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Production potential and economics of intercropping of lentil (*Lens culinaris*) with brown sarson (*Brassica compestris*) and oat (*Avena sativa*)

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ABSTRACT

A field experiment was conducted during winter season of 2004-05 and 2005-06 at Wadura, Jammu and Kashmir to evaluate the production potential, biological feasibility and economic viability of intercropping of lentil (*Lens culinaris* Medikus) either with brown sarson (*Brassica campestris* L. sub sp. *oleifera* var. *brown sarson*) or oat (*Avena sativa* L.) in row ratios of 1:1, 2:1, 4:1 and 6:1. Lentil yield decreased by 16ñ68% due to intercropping, and yield of oat was inversely proportional to lentil row number, whereas yield of brown sarson was in the order 4:1, 2:1, 1:1 and 6:1. Yield components, viz. pods/plant, grains/pod and 1,000-grain weight of main crop of lentil, and siliqua/plant or tiller/m row, grains/siliqua or grains/panicle and 1,000-grain weight of intercrops (brown sarson or oat) also decreased in the intercropping systems. Lentil with brown sarson in 4:1 row proportion or oat in 2:1 row proportion was most remunerative in respect of net returns (Rs 20,755 and 21,782) and benefit : cost ratio (3.13 and 2.67). These two intercropping systems showed higher lentil-equivalent yield, land-equivalent ratio, income-equivalent ratio, area-time equivalent ratio, biological efficiency and monetary advantage among all the intercropping systems.

Key words: Brown sarson, Competition functions, Economics, Equivalent yield, Intercropping, Lentil, Monetary advantage, Oat, Yield

Lentil (*Lens culinaris* Medikus), brown sarson (*Brassica campestris* L. sub sp. *oleifera* var. *brown sarson*) and oat (*Avena sativa* L.) are grown in sole as well as in mixed stands because of their diverse morphology, growth rhythm and similar climatic requirements. In Kashmir valley these crops survive under rainfed conditions and withstand freezing temperature during winter and higher temperature at maturity. Traditional practice of growing two or more crops together without any spatial arrangement is being followed under rainfed situation, where probability of crop failure is generally high. Owing to frequent occurrence of aberrant weather, intercropping can become more profitable and dependable than sole cropping. Diversification of cropping systems is necessary to get higher yield and returns, to maintain soil health, preserve the environment and meet the daily requirement of food and feed for human and animals. Thus not only the number of crops but the type of crops included in the intercropping system are also important. Adoption of suitable intercropping systems might increase the total production through efficient utilization of production factors like space, water, nutrient etc., and stability of crop yield in rainfed situation can be achieved with crop substitution and intercropping (Singh and Rana, 2006). When the crops of different growth habits are grown together in an intercropping system, it provides greater opportunity to secure higher yield from the same piece of land. Instead of growing sole lentil, intercropping of brown sarson and oat can be more profitable in this zone. Moreover, spatial arrangement and plant population in an intercropping have important effects on the balance of competition between components crops and their productivity. Hence the present experiment was undertaken to evaluate the comparative performance of intercropped lentil with brown sarson and oat at different row proportions under rainfed temperate conditions of Kashmir valley.

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MATERIALS AND METHODS

The experiment was conducted during the winter season of 2004-05 and 2005-06 at the research farm of Faculty of Agriculture and Regional Research Station, Wadura, Sopore in Kashmir, situated at 34°17' N, 74°33' E and 1,524 m above mean sea-level. The experimental site was well drained silty clay-loam (*Eutrochrept*), non-saline (electricity condictivity 0.29 dS/m) with pH 7.5 (1: 2.5

soil water) and contained 0.73% organic C, 294 kg/ha, available N, 22.5 kg/ha 0.5 M $NaHCO_3$-extractable available P and 254 kg/ha available K. The mean temperature during the experimental period ranged from -9.3°C (January 2005) to 31.6°C (June 2005) in 2004-05, and -7.4°C (January 2006) to 34.7°C (June 2006) in 2005-06. The crop was grown under rainfed condition, and the rainfall and snowfall received during the crop season in 2004-05 (633.1 mm) and 2005-06 (604.3 mm) were utilized for raising the crops.

The experiment consisting of 11 treatments was laid out in randomized complete block design with three replications. The treatments consisted of three sole crop treatments of lentil cv 'Shalimar Masoor-1', brown sarson cv 'KOS1' and oat cv 'Sabzaar', along with eight additive intercropping systems of lentil either with brown sarson or with oat in row ratios of 1:1, 2:1, 4:1 and 6:1. The additive rows of brown sarson or oat were adjusted according to row ratio of the treatments. The fertilizers in sole stands of lentil, brown sarson and oat were applied 40+25.8+16.6, 60+12.9+16.6 and 80+17.2+16.6 kg N, P and K/ha, respectively. The sources of fertilizers were urea, diammonium phosphate and muriate of potash. The crops of lentil, brown sarson and oat were sown in the first week of October at a row space of 23, 30 and 25 cm, using 50, 10 and 100 kg/ha seed rate respectively. All the crops were harvested 215, 210 and 235 days after sowing in both the years of experimentation. The results of both the years were more or less similar and hence the data of 2 years were pooled and analysed statistically. For assessing the economic viability of the system, land use and production efficiencies were computed by using the formulae given by Ahlawat *et al.* (2005).

RESULTS AND DISCUSSION

Crop productivity

Sole crop of lentil proved superior in terms of yield attributes than the intercropped lentil (Table 1). Pods/plant, grains/pod and 1,000-grain weight decreased significantly in intercropping system, depending on the nature of intercrops and their row arrangement. Lentil in association with brown sarson or oat in 6:1 row proportion recorded significantly more pods/plant, grains/pod and 1,000-grain weight owing to wider spacing of intercrops compared with other row arrangements. Maximum reduction in yield attributes was recorded in lentil intercropped with brown sarson or oat in 1:1 row proportion due to greater shading and competition effect of the intercrops on lentil.

Intercropping significantly reduced the grain and straw yields of lentil compared with those of sole lentil due to more interspecific competition. Maximum reduction in growth, yield attributes and yield of lentil was recorded in intercropping under 1:1 row proportion, irrespective of crop. Singh *et al.* (2000) and Tiwari *et al.* (1992) also reported similar reduction in lentil yield by intercropping with Indian mustard due to the depressing effect of the later on the former crop. Intercropping of lentil with brown sarson or oat in 6:1 row proportion recorded

Table 1. Yield components and yield of sole and intercrops as influenced by intercropping system (average data of 2 years)

Treatment	Lentil					Intercrop					
	Pods/ plant	Grains/ pod	1,000 grain weight (g)	Straw yield (t/ha)	Grain yield (t/ha)	Siliqua/ plant or tiller/m row	Grains/ siliqua or grains/ panicle	1,000 grain weight (g)	Green fodder yield of first cut (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)
Sole cropping											
Lentil	52.3	1.72	19.3	2.06	0.79						
Brown sarson						211.3	20.7	4.8		4.47	1.53
Oat						227.2	49.6	19.6	18.67	2.82	2.33
Intercropping system											
Lentil + brown sarson											
1:1	35.1	1.39	12.7	1.08	0.47	176.4	15.7	4.5		2.02	0.75
2:1	39.6	1.48	14.5	1.39	0.53	188.3	16.2	4.6		2.73	0.97
4:1	43.2	1.57	15.9	1.52	0.62	196.7	17.6	4.7		3.06	1.01
6:1	47.7	1.66	17.2	1.73	0.68	173.2	13.8	4.4		1.27	0.67
Lentil + oat											
1:1	36.1	1.37	12.5	1.07	0.51	196.3	48.6	19.3	10.12	1.86	1.35
2:1	39.4	1.46	14.1	1.26	0.63	193.2	45.3	18.8	9.46	1.53	1.29
4:1	42.6	1.55	15.4	1.51	0.65	186.3	42.2	17.7	7.04	1.33	0.77
6:1	46.3	1.63	16.7	1.64	0.68	182.6	39.8	17.3	5.06	1.26	0.72
SEm±	1.1	0.02	0.4	0.04	0.004						
CD (P=0.05)	3.1	0.06	1.1	0.12	0.013						

markedly higher yield of lentil on account of improvement in its yield attributes under this ratio, because the depressing effect of intercrops on lentil was minimized due to lesser number of intercrop rows and greater space occupied by lentil.

Sole crops of brown sarson and oat recorded higher yield attributes and yield over their respective intercropped stands. The magnitude of reduction in yield and yield attributes varied with plant population and spatial arrangement of the component species. Maximum reduction in their yield attributes and yield was recorded in intercropping with lentil under 6:1 row proportion due to proportionately low plant stand/unit area. However, minimum reduction in their yield attributes and yield was found in intercropping with lentil in 4:1 and 1:1 row proportion, respectively.

All the intercropping systems proved superior to sole lentil in terms of lentil grain-equivalent yield in all the row proportions in intercropping irrespective of the intercrop (Table 2). Higher lentil-equivalent yield was obtained with lentil intercropped with brown sarson in 4:1 row ratio and with oat in 2:1 row ratio. However, both the intercropping systems were statistically superior to their other respective row ratios. Higher lentil grain-equivalent yield under both these intercropping systems might be due to efficient utilization of resources and less competition between the component crop species.

Table 2. Lentil-equivalent yield and economics of lentil, brown sarson and oatin intercropping system (average data of 2 years)

Treatment	Lentil-equivalent yield (t/ha)	Net returns (x 10^3 Rs/ha)	Benefit : cost ratio	Income-equivalent ratio
Sole cropping				
Lentil	0.79	6.72	1.06	1.00
Brown sarson	1.71	18.66	2.54	1.99
Oat	0.83	26.06	2.78	4.94
Intercropping system				
Lentil + brown sarson				
1:1	1.31	13.60	1.98	1.56
2:1	1.61	18.50	2.74	1.93
4:1	1.74	20.76	3.13	2.09
6:1	1.43	16.07	2.45	1.73
Lentil + oat				
1:1	0.99	21.06	2.52	2.16
2:1	1.09	21.78	2.67	2.20
4:1	0.92	16.51	2.07	1.82
6:1	0.93	14.45	1.84	1.65
SEm±	0.03			
CD (P=0.05)	0.09			

Prevailing market prices (Rs/t): lentil grain, 15,250; brown sarson grain, 17,000; oat grain, 5,400; lentil straw, 500; green fodder of oat, 1200; oat straw, 900

Competition functions

Intercropping of lentil with brown sarson and oat resulted in land equivalent ratio (LER) > 1, indicating its advantage (Table 3). This intercropping system in 4:1 row proportion and with oat in 2:1 row proportion showed greater biological efficiency of the system. This yield advantage owing to intercropping might be attributed to the combined effect of better utilization of natural resources than owing to sole cropping of companion crops, resulting in higher productivity/unit area. The association of lentil with brown sarson in 1:1 row ratio gave lower LER (1.08), indicating less efficient system. The companion crop either brown sarson (except 1:1 row proportion) or oat (except 1:1 and 2:1 row proportion) appeared more competitive than lentil, giving higher values of competitive ratio (CR) in the intercropping system. Lentil proved the dominated companion to intercrops, having negative aggressivity (A), which was further evident from lower competitive ratio (except 1:1 ratio). The values of relative crowding coefficient (RCC) of lentil were always > 1, indicating that lentil gave more yield than expected, except

Table 3. Competition functions and monetary advantages of lentil, brown sarson and oatin intercropping system (average data of 2 years)

Intercropping system	LER	Competitive ratio		Aggressivity (A)		RCC		Product of RCC (K)	ATER	Monetary advantage (x 10^3 Rs/ha)
		CR (lentil)	CR (intercrop)	A (lentil)	A (intercrop)	K (lentil)	K (intercrop)			
Lentil + brown sarson										
1:1	1.08	1.21	0.82	+ 0.21	- 0.21	1.47	0.96	1.41	0.98	1.52
2:1	1.30	0.53	1.89	- 0.89	+ 0.89	1.02	3.46	3.53	0.61	5.83
4:1	1.44	0.30	3.36	- 2.32	+ 2.32	0.91	7.77	7.07	1.31	8.37
6:1	1.30	0.33	3.05	- 2.06	+ 2.06	1.03	4.67	4.81	1.18	5.22
Lentil + oat										
1:1	1.22	1.11	0.89	+ 0.13	- 0.13	1.82	1.38	2.51	1.17	5.31
2:1	1.35	0.72	0.35	- 0.46	+ 0.46	1.96	2.48	4.86	1.28	7.76
4:1	1.15	0.62	1.61	- 0.62	+ 0.62	1.16	1.97	2.29	1.08	3.19
6:1	1.17	0.46	2.15	- 1.16	+ 1.16	1.03	2.68	2.76	1.09	3.24

lentil + brown sarson intercropping in 4:1 row proportion. The product of relative crowding coefficient indicated definite yield advantage to grow lentil with brown sarson or oat (K>1.00), highest being with lentil + brown sarson under 4:1 row ratio (7.07) and lentil + oat under 2:1 row proportion (4.86), due to balanced competition between the component crops and their productivity. Highest area-time equivalent ratio (ATER) was recorded for lentil intercropping with brown sarson in 4:1 row ratio (1.31), followed by lentil intercropping with oat in 2:1 row ratio (1.28), indicating a more efficient use of area by intercropping over other systems. Thus the biological parameters indicated that intercropping of lentil with brown sarson or oat could be biologically sustainable.

Economics

The monetary advantage based on LER indicated superior economic viability of lentil + brown sarson (Rs 8,367) intercropping in 4:1 row ratio, followed by lentil + oat (Rs 7,760) in 2:1 row ratio (Table 3). The intercropping of lentil with oat in 2:1 row ratio gave the maximum net return of Rs 21,782/ha (Table 2), followed by lentil with brown sarson intercropping in 4:1 row ratio (Rs 20,755/ha). The benefit : cost ratio values were higher under lentil + brown sarson intercropping in 4:1 ratio (3.13) and lentil + oat in 2:1 ratio (2.67), mainly owing to higher economic production in these systems.

Nutrient uptake

Sole lentil, brown sarson and oat recorded significantly higher N, P and K uptake than lentil + brown sarson and lentil + oat intercropping systems, irrespective of the row proportion (Table 4). It was attributed to higher biomass production under sole cropping system. Significantly higher N, P and K uptake by lentil was observed in lentil + brown sarson intercropping under 6:1 row ratio, being 52.1, 29.2 and 54.6% higher than under 1:1 ratio, respectively. Further, the N, P and K uptake by lentil in lentil + oat intercropping was markedly superior under 4:1 ratio than under other row ratios, being 43.9, 58.4 and 46.4% more over 1:1 ratio respectively. This could be due to more plant population, yield attributes and yield of lentil in lentil + brown sarson and lentil + oat intercropping system under these row ratios compared with that under other row proportions. Similarly, marked improvement in N, P and K uptake was also shown by brown sarson when lentil was intercropped with brown sarson in 4:1 row ratio. The magnitude of increase was respectively 19.7, 19.8 and 17.7% higher N, P and K uptake over 1:1 ratio. However, the N, P and K uptake by oat was significantly higher in lentil + oat intercropping under 1:1 row ratio over other ratios. Significant increase in N, P and K uptake under these row

Table 4. Nutrient uptake and moisture-use indices as influenced by sole and intercropping systems (average data of 2 years)

Treatment	Nutrient uptake by lentil (kg/ha)			Nutrient uptake by intercrops (kg/ha)			Nutrient uptake by intercropping system (kg/ha)			Consumptive use (mm)	Water-use efficiency (kg/ha-mm)	Rate of moisture use (mm/day)	Moisture-extraction pattern		
	N	P	K	N	P	K	N	P	K				0-30 cm	30-60 cm	60-90 cm
Sole cropping															
Lentil	63.2	10.5	19.7				63.2	10.5	19.7	186.6	4.4	0.87	52.3	27.2	18.3
Brown sarson				97.3	22.6	51.3	97.3	22.6	51.3	211.3	8.2	1.10	48.7	27.4	18.9
Oat				136.4	17.1	108.2	136.4	17.1	108.2	223.2	3.8	1.06	49.2	27.3	18.7
Intercropping system															
Lentil + brown sarson															
1:1	37.8	7.2	10.8	72.6	17.7	62.1	110.4	24.9	72.9	241.2	5.5	1.15	46.4	28.3	19.3
2:1	45.7	8.1	13.3	78.3	19.6	68.3	124.0	27.7	81.6	231.3	7.2	1.11	47.6	28.4	19.6
4:1	51.6	8.7	14.8	86.7	21.1	73.1	138.3	29.9	87.9	222.4	8.1	1.06	48.3	28.6	19.9
6:1	57.5	9.3	16.7	63.3	18.1	58.6	120.8	27.3	75.3	216.3	6.8	1.04	47.2	28.1	19.1
Lentil + oat															
1:1	39.1	5.3	11.1	121.3	16.6	101.6	160.4	21.9	112.7	221.3	4.7	0.95	49.1	28.6	19.8
2:1	47.2	7.1	13.3	115.2	15.1	96.7	162.4	22.2	110.0	219.1	5.1	0.94	48.7	28.8	19.7
4:1	52.6	7.8	15.2	106.7	14.6	88.3	159.3	22.4	103.5	215.2	4.5	0.92	48.2	28.5	19.4
6:1	56.3	8.4	16.4	101.3	13.3	81.2	157.6	21.7	97.6	213.3	4.6	0.91	47.4	28.5	19.2
SEm±	1.1	0.2	0.4	2.8	0.4	2.1	3.4	0.7	1.8						
CD (P=0.05)	3.2	0.4	1.1	8.2	1.2	6.3	10.2	2.1	5.3						

proportions appears to be the result of improved biomass production and yield of brown sarson and oat.

Total N, P and K uptake of the system was significantly higher in lentil + brown sarson and lentil + oat intercropping than in sole lentil, brown sarson and oat. This could be attributed to the higher total biomass production under intercropping systems and hence higher total uptake of N, P and K over sole cropping. These results confirm those of Singh and Rana (2006).

Water-use efficiency

Water-use efficiency (WUE) in terms of lentil-equivalent yield showed marked variation due to intercropping system (Table 4). Intercropping of lentil + brown sarson and lentil + oat recorded higher WUE than sole lentil. This might be attributed to proportionately higher grain yield of both the crops than the amount of water used for biomass production. Lentil intercropped with brown sarson and oat utilized more water for evapotranspiration and metabolic activities. Maximum WUE was recorded with lentil + brown sarson under 4:1 (8.1 kg/ha-mm) and lentil + oat under 2:1 row ratio (5.1 kg/ha-mm). This could be due to higher productivity in terms of lentil-equivalent yield under these row proportions. The rate of moisture use was higher in lentil + brown sarson and lentil + oat intercropping systems irrespective of the row ratio than in lentil sole. It could be attributed to the fact that both the crops absorbed more moisture for dry matter production than sole lentil, which resulted in higher rate of moisture use in these intercropping system. Similarly, consumptive use of water was also recorded higher under intercropping system than in lentil sole.

In general, the crops extracted greater amount of soil moisture from the top 0-30 cm soil layer than from 30-60 and 60-90 cm soil depth in sole cropping as well intercropping systems. It might be due to greater availability of soil moisture in this soil layer, and the existence of maximum root biomass in this soil profile, which resulted in maximum extraction of soil moisture from this profile. Moisture depletion from deeper layers by lentil + brown sarson and lentil + oat intercropping systems might be due to moisture stress in the upper 0-30 cm soil profile, compelling the roots to go deeper in search of moisture. It explains the reason behind greater depletion of soil moisture from deeper soil profiles. Singh *et al.* (2000) also reported similar results.

It was concluded that intercropping of lentil either with brown sarson in 4:1 row ratio or with oat in 2:1 row ratio is a biologically sustainable intercropping system for rainfed temperate conditions of Kashmir valley.

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