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RESEARCH PAPER

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

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Abstract : The field experiment was carried out during *Rabi* season of 2012-013 and 2013-14 at Indore (M.P) to find out the performance of different wheat and lentil inter and mixed cropping systems on the productivity and profitability of late sown wheat.Treatments tested were wheat sole, lentil sole, wheat (line sowing)+lentil (broadcasted), wheat (broadcasted)+ lentil (line sowing), wheat+ lentil (mixed sowing of 100% seed rates of both), wheat+ lentil (mixed sowing of 50% seed rates of both), 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). Results indicated that line sowing of wheat at 20 cm a part rows + broad cast sowing of lentil as @ 30kg seed/ha recorded higher values of no. of fertile tillers/m^2, length of spike (cm), number of spikelet/spike, grain yields (5.81 and 5.93 t/ha), biological yields (14.8 and 14.8 t/ha), wheat grain equivalent yields (5.94 and 5.99 t/ha) and land equivalent ratio (1.06 and 1.09) than wheat sole along with a bonus yield of lentil grain to the tune of 50 and 20 kg/ha during first and second years, respectively. Similar trend was observed fornet benefits and on mean data basis treatment line sowing of wheat + broad casting of lentil recorded highest values of net returns (Rs.55675=00) and B:C ratio (2.65). Hence, for getting higher and economic wheat productivity, broad casting of lentil can be done in line sowing of wheat and can be recommended to farmers practice in Central India.

Key Words : Intercropping, Grain, Biological yield, Land equivalent ratio, Lentil, Mixed cropping, Wheat, Wheat equivalent yield

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INTRODUCTION

Among food-grains,wheat is the most important staple food grain crop and stands next only to rice at global level. Due to ever-increasing human population and decreased area under cultivation, there is a pressure on limited land resource to meet basic demands of increased population towards food, fodder, pulses, oilseeds etc. Therefore, it was realized that there is a need not only to increase production of cereal crops, but also the ability to grow multiple crops with inclusion of oilseed and pulse in existing crops or cropping systems

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in same piece of land. In India, there is a sizeable area under late sown wheat due to late harvesting of some long duration crop/varieties *viz.*, pigeonpea, paddy, chillies etc. of *Kharif* season. In these conditions, intercropping systems have the scope and potential to exceed the yields possible in monocultures of their component species (Willey, 1979 and Liebman, 1988). It provides a variety of returns from land and labour to the farmers, often increases the efficiency with which scarce resources are used and reduces the failure risk of a single crop that is susceptible to environmental and economic fluctuations (Khan *et al.*, 2005). Efficiency of resource utilization can be increased with intercropping (Tilman *et al.*, 2002; Gao and Wu, 2014 and Nasri *et al.*,2014). According to Sullivan (2003), intercrops staggered the maturity dates or development periods and take advantage of variations in peak resource demands for nutrients, water and sunlight. Intercropping is also known to intercept more solar energy and provide comparatively higher yield stability (Tsubo *et al.*,2003) and yield insurance during aberrant weather conditions compared with sole crops (Willey, 1979; Sinha *et al*.,1985 and Mandal *et al*.,1991). The intercropping system greatly contributes to crop production through the effective utilization of natural resources compared to the mono-cropping system (Francis, 1989; Li *et al.*,1999 and 2001). 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 (Hauggaard –Nielsen *et al.*, 2006; Li *et al*.,1999 and 2001) as compared to mono- cropping.

Improvement of soil fertility through the addition of nitrogen in the soil rhizosphere by fixation of component legume crops (Hauggaard-Nielsen *et al*., 2001).Legume/ cereal intercropping is one of the most common practices and has been popular in rainfed areas of the world due to its low cost of production and high monetary returns to the farmers (Ofori and Stern, 1987). Intercropping yield advantage systems has been well documented during the past decades. Intercropping have some advantages e.g. better use of growth resources, control of weeds, pests and diseases and greater stability of yield in case of environmental hazards over the monoculture of the companion crops. The merits of intercropping have been maintained by (1) additional income from companion crop, (2) insurance against failure of the main crop and (3) quick growth of companion crop tends to suppress weeds (Ram *et al.*,1963). Keeping above in view, present investigation was undertaken to find out the effect of lentil as inter or mixed crop in association of wheat crop in vertisols of Central India under late sown conditions.

MATERIAL AND METHODS

The field experiments was carried out for two consecutive years during *Rabi* season of 2012-13 and 2013-14 at Research Farm of ICAR-Indian Agricultural Research Institute-Regional Station, Indore (M.P), India. The experimental field is situated between 22°37'N latitude to 75°50'E longitude at 557m above mean sea level and has a semi-arid tropical climate with mean annual rainfall of 758 mm. The soil was very fine clay loam hyperthermictypic Haplustert (Vertisol) with the following characteristics in 0-15 cm depth: pH 7.4 (1:2.5 soil/water suspension), EC 0.23 dS/m, medium in organic carbon (0.52%), available nitrogen (232 kg/ha), available phosphorus (20.5 kg P_2O_5/ha) and high in available potash (423.5 kg K_2O/ha). Ten inter/mixed cropping treatments consisted of T_1- wheat (*Triticum aestivum* L.) sole, T_2- lentil (*Lens culinaris*) sole, T_3- wheat (line sowing) + lentil (broadcasted), T_4- wheat (broad casted)+ 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 laid out in Randomized Block Design with three replications. Cultivars DL 788-2 (Vidisha) of wheat and L 4076 of lentil were used in the trial. 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 super phosphate and muriate of potash on the basis of proportionate area of plot. In plots of wheat (except lentil sole) 50 per cent N and full doses of P and K were applied as basal and remaining N topdressed at just before first irrigation. While in lentil sole plots whole dose of fertilizers was used as basal at the time of sowing. One hand weeding was carried out at 35-40 days after sowing in both the years.The crops were harvested at maturity. Wheat equivalent yield was worked out on the basis of prevailing market price of each crop in the respective years by using following formula:

$$\text{WEY} = \frac{\{\text{Yield of lentil (tha}^{-1}\text{) x Price of lentil (Rs.t}^{-1}\text{)}\}}{\text{Price of wheat (Rs. t}^{-1}\text{)}}$$

Economic benefits were worked out evaluation on

the basis of mean data over two years and prevalent market prices for different outputs and inputs were used. The prices of different produce per tonne used for calculation were: Rs.15000 for wheat grain, Rs. 4000 for wheat straw, Rs. 40000 for lentil grain and Rs. 6000 for lentil straw. The input costs used for calculation of cost of cultivation were: Rs.167/manday, Rs.800/ harrowing, Rs.1000/rotavator, Rs.1200/irrigation, Rs.13.0/kg N, Rs. 31.2/kg P and Rs.11.7/kg K, whereas the prices of seed were based on market price. The intercropping indices, *viz.*, wheat equivalent yield (WEY) and land equivalent ratio (LER) were also computed to evaluate the treatment effects under inter/mixed cropping system. All necessary observations including growth and yield attributes and grain yield of wheat and lentil were recorded at the time of harvesting. For treatment comparison, F-Test was used following the procedures of Factorial Randomized Block Design.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Growth and yield attributes :

Data on growth and yield attributes revealed that significant variation in plant height and number of fertile tillers/m^2 of wheat was observed during 2012-13 due to inter-mixed cropping system, but in second year differences were non-significant (Table 1). Plant height was highest under wheat sole (T_1), but number of fertile tillers/m^2 were observed maximum with the treatment T_3-wheat (line sowing) + lentil (broadcasted) in both the years with minimum values of both the traits under wheat and lentil row ratio of 1:1 (T_7). Higher values in T_3 might be due to beneficial symbiotic effect of lentil broadcasted in wheat. Treatment T_3 also recorded highest values of spike's length and number of spikelet/spike followed by wheat sole in both the years except length of spike during 2013-14, where T_4 and T_{10} treatments recorded higher values than wheat sole. Reduction in fertile tillers under mixed cropping was mainly due to poor germination and in intercropping, decreased area under wheat crop might be responsible for lower values as treatments were imposed under replacement series. Difference in 1000 grain weight was non-significant in both the years but treatment T_3 recorded maximum values, which were 1.09 and 1.28 per cent higher than T_1 (wheat sole). Increased values of length of spike, number of spikelet/spike and 1000 grain weight under T_3 may be owing to less competition and additional nitrogen supplied through BNF from broadcasted lentil. Khan *et al*. (2005) also reported that the plant height, spike length, number of grains per spike and grain yield of wheat was higher with chickpea intercropping, while the effect on 1000-grain weight was non-significant.

Table 1: Effect of mixed and intercropping of lentil on yield attributes of wheat

Treatments	Plant height (cm.)			No. of fertile tillers/m^2			Length of spike (cm)			No. of spikelet/spike			1000 grain weight (g)		
	Ist year	IInd year	Mean	Ist year	IInd year	Mean	Ist year	IInd year	Mean	Ist year	IInd year	Mean	Ist year	IInd year	Mean
T_1	85.1	89.5	87.3	441.7	450.0	445.8	9.10	9.20	9.15	15.7	17.4	16.5	45.9	47.5	46.7
T_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T_3	82.1	88.9	85.5	467.3	455.0	461.1	9.17	9.93	9.55	16.0	17.6	16.8	46.4	48.3	47.3
T_4	81.9	85.2	83.5	342.3	430.8	386.5	8.00	9.63	8.81	13.5	15.2	14.3	45.3	48.0	46.6
T_5	84.6	87.5	86.0	443.0	423.3	433.1	8.17	9.00	8.58	13.5	17.3	15.4	46.0	47.8	46.9
T_6	82.3	89.1	85.7	380.0	403.7	391.8	8.07	8.50	8.28	14.9	16.1	15.5	45.2	47.7	46.4
T_7	80.6	87.2	83.9	359.0	380.7	369.8	8.93	8.10	8.51	13.3	16.3	14.8	44.2	47.8	46.0
T_8	81.4	86.5	84.1	416.7	383.7	400.2	8.27	8.70	8.48	14.7	16.2	15.4	45.0	48.0	46.5
T_9	81.7	86.9	84.3	361.7	393.0	377.3	8.33	9.07	8.70	13.7	16.9	15.3	45.1	48.3	46.7
T_{10}	83.3	88.1	85.7	429.3	411.3	420.3	8.57	9.57	9.07	15.2	17.1	16.1	44.9	48.2	46.5
S.E.±	0.71	1.43	-	14.70	10.30	-	0.37	0.47	-	0.72	0.59	-	0.44	0.69	-
C.D. (P=0.05)	2.14	NS	-	44.08	NS	-	NS	1.41	-	NS	NS	-	NS	NS	-

T_1 – Wheat sole, T_2- Lentil sole, T_3- Wheat (line sowing) + Lentil (Broadcasted), T_4 – Wheat (broadcasted) + 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)
Ist year – 2012-13 and IInd year – 2013-14 NS= Non-significant

Gain and biological yields :

Maximum grain and biological yields of wheat were observed with T_3 (line sowing of wheat + broadcasting of lentil), which were significantly higher over rest of the treatments in both the years except wheat sole (T_1) and grain yield of wheat and lentil row ratio of 3:1 (T_{10}) in 2012-13, where differences were non-significant (Table 2). The increase in grain and biological yields was to the tune of 2.11, 6.65 and 4.45 per cent in grain and 1.15, 6.32 and 3.70 per cent in biological yield during 2012-13, 2013-14 and on mean data basis, respectively in comparison to wheat sole (T_1). Increase in wheat yields under T_3 treatment might be due to beneficial effect of legume component lentil through symbiotic effect, which improved the growth and yield attributes resulted higher yields of wheat crop. While significant reduction grain and biological yields under rest of the treatments was mainly because of reduction in number of fertile tillers per unit area compared with wheat sole or treatment T_3. As per finding of Subedi (1997), mixing of pea @ 30-45 kg was most profitable in terms of grain yield, land advantage, monetary advantage, economic returns and meeting the dietary requirements of the subsistence farmers.In case of intercrop yield, maximum grain and biological yields of lentil recorded under lentil sole (T_2) were significantly higher over all other treatments mainly provided very nominal yields. Lower lentil yields under inter-mixed cropping systems was mainly because of combined effect of proportionately decrease in area of lentil and dominance of wheat crop,

Table 2: Effect of mixed and intercropping of lentil on yield grain and biological yields of wheat

Treatments	Grain yield (t/ha)						Biological yield (t/ha)					
	Main crop			Intercrop			Main crop			Intercrop		
	Ist year	IInd year	Mean	Ist year	IInd year	Mean	Ist year	IInd year	Mean	Ist year	IInd year	Mean
T_1	5.69	5.56	5.62	-	-	-	14.73	13.92	14.32	-	-	-
T_2	-	-	-	1.38	0.93	1.16	-	-	-	5.45	4.97	5.21
T_3	5.81	5.93	5.87	0.05	0.02	0.04	14.90	14.80	14.80	0.34	0.13	0.23
T_4	5.00	5.06	5.03	0.09	0.07	0.08	12.73	13.21	12.97	0.65	0.32	0.49
T_5	5.21	5.38	5.29	0.04	0.07	0.05	14.02	13.71	13.86	0.25	0.28	0.27
T_6	4.49	5.03	4.76	0.05	0.06	0.05	12.89	13.07	12.98	0.17	0.27	0.22
T_7	5.07	4.77	4.92	0.15	0.14	0.14	13.10	11.31	12.20	0.76	0.64	0.70
T_8	5.29	5.00	5.14	0.08	0.09	0.08	14.00	11.77	12.88	0.51	0.43	0.47
T_9	4.43	4.35	4.39	0.24	0.21	0.23	11.37	10.34	10.85	1.61	1.09	1.35
T_{10}	5.52	5.29	5.40	0.08	0.05	0.07	13.74	12.81	13.27	0.34	0.39	0.37
S.E.±	0.13	0.015	-	0.04	0.024	-	0.25	0.34	-	0.12	0.083	-
C.D. (P=0.05)	0.40	0.44	-	0.12	0.071	-	0.74	1.03	-	0.37	0.25	

Table 3: Effect of mixed and intercropping of lentil on yield LER, WEY and economics of wheat + lentil inter/mixed cropping system

Treatments	Wheat equivalent yield (t/ha)			Land equivalent ratio			Economics			
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	Cost of cultivation (Rs. /ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T_1	5.69	5.56	5.62	1.00	1.00	1.00	32995	84300	51305	2.55
T_2	3.68	2.49	3.08	1.00	1.00	1.00	18522	46240	27718	2.50
T_3	5.94	5.99	5.96	1.06	1.09	1.07	33815	89490	55675	2.65
T_4	5.23	5.25	5.24	0.94	0.99	0.96	33415	78650	45235	2.35
T_5	5.31	5.56	5.43	0.94	1.04	0.99	34615	81470	46855	2.35
T_6	4.61	5.19	4.90	0.82	0.97	0.89	32615	73520	40905	2.25
T_7	5.46	5.13	5.29	1.00	1.00	1.00	31979	79400	47421	2.48
T_8	5.49	5.25	5.37	0.98	1.00	0.99	32324	80420	48096	2.49
T_9	5.07	4.91	4.99	0.95	1.01	0.98	31979	74890	42911	2.34
T_{10}	5.73	5.43	5.58	1.03	1.01	1.02	32497	81470	48973	2.51

which exerted higher competition on intercrop, resulted poor productivity of lentil. Among mixed cropping from 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), whereas, seed rate decreased to 50 per cent of both species recorded lowest yields due to poor germination and plant stand. In case of intercropping (T_7 to T_{10}), maximum grain yields (5.52 and 5.29 t/ha) of wheat were observed with wheat and lentil row ratio of 3:1 (T_{10}), which were at par with T_8 (2:1) but significantly higher over T_7 and T_9. This difference in yields might be due to greater reduction in area under main crop of wheat. Regarding lentil yields among mixed or intercropping systems {(other than lentil sole (T_2)}, significantly higher grain and biological yields were observed with T_9 (2:2 row ratio) except grain yield, where grain yields recorded at T_9 and T_7 were statistically at par in both the year.

Wheat equivalent yield:

Different treatment had different yield potential and economic values, and, therefore, for better comparison, the yields of wheat and of lentil were converted into wheat equivalent yield (WEY) on prevalent market price basis (Table 3). Based on two years data, it was noted that the highest wheat equivalent yield (5.94 and 5.99 t/ha) was obtained under the treatment T_3 followed by wheat sole (T_1), with minimum values recorded with lentil sole (3.68 and 2.49 t/ha) in both the years. The magnitude of increase in WEY under the treatment T_3 was 4.39, 7.73 and 6.05 per cent during 2012-13, 2013-14 and on mean data basis, respectively in comparison to treatment T_1 (wheat sole). Mixed cropping of lentil with wheat under T_3 treatment showed advantageous in terms of wheat-equivalent yield.Among mixed-inter cropping systems (except T_3), treatment T_{10}(3:1 row ratio) in first year and T_5 (mixed cropping of 100% seed rate of both crops) during second year recorded the second highest wheat equivalent yields.

Land equivalent ratio (LER):

LER is frequently used as index of biological advantage, which places the component crops on a relative and directly comparable basis (Willey, 1979). In particular, LER verifies the effectiveness of mixed cropping for using the resources of the environment compared to sole cropping (Mead and Willey, 1980 and Dhima *et al*., 2007). When LER is greater than 1, the mixed cropping favours the growth and yield of the species. In contrast, when LER is lower than 1, the mixed cropping negatively affects the growth and yield of plants grown in mixtures (Ofori and Stern, 1987; Caballero *et al.,* 1995 and Dhima *et al.*, 2007). In present study, highest land equivalent ratio (LER) was recorded under T_3 (1.06 and 1.09) followed by T_{10} (1.03) in first year and byT_5 (1.04) during second year. Rest of the inter-mixed cropping systems recorded LEY values almost 1 or lower than 1, which are not beneficial and recommendable for adoption. Akter *et al.* (2004) reported that higher yield of wheat and lentil was achieved when both crops were sown in lines than broadcast systems. Kumar *et al*. (2008) and Banik (1996) also recorded comparatively higher wheat equivalent yield under wheat + lentil than wheat sole.

Economics:

Based upon mean data over two years, the economic analysis (Table 3) showed that treatment T_3 {wheat (line sowing) + lentil (broadcasted)} gave highest net returns of Rs. 55675/ha and B:C ratio of 2.65 followed by wheat sole (Rs. 51305/ha and 2.55) with minimum values under sole lentil (Rs. 27718/ha and 2.50). This higher net benefit in wheat (line sowing) + lentil (broadcasted) was the result of higher total wheat yields along-with 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 yields compared with wheat sole. Akter *et al*. (2004) also reported the maximum LER (1.52), monetary advantage (63%), benefit cost ratio (1.84) under lentil + 40% wheat as mixed cropping system. Under intercropping system 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 'row replacement series' and reported that when actual sown proportion was considered wheat + lentil (1:1) resulted in maximum monetary advantage.

On basis of two year study, it is inferred that line sowing of wheat with recommended seed rate and broadcast sowing of lentil at half (30 kg/ha) of recommended seed rate holds promise to provide higher and economical wheat productivity with some bonus yield of lentil compared with wheat sole in vertisols of Central India.

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