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Research Paper

Inter/mixed cropping of lentil (*Lens culinaris*) in late-sown wheat (*Triticum aestivum*) for higher productivity and profitability of wheat in Vertisols of Central India

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ABSTRACT

A field experiment was carried out the during winter (*rabi*) seasons of 2012–13 and 2013–14 at Research Farm of ICAR-Indian Agricultural Research Institute, Regional Station, Indore, Madhya Pradesh, to study the performance of different inter and mixed cropping systems of lentil (*Lens culinaris* Medik.) in late-sown wheat (*Triticum aestivum* L.). Treatments tested were wheat sole, lentil sole, wheat (line sowing) + lentil (50% seed broadcast), wheat (broadcast) + lentil (line sowing), wheat + lentil (mixed sowing of 100% seed rates), wheat + lentil (mixed sowing of 50% seed rates), wheat + lentil (1 : 1 row ratio), wheat+ lentil (2 : 1 row ratio), wheat + lentil (2 : 2 row ratio) and wheat + lentil (3 : 1 row ratio). Pooled over data of 2 years indicated that grain and biological yields (5.87 and 14.8 t/ha) recorded with wheat (line sowing) + lentil (broadcast), which being substantially higher to the tune of 4.45 and 3.35% over wheat sole in addition to a bonus yield of 40 kg lentil/ha were significantly higher than rest of the treatments. The same treatment also recorded the highest values of number of fertile tillers/m^2 (461.1/m^2), length of spike (9.55 cm), number of spikelets/spike (16.8), total N uptake (169.6 kg/ha), wheat-equivalent yield (5.96 t/ha), land-equivalent ratio (1.07), aggressivity index (1.01), sustainability-yield index (0.96), production efficiency (47.5 kg/ha/day), monetary return-use efficiency (₹443.6/ha/day), net returns (₹55.7 thousands/ha) and benefit: cost ratio (2.65). However, relative crowding coefficient (73.6) and total protein yield were observed with wheat + lentil (3 : 1 row ratio) and lentil sole respectively.

Key words : Grain and biological yield, Intercropping, Land-equivalent ratio, Lentil, Mixed cropping, Wheat, Wheat-equivalent yield

Intercropping systems have the potential to exceed the yields possible in monocultures of their component species (Willey, 1979) and Banik *et al.* (2006) indicated that intercropping systems register significant increase in total productivity per unit area and improve land-use efficiency. It also reduces the failure risk of a single crop that is susceptible to environmental fluctuations (Khan *et al.,* 2005). Intercropping system intercepts more solar energy and provides comparatively higher yield stability (Tsubo *et al.*, 2003). According to Sullivan (2003) intercrops staggered the maturity dates or developmental periods and take advantage of variations in demands for nutrients, water, and sunlight. Mixed cropping systems which define growing of two or more species or cultivars on the same piece of land during the same season is known to increase the size and stability of yields through the effective utilization of natural resources as compared to mono-cropping (Hauggaard-Nielsen *et al.*, 2006). Considering that wheat is the most important cereal crop in the world and it plays a vital role in global agricultural economy, and in India, it ranks second only after rice and has a large land area (more than 30 million ha) under wheat crop. Aziz *et al.* (2015) reviewed the wheat-based intercropping systems and found wheat a most suitable crop for intercropping system. Growing of multiple crops as mixed or intercropping systems in association of wheat not only opens the avenues of production of pulses and oilseeds in association of wheat but also beneficial for soil health (Hauggaard-Nielsen *et al*., 2001). Khan *et al*. (2005) also concluded that, intercropping of chickpea and wheat in 1 : 1 ratio increased the grain yield of wheat.

In Central Zone of the country, a sizeable land area is under late sown wheat due to late harvesting of some long-duration crops of rainy (*kharif*) season, viz. paddy, cotton, chilly, etc. These preceding crops are highly exhaustive for nutrients and succeeded wheat crop puts heavy demand of

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nutrients on soil. In these conditions, inter/mixed cropping systems by inclusion of legume as a complementary crop in the system have the scope and potential to exceed the yields not possible in monocultures of their component species (Willey, 1979). The intercropping of pulses like lentil, chickpea, pea in association of wheat has been advocated by several researchers for higher productivity and economic viability under different configurations (Akter *et al.*, 2004, Khaliq *et al.*, 2001, Khan e*t al.*, 2005; Das *et al.*, 2012). However, information on legume intercropping in late-sown wheat is lacking. Keeping these in view, present investigation was carried out to find out the effect of lentil as inter or mixed crop on late-sown wheat in Vertisols of Central India.

MATERIALS AND METHODS

The field experiment was carried out during the winter (*rabi*) seasons of 2012–13 and 2013–14 at Research Farm of ICAR-Indian Agricultural Research Institute, Regional Station, Indore, (22°37°N, 75°50°E, 557 m above mean sea-level) Madhya Pradesh, and has a semi-arid tropical climate with mean annual rainfall of 758 mm. The soil was very fine clay loam (Vertisols) with the following characteristics in 0–15 cm depth: *p*H 7.4 (1:2.5 soil/water suspension), electrical conductivity 0.23 dS/m, medium in organic carbon (0.52%), available nitrogen (232 kg/ha) and available phosphorus (20.5 kg P_2O_5/ha), and high in available potassium (423.5 kg K_2O/ha). Mean monthly meteorological observations during the crop seasons of both the years are presented in Table 1. A total of 10 inter/mixed cropping treatments, consisting T_1, wheat sole; T_2, lentil sole; T_3, wheat (line sowing) + lentil (broadcast); T_4, wheat (broadcast) + lentil (line sowing); T_5, wheat + lentil (mixed sowing of 100% seed rates of both); T_6, wheat + lentil (mixed sowing of 50% seed rates of both); T_7, wheat + lentil (1 : 1 row ratio), T_8, wheat + lentil (2:1 row ratio); T_9, wheat + lentil (2 : 2 row ratio) and T_{10}, wheat + lentil (3 : 1 row ratio), were laid out in randomized block design with 3 replications. All mixed cropping treatments (T_3 to T_6) were planted in additive series and treatments T_7 to T_{10} (intercropping treatments) were sown in replacement series. Cultivars 'Vidisha' of wheat and 'L 4076' of lentil were used in the trial. The crops were raised on 6 and 4 December and harvested on 14 and 16 April during the first and second years respectively. The recommended dose of fertilizers for wheat @ 120 : 26.4 : 33.2 kg of N : P : K/ha and 20 : 26.4 : 33.2 of N : P : K/ha to lentil were applied through urea, single superphosphate and muriate of potash on the basis of proportionate area of crop in plot. In wheat and wheat + lentil, 50% N and full doses of P and K were applied basal and the remaining N was top-dressed just before the first irrigation. While in lentil sole, whole dose of fertilizers was used basal at the time of sowing. Experiment was conducted under irrigated conditions and 2 irrigations were applied to lentil sole and 3 irrigations to wheat as well as wheat + lentil plots in both the years. One hand-weeding was carried out at 35–40 days after sowing in both the years. Available N, P and K contents in soil samples were determined by modified Kjeldahl procedure by using Kjeltec Auto Analyser, Calorimetric by vanadomolybdate yellow colour method and flame photometer method (Jackson, 1973) respectively. The powdered fractions of grain and straw of wheat samples were digested in di-acid HNO_3 + $HClO_4$ (3 : 1) and N content was estimated according to modified Kjeldahl procedure using Kjeltec Auto Analyser. Estimated N was used for crude protein content and yield. The observations on tillers height and number/m^2were undertaken just before harvesting and 5 tillers/plot were uprooted randomly for post-harvest studies. Grain and biological yields were recorded at harvest. All the data recorded on growth, yield attributes, yield and quality were statistically analysed as per procedure outlined by Gomez and Gomez (1984). Wheat-equivalent yield of lentil was worked out on the basis of prevailing market price of each crop by using following formula and added in the yields of wheat in mixed or intercropped systems:

WEY = {Yield of intercrop (t/ha) × Price of intercrop (₹/t)}/ Price of main crop ((₹/t)

Land-equivalent ratio (LER), aggressivity index (AI) and relative crowding co-efficient (RCC) were worked out as per Verma *et al*. (2005) and all mixed cropping treatments were considered as 50 : 50 rows proportion. The inter/mixed cropping systems were also evaluated based on sustainability-yield index (SYI) using mean wheat-equivalent yield (Y_{mean}), standard deviation (ó) and maximum equivalent yield ($Y_{maximum}$) and it was calculated as per formula suggested by Wanjari *et al.* (2004). Production efficiency and monetary return-use efficiency were also worked out as per their procedures of calculation. Economic benefits were worked out on the basis of mean data over 2 years and prevalent market prices for different outputs and inputs were used.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth and yield attributes revealed that there was no significant variation in plant height, length of spike and 1,000-grain weight due to inter/mixed cropping treatments, but fertile tillers/$m^2$and spikelets/spike of wheat varied significantly with highest values under treatment T_3, where wheat was sown at 20 cm apart rows and lentil as broadcast (Table 2). Fertile tillers/m^2 of treatment T_3 were statistically at par with treatment T_1, T_5 and T_{10} but significantly higher over rest of the treatments. Whereas, spikelets/spike of treatment T_3 were at par with most of the treatments except treatments T_4 and T_7, where difference was significant. It was also noted that highest values of length of spike (9.55 cm.) and 1,000-grain weight (47.3 g, which was 1.28% higher than T_1) were also observed with treatment T_3, but these could not reach the level of significance. However, the maximum height of wheat plant (87.3 cm) was observed under wheat sole (T_1). Reduction in fertile tillers under mixed cropping was mainly because of poor tillering in wheat. But in intercropping systems, decreased area under wheat crop might be responsible for lower values, as treatments were imposed under replacement series and legume incorporation could not be able to benefit the crop to that extent needed for comparable yields of wheat sole or wheat + lentil grown in additive series. Increased values of length of spike, spikelet/spike and 1,000-grain weight under T_3 (mixed cropping) might be owing to less competition and additional N supplied through biological nitrogen fixation activity of broadcast lentil. These results confirm the findings of Khaliq *et al.* (2001) and Khan *et al.* (2005).

Grain and biological yields

Different inter/mixed cropping treatments brought about significant variation in grain and biological yields of both component crops and the maximum wheat yields were obtained under treatment T_3 (line sowing of wheat + broadcasting of lentil), which were significantly higher than rest of the treatments except wheat sole (T_1), where differences were non-significant. Among the mixed cropping systems (T_3 to T_6), grain and biological yields recorded with T_3 treatments were followed by T_5 (sowing of 100% seed rate of both crop species), and recorded the lowest yields when seed rate was decreased to 50% of both species. However, in case of intercropping systems (T_7 to T_{10}), treatment T_{10} (3 : 1 ratio) resulted in the highest wheat grain (5.40 t/ha) and biological (13.27 t/ha) yields, which being at par with ratio 2 : 1 (T_8) were significantly higher than rest of the intercropping systems.The increase in grain and biological yields of wheat under treatment T_3 was to the tune of 4.45 and 3.35%, respectively, over wheat sole (T_1) in addition to a bonus yield of 40 kg/ha of lentil grain. Increase in wheat yields under T_3 treatment might be owing to beneficial effect of legume

Table 1. Mean monthly meteorological observations during crop seasons of both the years

Month	Temperature (ºC)				Rainfall (mm)		Relative humidity (%)		Open PER (mm/day)	
	Maximum		Minimum		2012–13	2013–14	2012–13	2013–14		
	2012–13	2013–14	2012–13	2013–14					2012–13	2013–14
December	27.5	26.0	8.6	9.0	0	2.2	78.0	80.2	3.9	4.0
January	23.8	23.4	5.8	7.1	0	0	78.4	80.1	3.4	3.7
February	26.4	25.6	10.4	7.5	23.2	42.2	79.4	78.7	4.3	4.6
March	33.4	31.7	15.0	12.5	0	0	76.0	79.4	6.9	6.5
April	37.7	38.7	19.2	18.8	0	0	80.3	81.6	7.8	8.9
Mean	29.8	29.1	11.8	11.0	4.6	8.9	78.4	80.0	5.3	5.5

Table 2. Effect of mixed and intercropping of lentil on growth, yield attributes and yields of wheat (pooled data of 2 years)

Treatment	Plant height (cm.)	Fertile tillers/m^2	Length of spike (cm)	Spikelets/ spike	1,000-grain weight (g)	Grain yield (t/ha)		Biological yield (t/ha)	
						Main crop	Intercrop	Main crop	Intercrop
T_1	87.3	445.8	9.15	16.5	46.7	5.62	–	14.32	–
T_2	–	–	–	–	–	–	1.16	–	5.21
T_3	85.5	461.1	9.55	16.8	47.3	5.87	0.04	14.80	0.23
T_4	83.5	386.5	8.81	14.3	46.6	5.03	0.08	12.97	0.49
T_5	86.0	433.1	8.58	15.4	46.9	5.29	0.05	13.86	0.27
T_6	85.7	391.8	8.28	15.5	46.4	4.76	0.05	12.98	0.22
T_7	83.9	369.8	8.51	14.8	46.0	4.92	0.14	12.20	0.70
T_8	84.1	400.2	8.48	15.4	46.5	5.14	0.08	12.88	0.47
T_9	84.3	377.3	8.70	15.3	46.7	4.39	0.23	10.85	1.35
T_{10}	85.7	420.3	9.07	16.1	46.5	5.40	0.07	13.27	0.37
SEm±	1.12	14.2	0.38	0.64	0.58	0.14	0.02	0.30	0.10
CD (P=0.05)	NS	40.9	NS	1.84	NS	0.40	0.07	0.86	0.30

T_1, Wheat sole; T_2, lentil sole; T_3, wheat (line sowing) + lentil (broadcast); T_4, wheat (broadcast) + lentil (line sowing); T_5, wheat + lentil (mixed sowing of 100% seed rates of both); T_6, wheat + lentil (mixed sowing, 50% seed rates of both); T_7, wheat + lentil (1 : 1 row ratio); T_8, wheat + lentil (2 : 1 row ratio); T_9, wheat + lentil (2 : 2 row ratio); and T_{10}, wheat + lentil (3 : 1 row ratio) component to the wheat crop through BNF activity, which improved the growth and yield attributes, resulting in higher wheat yield attributes and yields. This higher wheat productivity was the function of higher no. of fertile tillers per unit area and comparatively increased values of length of spike, spikelets/spike and 1,000-grain weight recorded under treatment T_3. In case of intercrop, the maximum grain and biological yields of lentil were obtained under lentil sole (T_2), which were significantly higher than all the other treatments. Lower lentil yields under inter/mixed cropping systems was the outcome of proportionately decreased in area under lentil and dominated plant stature of wheat causing over-shading, exhaustive nutrients and greater competition for light with lentil, resulting poor productivity. Similar trend in productivity of wheat and lentil in sole and intercropping systems was also observed by Khaliq *et al.*, (2001). Subedi (1997) also reported that mixing of pea @ 30–45 kg in Indian mustard was most profitable in terms of grain yield. Khan *et al.* (2005) reported higher wheat yield when grown in association of chickpea.

Nitrogen uptake and protein yield

Data on nitrogen uptake and protein yields by component crops indicate that, N uptake individually in grain and straw as well as total differed significantly and N uptake recorded with grain and straw of wheat under treatment T_3 (wheat was sown in line at 20 cm apart rows and lentil as broadcast) was significantly higher over rest of the treatments except straw of treatment T_1, where difference was statistically non-significant (Table 3). The magnitude of increase of N uptake in grain and straw of wheat in T_3 was to the tune of 6.15 and 7.04%, respectively, compared with wheat sole (T_1). However, among the intercropping systems, the highest N uptake in wheat and straw was observed under treatment T_{10}, where wheat and lentil were sown at 3:1 row ratio, followed by T_8 (2 : 1 row ratio). Higher uptake of N under treatment T_3 was the combined effect of the highest wheat yield and production of N-rich production of lentil grain and straw. Among the intercropping systems, the highest N uptake in wheat grain and straw under treatment T_{10} were the sole reason of the highest wheat yields compared with the other intercropping systems. This may also be explained by the fact that symbiotic effect of legume crop might be beneficial in improving N content of soil for both border rows of the system and crop yields, and in-turn increased the N uptake. In case of N uptake in grain and straw of lentil, treatment T_2 (lentil sole) recorded the highest N uptake values due to growing in non-competitive atmosphere. But in the case of different inter or mixed cropping systems, treatment T_9 recorded the maximum values of 9.2 and 33.3 kg/ha of N uptake in grain and straw of lentil, respectively, followed by T_7 (5.7 and 16.4 kg/ha). It was mainly because of higher productivity of N-rich grain and straw of lentil in T_9 due to comparatively less competition with wheat crop because of growing in replacement series (2 : 2 rows ratio). Similar trend was also observed for protein yields in main and intercrop as well as total protein yield except treatment T_2 (lentil sole), where total CP recorded slightly higher than treatment T_3. It was mainly because of proportionally higher protein rich straw yield of lentil compared to wheat + lentil (T_3).

Table 3. Effect of mixed and intercropping of wheat and lentil on nitrogen uptake and protein yield (pooled data of 2 years)

Treatment	N uptake (kg/ha)					Protein yield (kg/ha)		
	Main crop		Intercrop		Total	Main crop	Intercrop	Total
	Grain	Straw	Grain	Straw				
T_1	117.1	35.5	–	–	152.6	891.7	–	891.7
T_2	–	–	48.6	115.3	163.9	–	998.6	998.6
T_3	124.3	38.0	1.5	5.7	169.6	948.5	44.2	992.7
T_4	104.9	32.3	3.2	10.3	151.5	801.9	82.7	884.6
T_5	110.2	35.2	2.1	6.0	153.5	850.3	49.5	899.8
T_6	99.9	34.0	2.2	4.6	140.7	783.9	41.3	825.2
T_7	102.0	29.9	5.7	16.4	154.0	770.3	135.1	905.4
T_8	108.6	31.6	3.4	11.1	154.8	818.7	88.8	907.5
T_9	93.3	27.2	9.2	33.3	163.0	703.7	260.7	964.4
T_{10}	113.1	32.8	2.7	8.8	156.6	851.9	70.4	922.3
SEm±	2.12	0.89	0.7	1.6	3.31	15.39	12.20	19.69
CD (P=0.05)	6.11	2.57	1.91	4.62	9.50	44.33	35.14	56.50

T_1, Wheat sole; T_2, lentil sole; T_3, wheat (line sowing) + lentil (broadcast); T_4, wheat (broadcast) + lentil (line sowing); T_5, wheat + lentil (mixed sowing of 100% seed rates of both); T_6, wheat + lentil (mixed sowing, 50% seed rates of both); T_7, wheat + lentil (1 : 1 row ratio); T_8, wheat + lentil (2 : 1 row ratio); T_9, wheat + lentil (2 : 2 row ratio); and T_{10}, wheat + lentil (3 : 1 row ratio).

Wheat-equivalent yield and competition indices

Different treatments had different yield potential of component crops and economic values, and therefore for better comparison, the yields of wheat and lentil were converted into wheat-equivalent yield (WEY) on the basis of prevalent market prices (Table 4). Wheat-equivalent yield values revealed that, the highest wheat-equivalent yield (5.96 t/ha) was obtained under the treatment T_3, followed by wheat sole (T_1), with minimum values recorded with lentil sole (3.08 t/ha).The magnitude of increase in WEY under the treatment T_3 was 6.05% over treatment T_1 (wheat sole). Mixed cropping of lentil with wheat under T_3 treatment showed advantage in terms of wheat-equivalent yield owing to improvement in wheat yield along with a bonus yield of lentil to the tune of 40 kg/ha. Among the mixed/intercropping systems (except T_3), treatment T_{10} (3 : 1 row ratio) recorded almost similar WEY to wheat sole. Despite reduction in area of wheat under treatment $T_{10,}$ similar productivity of WEY might be the function of border effect, which might be beneficial in enhancing wheat yield despite of substantial reduction in wheat area under 3 : 1 rows ratio of treatment T_{10} and lentil yield recorded under the treatment as well. Banik (1996) and Kumar *et al*. (2008) also recorded comparatively higher wheat-equivalent yield under wheat + lentil than wheat sole.

Land-equivalent ratio (LER) is frequently used as index of biological advantage, which places the component crops on a relative and directly comparable basis (Willey, 1979). The LER also verifies the effectiveness of mixed cropping for using the resources of the environment compared to sole cropping (Mead and Willey, 1980; Dhima *et al*., 2007). In present study, the highest land-equivalent ratio (LER) was recorded under T_3 (1.07), followed by T_{10} (1.02), whereas rest of the inter-mixed cropping systems recorded LEY values almost 1 or less than 1, which are not beneficial and recommendable for adoption by farmers. Akter *et al.* (2004) reported that, higher yield of wheat and lentil was achieved when both crops were sown in lines than broadcast systems.

Computation of aggressivity index (AI) indicated that, all treatments (T_3 to T_6) planted as mixed sowing under additive series recorded higher AI values, ranging from 0.73 to 1.01, than intercropping systems planted under replacement series (0.26 to 0.75). The maximum value of AI was worked out under treatment $T_{3,}$ which was followed by T_4 (sowing of lentil in line and wheat broadcast). However, the minimum AI value was observed under treatment $T_{10,}$ which being almost similar to T_9 was substantially lower than the other intercropping treatments, viz., T_8 and T_7. These results showed that sowing of legume component in additive series might have increased the competition between plants of component crops and thereby resulted increase the dominance power of wheat and recorded higher value of AI. However, intercropping systems due to sowing in replacement series might have decreased the competition between both the component crops and lowered the power of dominance of wheat crop and thus recorded lower values of aggressivity index. However, treatments T_6 (mixed seed of 50% seed of both component crops in additive series) and T_7 (1:1 row ratio in replacement series) recorded almost similar values of AI to the extent of 0.73 and 0.75, respectively, indicated simi-

Table 4. Effect of mixed and intercropping of lentil on wheat-equivalent yield, competition indices and economics of late-sown wheat

Treatment	Wheat-equivalent yield (t/ha)	Land-equivalent ratio	Relative crowding coefficient	Aggressivity index	Sustainability yield index	Production efficiency (kg/ha/day)	Monetary return-use efficiency (₹/ha/day)	Economics			
								Cost of cultivation (×10³ ₹/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
T_1	5.62	1.00	-	-	0.90	44.8	408.8	33.0	84.3	51.3	2.55
T_2	3.08	1.00	-	-	0.48	24.5	220.9	18.5	46.2	27.7	2.50
T_3	5.96	1.07	23.5	1.01	0.96	47.5	443.6	33.8	89.5	55.7	2.65
T_4	5.24	0.96	8.5	0.92	0.84	41.7	360.4	33.4	78.6	45.2	2.35
T_5	5.43	0.99	16.0	0.90	0.87	43.3	373.3	34.6	81.5	46.8	2.35
T_6	4.90	0.89	5.5	0.73	0.78	39.0	325.9	32.6	73.5	40.9	2.25
T_7	5.29	1.00	7.0	0.75	0.85	42.1	377.8	32.0	79.4	47.4	2.48
T_8	5.37	0.99	21.4	0.39	0.86	42.8	383.2	32.3	80.4	48.1	2.49
T_9	4.99	0.98	3.6	0.29	0.80	39.8	341.9	32.0	74.9	42.9	2.34
T_{10}	5.58	1.02	73.6	0.26	0.89	44.5	390.2	32.5	81.5	49.0	2.51
SEm±	0.11	0.02	-	-	-	-	-	-	-	1.56	0.05
CD (P=0.05)	0.31	0.06	-	-	-	-	-	-	-	4.64	0.14

The prices of different produce per tonne used for calculation were: ₹15,000 for wheat grain, ₹4,000 for wheat straw, ₹40,000 for lentil grain and ₹6,000 for lentil straw. The input costs used for calculation of cost of cultivation were: ₹167/manday, ₹800/harrowing, ₹1,000/rotavator, ₹1,200/irrigation, ₹13.0/kg N, ₹31.2/kg P and ₹11.7/kg K, whereas the prices of seed were based on market price lar level of competition and dominance power of wheat over legume component.

Relative crowding coefficient (RCC) revealed that all the inter and mixed cropping systems recorded more than 1 values with a maximum value of 73.6 under $T_{10,}$ where wheat and lentil were sown at a row ratio of 3 : 1 in replacement series, which was followed by treatment T_3 (23.5). Treatment T_9 (2:2 row ratio) and T_6 (mixed sowing of 50% each of component crops) recorded lowest values to the tune of 3.6 and 5.5, respectively. Higher values of RCC indicate better land utilization efficiency of the system by the component crops. Differential effectiveness of legume component in different planting systems might be the reason of varied values of RCC observed.

Sustainability-yield index (SYI) and production efficiency (PE) computed based on wheat-equivalent yields and monetary return-use efficiency (MRUE) based on prevalent market prices of inputs and outputs showed that treatment T_3 holds its superiority and recorded the highest values of all the above traits, viz., SYI 0.96, PE 47.5 kg/ha/day and MRUE ₹443.6/ha/day, which were greater than wheat sole (T_1) and substantially higher over rest of the inter/ mixed cropping systems. These parameters indicate the comparative production potentiality and economic viability of the system. Thus, treatment T_3 can be considered a productive and economically efficient planting system rather than wheat sole or other mixed or intercropping systems.

Economics

Based on mean data over 2 years, the economic analysis (Table 4) showed that, treatment T_3, i.e. wheat (line sowing) + lentil (broadcast) gave the highest net returns of ₹55,675/ha and benefit: cost ratio of 2.65, followed by wheat sole (₹51,305/ha and 2.55) with the minimum values under lentil sole (₹27,718/ha and 2.50). This higher net benefit in wheat (line sowing) + lentil (broadcast) was the result of higher total wheat yields alongwith a bonus yield of lentil as compared to wheat sole (T_1). Reduction in net benefits under other inter-mixed cropping treatments was the outcome of lower wheat and lentil yields compared with sole. Akter *et al*. (2004) also reported the maximum LER (1.52), monetary advantage (63%), benefit: cost ratio (1.84) under lentil + wheat as mixed cropping system. Under intercropping systems, the highest BCR (2.07) was recorded in wheat–lentil intercropping at 1:1 row ratio (Das *et al*., 2012). Banik (1996) evaluated gram, pea and lentil crops as intercrop with wheat in 1 : 1 and 2 : 1 under row replacement series and reported that when actual sown proportion was considered wheat + lentil (1:1) resulted in the maximum monetary advantage.

On basis of two year study, it may be inferred that line sowing of wheat with recommended seed rate at 20 cm. apart rows and broadcast sowing of lentil at half rate (30 kg/ha) holds promise to provide higher and economical wheat productivity with a bonus yield of lentil in Vertisols of Central India.

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