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Yield advantage, reciprosity functions and energy budgeting of lentil (*Lens culinaris*) + oat (*Avena sativa*) intercropping under varying row ratio and phosphorus management

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ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2006–08 at Sopore to evaluate the production potential, biological feasibility, economic viability and energy efficiency of intercropping of lentil (*Lens culinaris* Medikus) with oat (*Avena sativa* L.) under varying row ratio, P levels and biofertilizers. Oat was found dominant and aggressive as compared to lentil. Lentil and oat under 2:1 row ratio proved more remunerative and recorded higher yield advantage than 3:1 and 1:1 as judged by lentil-equivalent yield (1.13 tonnes/ha), crop productivity (4.77 kg/ha/day), land-equivalent ratio (1.35), income-equivalent ratio (1.27), crop profitability (₹ 96.34/ha/day), area-time equivalent ratio (1.20), monetary advantage (₹ 8 580), net return (₹ 22 833/ha), biological efficiency, water-use efficiency (5.76 kg/ha-cm), P uptake (22.5 kg/ha) and energy productivity (739.3 g/MJ). Application of 17.2 kg P/ha recorded markedly higher lentil-equivalent yield, competition functions, water use, economics and energetics compared with rest of the treatments. Dual inoculation of lentil and oat seed with phosphorus solubilising bacteria +vasicular arbuscular mycorrhizae also showed significantly higher lentil-equivalent yield (1.18 tonnes/ha), yield attributes and other parameters, like biological efficiency, P uptake, water use, economic advantage and energy efficiency over seed inoculation with phosphorus-solubilizing bacteria or vasicular arbuscular mycorrhizae alone.

Key words: Competition functions, Economics, Energy budgeting, Lentil, Moisture use, Oat, Phosphorus uptake

Reciprocity or competition functions are one of the significant factors to affect the yield advantage in lentil (*Lens culinaris* Medikus)+oat (*Avena sativa* L.) intercropping which is commonly adopted cropping pattern in Kashmir Valley. In Kashmir Valley these two crops survive under rainfed conditions and withstand the freezing temperatures during winter and higher temperatures 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. Accordingly their compatible combination for the maximum utilization of growth resources based on complimentarity is essential. In lentil+oat intercropping, competition offered by oat is much higher than the lentil, however, it could be altered to some extent by changing crop geometry through manipulation of row ratio, effective phosphorus and biofertilizer management. Adoption of suitable intercropping systems with P management might increase the total production through efficient utilization of production factors, like space, water, nutrient use etc. and stability of crop yield in rainfed situation can be achieved with crop substitution and intercropping (Singh *et al*. 2008). When the crops of different habits are grown together in an intercropping system, it provides greater opportunity to secure higher yield from same piece of land (Yildirim and Guvence 2005). Instead of growing sole lentil, intercropping of oat under efficient phosphorus management can be more profitable in this zone. Moreover, spatial arrangement, plant population and P management in an intercropping have important effects of the balance of competition between components crops and their productivity (Zhang and Li 2003). Hence present experiment was undertaken to evaluate the comparative

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performance of intercropped lentil with oat at different row proportions, P levels and biofertilizers under rainfed temperate conditions of Kashmir valley.

MATERIALS AND METHODS

The experiment was conducted during the winter (*rabi*) seasons of 2006–08 at the Research Farm of Faculty of Agriculture and Regional Research Station, Wadura, Sopore in Kashmir situated at 34° 172 N latitude, 74° 332 E longitude at an elevation of 1 524 m above mean sea level. The site was well-drained and soil was silty–clay loam (Eutrochrept), non-saline (EC 0.28 dS/m) with *p*H 7.4 (1: 2.5 soil:water) and contained 0.72% organic carbon, 291 kg/ha available N 17.6 kg/ha, 0.5 M $NaHCO_3$ extractable available P and 251 kg/ha available K. The mean monthly temperature during the experimental period ranged from "10.2°C (January 2007) to 32.8°C (June 2007) in 2006–07 and "9.4°C (January 2008) to 34.6°C (June 2008) in 2007–08. The crop was grown under rainfed conditions and the rainfall and snowfall, received during the crop season was 704.3 mm in 2006–07 and 669.2 mm in 2007–08.

The experiment was laid out in factorial randomized complete block design with three replications having 29 treatment combinations of three row ratios of 'Shalimar Masoor 1' lentil + 'Sabzaar' oat (1:1, 2:1, 3:1), 3 P levels (8.6, 17.2 and 25.8 kg P/ha) and three biofertilizers (PSB, VAM and PSB+VAM) and with two absolute sole controls of lentil and oat. The crops of lentil and oat were sown in the first week of October at a row space of 23 and 25 cm, using 50 and 100 kg seed/ha, respectively. The crop of oat was grown as base crop for dual purpose. The additive rows of oat were adjusted according to row ratio of the treatments. Phosphorus was applied through Diammonium phosphate as a basal dose as per treatments. The phosphate-solubilizing bacteria inoculums of *Pseudomonas striata* (500 g/ha seed) and vesicular-arbuscular mycorrhizae culture of *Glomus mosseae* (500 g/ha seed) were used for inoculating seeds of lentil and oat as per treatments. The crops were fertilized with N and K 40+16.6 and 80+16.6 kg N and K/ha, respectively. To the intercropping system a fertilizer dose proportionate to the area occupied by intercrop population was applied in addition to the fertilizer dose given to the base crop. The sources of fertilizers were urea and muriate of potash. Both the crops were harvested 216 and 237 days after sowing in both the years. For assessing the economic viability of the system, land use and production efficiencies were computed by using the formulae as given by Ahlawat *et al*. (2005) and energy use indices were computed as suggested by Binning *et al.* (1983). Crop productivity (based on equivalent yield), crop profitability, income-equivalent ratio and water use indices were calculated as:

Energy efficiency = energy output (MJ/ha) ÷ energy input (MJ/ha)

Energy productivity (g/MJ) = output (grain+by-product, g/ha) ÷ energy input (MJ/ha)

Crop productivity (Rs/ha/day) = net returns (Rs/ha) ÷ Number of days field occupied

Income-equivalent ratio = (Iab ÷ Iaa) + (Iba ÷ Ibb)

Crop water-use efficiency (kg/ha-cm) = yield (kg/ha) ÷ Consumptive use (mm)

Where Iab, gross income (₹/ha) of component 'a' in mixed stand with 'b'; Iaa, gross income (₹/ha) of component 'a' in pure stand; Iba, gross income (₹/ha) of component 'b' in mixed stand with 'a'; Ibb, gross income (₹/ha) of component 'b' in pure stand. The results of both the years were more or less similar and hence two years data were pooled and analyzed statistically.

RESULTS AND DISCUSSION

Yield attributes and crop yields

In lentil+oat intercropping row ratio of lentil:oat from 1:1 to 3:1 row proportion recorded significantly more pods/plant, grains/pod, tillers/m row, grains/panicle and 1 000– grain weight owing to wider spacing of intercrops compared with other row arrangement. Maximum reduction in yield attributes were recorded in lentil intercropped with oat in 1:1 row proportion due to greater shading and competition effect of the intercrops. Markedly higher grain and straw yield of lentil was recorded under 3:1 row ratio (0.68 and 1.53 tonnes/ha) compared with 2:1 and 1:1 row ratio 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.

Maximum reduction in green fodder yield, straw yield and grain yield of oat was recorded in intercropping with lentil under 3:1 row proportion due to proportionately low plant stand/unit area. However, minimum reduction in green fodder yield (11.12 tonnes/ha), straw yield (1.92 tonnes/ha) and grain yield (1.12 tonnes/ha) and maximum reduction in lentil grain and straw yield was found in intercropping with lentil in 1:1 row proportion. Singh *et al.* (2008) also reported similar reduction in lentil yield by intercropping with oat due to the depressing effect of the later on the former crop.

Application of P up to 17.2 kg P/ha being at par with 25.8 kg P/ha significantly increased the yield attributes, viz pods/plant, grains/pod, tillers/m row, grains/panicle and 1 000 grain-weight of lentil and oat over 8.6 kg P/ha (Table 1). Similarly, grain and straw yield of lentil and grain straw and fodder yield of oat was also improved markedly with the application of P up to 17.2 kg over 8.5 kg P/ha. Application of 17.2 kg P/ha enhanced the grain and straw yield of lentil by 54.5 and 36.3% and grain, straw and fodder yield of oat by 54.6, 25.7 and 40.6% over 8.6 kg P/ha, respectively. Lentil being a legume is known to respond to P fertilization as it plays a pivotal role in root and nodulation, energy transformation and metabolic processes of the plant (Tisdale *et al.* 1995). Similarly, higher yield of oat could be attributed to the availability of more amount of P for better growth and

Table 1 Effect of row ratio and P management on yield attributes and yield of lentil and oat (pooled data of two years)

Treatment	Lentil					Oat					
	Pods/ plant	Grains/ pod	1 000–grain weight (g)	Straw yield (tonnes/ ha)	Grain yield (tonnes/ ha)	Tillers/ m	Grains/ panicle	1 000–grain weight (g)	Green fodder yield of first cut (tonnes/ha)	Straw yield (tonnes/ ha)	Grain yield (tonnes/ ha)
Row ratio (lentil:oat)											
1:1	33.2	1.36	13.3	1.06	0.48	195.4	37.4	16.6	11.12	1.92	1.42
2:1	38.4	1.44	15.2	1.27	0.65	217.3	42.3	18.1	9.53	1.61	1.33
3:1	41.1	1.52	16.6	1.53	0.68	239.2	47.1	19.4	7.07	1.32	0.85
CD (P=0.05)	2.4	0.05	1.1	0.11	0.021	18.6	3.2	1.1	0.82	0.21	0.18
P levels (kg P/ha)											
8.6	31.1	1.35	12.3	1.02	0.44	181.2	35.2	15.4	7.26	1.36	0.86
17.2	40.2	1.48	16.2	1.39	0.68	230.5	45.5	19.2	10.21	1.71	1.33
25.8	41.2	1.49	16.6	1.46	0.69	240.2	46.1	19.5	10.33	1.78	1.42
CD (P=0.05)	2.4	0.05	1.1	0.11	0.021	18.6	3.2	1.1	0.82	0.21	0.18
Biofertilizers											
PSB	33.5	1.39	13.7	1.09	0.52	204.3	39.2	17.1	8.42	1.43	0.98
VAM	35.3	1.43	14.3	1.18	0.53	214.5	41.4	17.6	9.03	1.54	1.09
PSB + VAM	43.7	1.51	17.1	1.59	0.76	233.1	46.2	19.4	10.35	1.89	1.54
CD (P=0.05)	2.4	0.05	1.1	0.11	0.021	18.6	3.2	1.1	0.82	0.21	0.18
Sole vs intercrop											
Sole lentil	50.4	1.71	19.4	2.04	0.81						
Intercropped lentil	37.5	1.44	15.0	1.29	0.60						
CD (P=0.05)	7.1	0.11	3.2	0.83	0.14						
Sole oat						261.6	51.2	21.2	21.61	2.97	2.42
Intercropped oat						217.3	42.3	18.0	9.27	1.62	1.20
CD (P=0.05)						30.4	6.7	1.7	2.31	0.46	0.34

development, which ultimately resulted in higher yield.

Dual inoculation of lentil and oat seeds with PSB and VAM recorded markedly higher yield attributes, viz pods/ plant, grains/pod, tillers/m row, grains/panicle and 1 000-grain weight over single inoculation either with PSB or VAM (Table 1). Grain and straw yields were significantly higher with PSB+VAM inoculation over single inoculation with either PSB or VAM. It might be the resultant effect of yield attributes and synergistic effect of dual inoculation (Saha *et al*. 2002).

Land-use indices

Higher lentil-equivalent yield (1.13 tonnes/ha) and crop productivity (4.77 kg/ha/day) was obtained when lentil intercropped with oat in 2:1 row ratio (Table 2). However, this intercropping system was statistically superior to their other respective row ratios. Higher lentil grain-equivalent yield under this intercropping system might be due to efficient utilization of resources and less competition between the component crop species. Yield proportionate of lentil (Table 2) showed increasing trend with increasing row ratio of lentil:oat. However, the total land-equivalent ratio which is the function of partial land- equivalent ratio of lentil and oat was found comparable at 1:1 (1.17) and 3:1 (1.20) row combinations but both recorded significantly lower yield advantage over 2:1 (1.35) row ratio.

Application of 17.2 kg P/ha recorded markedly higher lentil-equivalent yield (1.14 tonnes/ha) and crop productivity (4.81 kg/ha/day) over 8.6 kg P/ha (0.79 tonnes/ha and 3.33 kg/ha/day) which remained at par with that of 25.8 kg P/ha, probably due to increase in economic yields of both the component crops on phosphorus application (Table 2).

Significantly higher lentil-equivalent yield (1.18 tonnes/ha) and crop productivity (4.98 kg/ha/day) was recorded under dual inoculation with PSB+VAM over PSB or VAM alone (Table 2). Being more aggressive and competitive at dual inoculation with PSB+VAM, lentil and oat registered marked and highest improvement in partial-land equivalent ratio with PSB+VAM inoculation, followed by VAM and PSB inoculation (Table 2). Similarly, total land equivalent ratio shown in Table 2 revealed that the production efficiency of the system was highest when both the component crops inoculated with PSB+VAM, followed by VAM or PSB.

Reciprocity functions

The relative crowding coefficients of component crops clearly showed that lentil produced less than expected but oat being more aggressive, competitive and dominant, yielded more than expected except in 1:1 row ratio (Table

Table 2 Lentil-equivalent yield, crop productivity and competitions as influenced by intercropping systems and P management (pooled data of two years)

Treatment	Lentil-equivalent yield (tonnes/ha)	Crop productivity (kg/ha/day)	Land-equivalent ratio (LER): Partial LER of lentil (L_l)	Land-equivalent ratio (LER): Partial LER of oat (L_o)	Land-equivalent ratio (LER): Total LER [$(L_l + L_o)$]	Yield proportion of [$L_l/(L_l + L_o)$]	Relative crowding coefficient (RCC): Lentil (K_{lo}) lentil	Relative crowding coefficient (RCC): Oat (K_{ol})	Relative crowding coefficient (RCC): System ($K=K_{lo}$ ÕK_{ol})	Competitive ratio: Lentil time	Competitive ratio: Oat	Aggressivity: Lentil	Aggressivity: Oat	Area equivalent ratio
Row ratio (lentil:oat)														
1:1	0.99	4.18	0.59	0.58	1.17	0.50	1.45	1.42	2.06	1.01	0.99	+0.01	–0.01	1.12
2:1	1.13	4.77	0.80	0.55	1.35	0.59	2.03	2.44	4.95	0.73	1.37	–0.44	+0.44	1.28
3:1	0.98	4.13	0.84	0.35	1.20	0.70	1.74	1.62	2.82	0.79	1.26	–0.29	+0.29	1.11
CD (*P*=0.05)	0.08	0.41	0.06	0.05	0.09	0.08	0.23	0.32	0.46	0.06	0.17	0.05	0.05	0.11
P levels (kg P/ha)														
8.6	0.79	3.33	0.62	0.39	1.01	0.61	1.38	1.31	2.12	0.71	0.84	–0.13	+0.13	0.85
17.2	1.14	4.81	0.79	0.54	1.33	0.59	1.88	2.06	3.62	0.89	1.32	–0.29	+0.29	1.31
25.8	1.17	2.94	0.82	0.57	1.39	0.59	1.96	2.11	4.09	0.93	1.46	–0.32	+0.32	1.36
CD (*P*=0.05)	0.08	0.41	0.06	0.05	0.09	0.08	0.23	0.32	1.36	0.06	0.17	0.05	0.05	0.11
Biofertilizers														
PSB	0.94	3.97	0.66	0.42	1.08	0.61	1.41	1.43	2.42	0.74	1.01	–0.16	+0.16	0.99
VAM	0.98	4.13	0.69	0.44	1.13	0.61	1.56	1.56	2.86	0.77	1.12	–0.19	+0.19	1.04
PSB + VAM	1.18	4.98	0.88	0.63	1.51	0.58	2.25	2.49	4.55	1.02	1.49	–0.39	+0.39	1.49
CD (*P*=0.05)	0.08	0.41	0.06	0.05	0.09	0.08	0.23	0.32	1.36	0.06	0.17	0.05	0.05	0.11
Sole vs intercrop														
Sole lentil	0.81	3.42			1.00									
Intercropped lentil	1.03	4.35			1.24									
CD (*P*=0.05)	0.11	0.62			1.00									
Sole oat	0.87	3.67			1.24									
Intercropped oat	1.03	4.35												
CD (*P*=0.05)	0.11	0.62												

Prevailing sale prices of lentil grain, oat grain, lentil straw, oat green fodder and oat straw were @ of ` 15 500, 5 600, 5 50, 1 400, and 9 50/tonnes, respectively

2). The intercropping system 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. The companion crop, oat (except 1:1 row proportion) appeared more competitive than lentil, giving higher values of competitive ratio in the intercropping system. Lentil proved the dominated companion to intercrops, having negative aggressivity, which was further evident from lower competitive ratio (except 1:1 row ratio). The values of relative crowding coefficient of lentil were always greater than 1, indicating that lentil gave more yield than expected. The product of relative crowding coefficient indicated definite yield advantage to grow lentil with oat under 2:1 row proportion (4.95), due to balanced competition between the component crops and their productivity. Highest area-time equivalent ratio (ATER) was recorded for lentil when intercropped with oat in 2:1 row ratio (1.28), followed by 1:1 (1.12) and 3:1 (1.11) row ratio indicating a more efficient use of area by intercropping over other systems. Thus the biological parameters indicated that intercropping of lentil with oat in 2:1 row ratio could be biologically sustainable.

Data presented in Table 2 show that oat was quite aggressive than the lentil and its aggressivity was significantly enhanced further with increasing level of P upto 17.2 kg/ha which remained at par with 25.8 kg P/ha. This resulted in corresponding decline in the aggressivity of lentil mainly due to greater shading effect exerted by oat at higher P levels. Accordingly similar pattern was noticed in respect of the competitive ratio of main (lentil) as well as in intercrop (oat) in lentil+oat intercropping. As lentil was more aggressive and competitive at lowest P level it recorded maximum yield proportion of lentil at lowest level of P (8.6 kg/ha), followed by 17.2 and 25.8 kg P/ha. The differences between 17.2 and 25.8 kg P/ha were non-significant but significant between 17.2 and 8.6 kg P/ha.

Being more aggressive and competitive at higher P doses, oat registered maximum partial-land equivalent ratio at maximum P level (25.8 kg P/ha), followed by 17.2 and 8.6

kg P/ha (Table 2), the differences between 17.2 and 8.6 kg P/ha was significant but at par between 17.2 and 25.8 kg P/ha. Further, the partial land equivalent ratio of lentil, oat and total land equivalent ratio differ significantly due to 17.2 kg P/ha over 8.6 kg P/ha but remained at par with 25.8 kg P/ha. The relative crowding coefficient of component crops as well as the product 'K' at various P levels, further confirmed the results of land-equivalent ratio, indicating marked yield advantage with the application of 17.2 kg P/ha to both the crops, being at par with 25.8 kg P/ha, over 8.6 kg P/ha (Table 2). Application of 17.2 kg P/ha being at par with 25.8 kg P/ha recorded markedly higher area-time equivalent ratio (1.31) over 8.6 kg P/ha (0.85) (Table 2), indicating a more efficient use of area over other P levels.

Dual inoculation with PSB+VAM noticed more aggressivity, competitive ratio, relative crowding coefficient and area-time equivalent ratio of main as well as intercrop in lentil+oat intercropping over VAM and PSB alone (Table 2).

P-uptake and moisture-use efficiency

Significantly higher P uptake by lentil was observed in 3:1 row ratio, being 15.5 and 49.1% higher than under 2:1 and 1:1 ratio, respectively (Table 3). Further, P uptake by oat in lentil+oat intercropping was markedly superior under 1:1 ratio than under other row ratios, being 7.8 and 17.1% more over 2:1 and 3:1 ratio, respectively. This could be due to more plant population, yield attributes and yield of lentil and oat in lentil+oat intercropping system under these row ratios compared with that under other row proportions. These results confirm those of Singh *et al*. (2008).

Water-use efficiency (WUE) in terms of lentil equivalent yield showed marked variation due to intercropping system (Table 3). Intercropping of lentil+oat under 2:1 recorded higher WUE compared with other row ratio. 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 oat under 2:1 row ratio utilized more water for evapotranspiration and metabolic activities. The rate of moisture use and consumptive use of water was higher under 1:1 row ratio than other row ratios. It could be attributed to the fact that both the crops under 1:1 row ratio absorbed more moisture for dry matter production than other ratio which resulted in higher rate of moisture use and consumptive use of water in this intercropping system.

In general, the crops extracted greater amount of soil moisture from the top 0–30 cm soil layer than from 30–60 cm and 60–90 cm soil depth in all the 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.

Application of P at 17.2 kg/ha being at par with 25.8 kg P/ha recorded statistically higher P uptake by lentil (8.3 kg/ha), oat (16.4 kg/ha) and intercropping system (23.3 kg/ha) over 8.6 kg P/ha (Table 3). This could be attributed to the fact that added P doses increased the P content in grain and

Table 3 P uptake and moisture-use indices as influenced by intercropping systems and P management (pooled data of two years)

Treatment	P uptake by lentil (kg/ha)	P uptake by oat (kg/ha)	P uptake by system (kg/ha)	Consumptive water-use (mm)	Crop efficiency (kg/ha-cm)	Rate of moisture of (mm/day)	Moisture-extraction pattern		
							0–30 cm	30–60 cm	60–90 cm
Row ratio (lentil:oat)									
1:1	5.7	16.6	22.3	237.3	5.08	1.01	48.7	27.4	18.9
2:1	7.1	15.3	22.4	233.2	5.76	0.99	47.6	27.7	18.6
3:1	8.2	14.2	22.4	226.4	5.24	0.96	47.1	27.2	18.2
CD (P=0.05)	0.5	0.8	1.5						
P levels (kg P/ha)									
8.6	3.8	12.3	16.1	227.5	4.38	0.96	46.7	26.6	18.2
17.2	8.3	16.4	24.7	229.1	5.88	1.02	48.3	27.8	18.7
25.8	8.9	17.4	26.5	240.3	5.77	0.97	48.4	27.9	18.8
CD (P=0.05)	0.5	0.8	1.5						
Biofertilizers									
PSB	6.5	14.2	20.7	229.6	5.00	0.97	47.4	27.1	18.2
VAM	6.7	14.6	21.3	230.4	5.16	0.98	47.6	27.2	18.3
PSB + VAM	7.8	17.3	25.1	236.9	5.90	1.00	48.4	28.0	19.2
CD (P=0.05)	0.5	0.8	1.5						
Sole vs intercrop									
Sole lentil	10.8		10.8	223.4	4.53	0.94	51.4	26.3	17.2
Intercropped lentil	7.1		22.4	232.3	5.34	0.99	47.8	27.4	18.6
CD (P=0.05)	1.1		3.6						
Sole oat		17.7	17.7	220.5	4.36	0.93	48.2	26.6	17.8
Intercropped oat		15.4	22.4	232.3	5.34	0.99	47.8	27.4	18.6
CD (P=0.05)		1.3	3.6						

straw of both the crops by providing ideal nutritional environment inside the plant and higher photosynthetic efficiency, which favoured better growth and crop yield and ultimately P uptake.

The highest water-use efficiency and rate of moisture use were recorded with 17.2 kg P/ha, followed by 25.8 kg P/ha and least with 8.6 kg P/ha (Table 3). It might be because that increase in lentil-equivalent yield was more than the corresponding increase in consumptive use of water due to P application (Saha *et al*. 2002). In general, soil moisture utilization by crops were maximum from the top soil layer (0–30) than from 30–60 and 60–90 cm layers.

Significant improvement in P uptake by lentil and oat and intercropping system was noticed under dual inoculation with PSB+VAM over PSB and VAM alone (Table 3). Being, 16.5 and 18.6% higher over VAM and PSB inoculation alone by intercropping system. Higher uptake of P with dual inoculation could be due to synergistic effect and production of growth promoting substances (Pramanik and Singh 2003).

Dual inoculation with PSB+VAM gave the highest average values of moisture characteristics, viz consumptive use, water-use efficiency and rate of moisture use and lowest with PSB alone (Table 3). Such increase in these parameters could be attributed to vigorous crop growth, resulting from enhanced availability of P nutrition. Soil moisture depletion from 0–30, 30–60 and 60–90 cm was maximum under dual inoculation treatment owing to favourable root growth of crops.

Economics

The monetary advantage based on land-equivalent ratio indicated superior viability of lentil+oat intercropping in 2:1 row ratio (₹ 8 580), followed by 1:1 (₹ 4 848) and 3:1 (₹ 4 626) (Table 4). The intercropping of lentil with oat in 2:1 row ratio gave the maximum gross return (₹ 33 993), net return (₹ 22 833), benefit:cost ratio (3.05), income-equivalent ratio (1.27) and crop profitability (₹ 96.34/ha/day) followed by 1:1 and 3:1 row proportions, mainly owing to higher economic production in these systems.

Application of P at 17.2 kg/ha recorded highest monetary advantage (₹ 8 517), net return (₹ 23 654), benefit:cost ratio (3.12), income-equivalent ratio (1.35) and crop profitability (₹ 99.81/ha/day) followed by 25.8 and 8.6 kg P/ha, owing to application of P to main and intercrop appear to be the result of increased productivity of both lentil and oat with increasing level of P up to 17.2 kg/ha.

Highest economic returns in terms of monetary advantage (₹ 12 687), gross returns (₹ 37 705), net returns (₹ 26 455), benefit:cost ratio (3.35), income-equivalent ratio (1.46) and crop profitability (₹ 111.62/ha/day) were observed under PSB+VAM inoculation, followed by single inoculation with VAM and PSB (Table 4). This could be attributed to higher productivity of crops under these inoculations.

Energy budgeting

Energy used in lentil and oat cultivation under different row ratio was computed to augment the energy-use efficiency (Table 4). As per computation, input energy differed due to

Table 4 Effect of intercropping system and P management on economics and energy use indices (pooled data of 2 years)

Treatment	Monetary advantage (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit: cost ratio	Income-equivalent ratio	Crop profitability (Rs/ha/day)	Energy budgeting			
							Energy input ('000 MJ/ha)	Energy output ('000 MJ/ha)	Energy efficiency	Energy productivity (g/MJ)
Row ratio (Lentil:oat)										
1:1	4 848	33 067	22 017	2.99	1.13	92.90	21.64	186.4	8.62	678.4
2:1	8 580	33 993	22 833	3.05	1.27	96.34	21.21	192.6	9.08	739.3
3:1	4 626	27 294	16 044	2.43	1.17	67.70	20.34	184.2	9.06	562.9
P levels (kg P/ha)										
8.6	2 234	23 795	13 745	2.15	0.89	53.78	19.87	176.3	8.87	550.6
17.2	8 517	34 814	23 654	3.12	1.35	99.81	21.51	192.2	8.94	718.9
25.8	7 308	35 745	23 495	2.92	1.33	99.13	21.81	194.7	8.92	712.2
Biofertilizers										
PSB	2 022	27 435	16 385	2.48	1.03	69.14	21.03	181.3	8.62	591.5
VAM	3 345	29 214	18 054	2.61	1.08	76.18	21.05	184.4	8.76	653.2
PSB + VAM	12 687	37 705	26 455	3.35	1.46	111.62	21.11	197.5	9.36	764.1
Sole vs intercrop										
Sole lentil		23 677	13 468	2.31	1.00	56.53	20.26	171.4	8.46	140.7
Intercropped lentil	6 018	31 451	20 298	2.82	1.19	85.65	21.06	187.7	8.92	660.1
Sole oat		26 628	16 363	2.59	1.00	69.04	20.72	178.3	8.60	570.8
Intercropped oat	6 018	31 451	20 298	2.82	1.19	85.65	21.06	187.7	8.92	660.1

difference in energy use under different row proportions. The output energy, however, is dependent on grain as well as dry fodder and straw yields under different treatments and higher yields registered greater output energy. Hence energy efficiency (output : input ratio) and energy productivity per unit of energy used (in Mega Joule) may be considered for energy relationships. Among different row proportions, 2:1 row ratio recorded maximum energy efficiency (9.08) and energy productivity (739.3 g/MJ), followed by 1:1 and 3:1 row ratio.

Application of 17.2 kg P/ha recorded maximum energy efficiency (8.94) and energy productivity (718.9 g/MJ), followed by higher dose of P at 25.8 kg P/ha and least at 8.6 kg P/ha (Table 4). Higher energy efficiency and energy productivity might be caused by higher production of output energy due to higher crop yields and lower input energy use in comparison to other P levels.

Among biofertilizer inoculations, dual inoculation with PSB+VAM recorded the maximum energy output (197.5×10^3 MJ/ha), energy efficiency (9.36) and energy productivity (768.1 g/MJ), followed by VAM and PSB alone (Table 4). Similar results were also reported by Mittal and Dhavan (1988).

Sole vs intercrop

Both the crops (lentil and oat) performed quite differently in the sole stand and intercropped stand. Differed yield attributes, viz pods/plant, grains/pod, tillers/m, grains/panicle and 1 000-grain weight improved significantly in sole stand compared with intercropped lentil or oat stand. Sole stand of lentil and oat gave 35 and 101.7% higher seed yield than respective intercropped stand (Table 1). This was because of considerably lower plant population of lentil and oat in intercrop therefore their yield was significantly lower than the sole stand of either of the crops.

Beside lower plant population, the more competitive, aggressive and crowded intercrop also contributed in lowering the grain yield in intercropping compared with sole stand. However, lentil-equivalent yield, crop productivity, land-equivalent ratio, P uptake, water use, economic advantage and energy productivity were recorded higher under intercropping system than sole cropping. This is because of the overall higher productivity or yield advantage under intercropping system.

Thus results of the present investigation clearly demonstrate that lentil + oat intercropping in 2:1 row ratio and application of 17.2 kg P/ha and dual inoculation of seeds of both the crops (lentil and oat) may be practised to achieve better land utilization, high yield as well as profitability under rainfed silty clay loam soil of Kashmir valley.

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