooled)

Treatment	Straw yield (q/ha)		Seed yield (q/ha)		Total biological yield (q/ha)		Harvest Index (%)		Mustard equivalent yield (q/ha)
	Mustard	Lentil	Mustard	Lentil	Mustard	Lentil	Mustard	Lentil	
Cropping system									
Sole mustard (URS)	73.6		20.8		94.9		22.1		20.8
Sole lentil (URS)		39.0		14.5		53.5		27.2	19.5
Mustard (PRS) + Lentil (2:2)	70.8	13.9	19.5	3.7	89.8	17.3	21.5	22.0	22.5
CD (P=0.05)	NS	1.8	NS	0.7	4.7	1.8	NS	2.2	1.5
Moisture conservation practices									
No mulch	68.2	24.9	18.7	8.4	86.9	33.3	21.5	24.0	19.4
Organic mulch + kaolin (6%)	73.0	26.3	20.5	9.3	93.4	35.7	21.8	24.2	20.7
FYM + Organic mulch + kaolin (6%)	75.4	27.5	21.3	9.7	96.6	37.2	22.0	24.6	21.3
CD (P=0.05)	5.4	2.5	1.8	0.9	5.8	1.8	NS	NS	1.7
Fertility levels									
Control	66.4	24.3	18.1	7.9	84.6	32.3	21.4	23.2	18.4
50% RDF	73.5	26.5	20.5	9.5	93.9	36.2	21.8	24.7	20.5
100% RDF	76.9	27.8	21.7	10.0	98.5	37.7	22.1	24.8	22.3
CD (P=0.05)	4.8	1.9	1.5	0.9	4.4	1.4	NS	NS	1.5

URS, Uniform row spacing; PR, paired row spacing (30/90 cm); FYM, farmyard manure; RDF, recommended doses of fertilizers

seed and straw yield of mustard. The harvest index (HI) was significantly higher for sole lentil while it remained at par for mustard. HI was not affected by moisture conservation practices and fertility levels.

Economics of mustard and lentil intercropping

The inspection of data indicated that the imposed treatments produced marked variation in economic parameters (Table 2). Eventhough, mustard and lentil intercropping system recorded highest cost of cultivation but provided with highest gross and net returns, B:C ratio and effective gain as compared to sole cropping system. Similar results were also reported by Neupane *et al.* (1997). FYM + organic mulch + kaolin spray (6%) recorded highest gross return while organic mulch + kaolin spray (6%) recorded maximum net return but both practices were found non-economical due to low B:C ratio and negative effective gain, while, among fertility levels, 100% RDF recorded highest gross and net returns and effective gain but low in B:C ratio than 50% RDF. Thus, 100% RDF of mustard was found economically sufficient for mustard + lentil intercropping system.

LER, ATER, CR, RCC, SPI, Aggressivity and % land saved

The effect of mustard paired row (30/90 cm) planting arrangement on LER, ATER and SPI were significantly different (Table 3). The higher value of LER (1.18) reflected the advantage of intercropping over sole cropping system as 18% more area would be required by sole cropping to recover the yield of intercropping system. Dhima *et al.* (2007) and Saban *et al.* (2008) also reported the similar

Table 2 Economics of mustard and lentil as influenced by moisture conservation practices and fertility levels under intercropping system in rainfed situations (Two year data pooled)

Treatment	Total cost of cultivation (₹/ha)	Gross (₹/ha)	Net return (₹/ha)	B:C ratio	Effective gain (₹)
Cropping system					
Sole mustard (URS)	10398.00	33520.00	23122.00	2.22	
Sole lentil (URS)	9430.00	27920.00	18490.00	1.96	
Mustard (PRS) + Lentil (2:2)	10796.00	37520.00	26724.00	2.48	3204.00
Moisture conservation practices					
No mulch	8647.00	30960.00	22313.00	2.58	
Organic mulch + kaolin (6%)	10127.00	33200.00	23073.00	2.28	-720.00
FYM + Organic mulch + kaolin (6%)	11849.00	34640.00	22791.00	1.92	-2724.00
Fertility Levels					
Control	9535.00	29600.00	20065.00	2.11	-
50% RDF	10132.00	33600.00	23468.00	2.32	2806.00
100% RDF	10954.00	35600.00	24646.00	2.25	3162.00

URS, Uniform row spacing; PR, paired row spacing (30/90 cm); FYM, farmyard manure; RDF, recommended doses of fertilizers (Prices: Mustard ₹ 1 600/q; Lentil ₹ 1 935/q)

Table 3 LER, ATER, CR, RCC, SPI, Aggressivity and % land saved under mustard and lentil intercrop association in rainfed situations (Two year data pooled)

Cropping system	LER	ATER	CR	RCC	Aggressivity	SPI	% land saved
Sole mustard (URS)	0.93	0.89	3.73	0.93	1.04	20.8	
Sole lentil (URS)	0.25	0.25	0.28	0.25	-1.26	14.5	
Mustard (PRS) + lentil (2:2)	1.18	1.15				24.7	15.25
CD (P=0.05)	0.09	0.09	0.39	0.08	0.19		

results. In this way 15.25% of land would be saved for other agricultural purposes. 15% higher ATER was recorded under mustard and lentil intercropping system while the component's ATER was declined (Table 3) due to the land occupation. In this way ATER would provide better estimate than LER and it permits an evaluation of crops on a yield per day basis. The SPI which standardized the yield of the secondary crop (lentil) in terms of the primary crop (mustard) and also identified the combination that utilized the growth resources most effectively and maintained a stable yield performance showed that mustard paired row with lentil intercropping pattern gave the highest value than sole cropping system. The value of SPI was higher and largely determined by mustard intercrop yield which was not much reduced by intercropping with lentil. The CR, RCC and Aggressivity values of mustard were higher than lentil, thus indicating its dominance in intercropping system. These results were in close conformity with the findings of Awal *et al*. (2007) in barley + peanut and Tajudeen (2010) in sorghum + cowpea intercropping system.

SUMMARY

It can be summarized from the results obtained that mustard and lentil populations are well compatible in intercrop association with 2:2 paired row ratio, i.e. two row mustard paired (30/90 cm) followed by two rows of lentil as indicated by higher seed yield, mustard equivalent yield, HI, effective gain, LER, and SPI. Mustard crop appeared to be the dominant crop due to higher values of RCC, CR and aggressivity. Moisture conservation practices were not economically viable even though they positively affected seed and straw yield of mustard and lentil. The 100% RDF of mustard is recommended for mustard and lentil intercropping under rainfed conditions of northern India where these two crops are predominantly grown during the winter season.

ACKNOWLEDGEMENT

The senior author is highly grateful to the Director, Indian Agricultural Research Institute, New Delhi, India for providing the all necessary field and laboratory facilities during course of the investigation for his Doctor of Philosophy degree programme.

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