



Performance of lentil (*Lens culinaris*) and toria (*Brassica campestris*) intercropping with wheat (*Triticum aestivum*) under rainfed conditions of north-west Himalaya

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ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2008–09 and 2009–10 at Hawalbagh to evaluate the performance of lentil (*Lens culinaris* Medikus) and toria (*Brassica campestris* L. var. *toria*) intercropping with wheat (*Triticum aestivum* L. emend. Fiori & Paol.). Wheat + lentil in 2:1 and 1:1 row ratios were superior to sole wheat and wheat + toria intercropping. Lentil yield was higher in 1:1 (0.45 tonne/ha) than in 2:1 (0.31 tonne/ha). Similarly, toria recorded higher yield in 1:1 (0.41 tonne/ha) than in 2:1 (0.30 tonne/ha) ratio. The highest wheat-equivalent yield (5.24 tonnes/ha), net returns (Rs 36 770/ha), benefit: cost ratio (1.81), monetary advantage index (Rs 7 207) and land-equivalent ratio (1.19) were obtained with wheat + lentil under 2:1 row ratio followed by 1:1 ratio. Negative values of aggressivity under intercrop indicated that wheat was dominant, and lentil and toria were the dominated crops. Competitive ratio and relative crowding coefficient of wheat was higher under intercropping of wheat with lentil under 1:1 and 2:1 ratios, respectively. Relative crowding coefficient of the system was highest for wheat + lentil under 2:1 ratio intercropping (5.90). Similarly, water use efficiency (27.6 kg/ha-mm) was highest with wheat + lentil under 2:1 ratio.

Key words: Intercropping, Land-equivalent ratio, Lentil, Toria, Wheat-equivalent yield

The productivity of rainfed winter crops in hills of North-West Himalayas is very low, mainly because of low and erratic rainfall, poor soil fertility and improper choice of crops, and also the cropping systems. In terms of land use, growing crops in mixed stands is regarded as more productive than growing them separately (Willey 1979). Increase in total production and stability of crop yield in rainfed situation can be achieved with crop substitution and intercropping (Singh and Rana 2006). Intercropping of oilseed and pulse crops is one of the ways to increase their production because intercropping is more advantageous than sole cropping of either oilseeds or pulses (Padhi and Panigrahi 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. Moreover, spatial arrangement and plant population in an intercropping have

important effects on the balance of competition between component crops and their productivity. Wheat followed by lentil and toria are the main choice of farmers of mid-hills of North-West Himalayas for winter (*rabi*) season under rainfed condition (Prakash *et al.* 2005). But the information on their compatibility as intercrops with wheat is still lacking, and hence the present investigation.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) seasons of 2008–09 and 2009–10 at the experimental farm, Hawalbagh (29°36' N, 79°40' S and 1 250 m altitude) of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora with a typical subtemperate climate. The total rainfall received during the crop season of 2008–09 and 2009–10 was 127 and 109 mm, respectively. Soil at the site was sandy loam, neutral in reaction (pH 6.8) and medium in organic C (0.6%), and low in available N (175 kg/ha) and medium in available P (17.3 kg/ha) and K (183 kg/ha). Cultivars VL Masoor 507 of lentil, VL Toria 3 and VL Gehun 804 of wheat were used in this experiment. The experiment was laid out in randomized block design with three replications. The treatments consisted of T₁, wheat sole; T₂, lentil sole; T₃, toria sole; T₄, wheat + lentil (1:1); T₅, wheat + toria (1:1); T₆, wheat + lentil (2:1) and T₇, wheat + toria (2:1) under intercropping with

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recommended seed rate of wheat (100 kg/ha), lentil (40 kg/ha) and *toria* (5 kg/ha). The crops were sown during the last week of November in both years. One-hand weeding was carried out at 45 days after sowing (DAS). The recommended dose of fertilizers for wheat 60, 13.2 and 8.3 kg NPK/ha was given to sole crop of wheat and inter-cropping systems, whereas 50, 13.2 and 8.3 kg NPK/ha for sole crop of *toria* and 20, 17.6 and 8.3 kg NPK/ha for sole crop of lentil were applied. All the fertilizers were applied at the time of field preparation. The crops of wheat, lentil and *toria* were sown at a row space of 24 cm in sole as well as in intercropping except for sole *toria* (30 cm). It was a replacement series intercropping. In 1:1 and 2:1 ratio, one row of wheat is replaced by either lentil or *toria* after one and two rows of wheat, respectively. Similarly, the plant population in the row was maintained by following the recommended seed rate of crops for all treatments. Wheat-equivalent yield was worked out on the basis of minimum support price of each crop in the respective years. For economic evaluation of the system, prevailing market price was used for different outputs and inputs. The prices of different produce per tonne used for calculation were: Rs 10 900 for wheat grains, Rs 1 600 for wheat straw, Rs 18 700 for lentil grains, Rs 17 350 for *toria* grains and Rs 2 750 for lentil/*toria* straw. The inputs costs used for calculation of net returns were: Rs 115/manday, Rs 11/kg N, Rs 23/kg P, Rs 8/kg K and Rs 6 000/ha for land preparation, whereas the prices of plant-protection chemicals and seed were based on actual market price. The intercropping indices, viz. competition ratio, relative crowding coefficient, land-equivalent yield, aggressivity and monetary advantage were worked out to evaluate the treatment effects reciprocity functions for intercropping. For treatment comparisons, F-test was used following the procedures of factorial randomized block design.

RESULTS AND DISCUSSION

Crop productivity

Significant variation in plant height of wheat was observed due to intercropping systems (Table 1). Plant height was highest under sole cropping of wheat, followed by intercropping with wheat + lentil and was significantly higher over wheat + *toria* under 1:1 intercropping. This might be due to better competitive ability of *toria* than of lentil with wheat. Significant reduction in effective tillers/m² was observed under both wheat + lentil and wheat + *toria* 1:1 intercropping in comparison with sole cropping of wheat. In the intercropping system, reduction was higher under wheat + *toria* intercropping in comparison with that under wheat + lentil over sole wheat irrespective of 1:1 or 2:1 row ratio. This could be because of crop competition under wheat + *toria* intercropping under both the row ratio (1:1 and 2:1). Reduction was 29.4 and 15.3% under 1:1 and 2:1 intercropping, respectively with *toria* over sole wheat. Similarly, the reduction was 17.2 and 7.8% due to 1:1 and 2:1 intercropping, respectively with lentil compared to sole wheat. No significant variation in grain weight/ear and 1 000-grain weight was observed either due to 1:1 or 2:1 intercropping. Data of grain weight/ear showed 16.6% reduction under wheat + *toria* (1:1) intercropping than sole cropping of wheat. The reduction in 1 000-grain weight was higher under wheat + *toria* with 1:1 intercropping than wheat + *toria* (2:1) and wheat + lentil (1:1 and 2:1). In wheat + lentil intercropping, higher values of yield attributes of wheat were obtained under wheat + lentil (2:1) than those under wheat + lentil (1:1). Similarly, in wheat + *toria* intercropping, higher values of yield attributes were obtained with 2:1 ratio than 1:1 ratio. The reduction was more in *toria* intercropping because of higher competition among *toria* and wheat for resources,

Table 1 Effect of intercropping on growth, yield attributes and yield of wheat and system productivity (pooled mean of 2 years)

Treatment	Plant height (cm)	Effective tillers/m ²	Grain weight/ear (g)	1000 grain weight (g)	Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Harvest index (%)		WEY (tonnes/ha)
					Wheat	Lentil/ <i>Toria</i>	Wheat	Lentil/ <i>Toria</i>	Wheat	Lentil/ <i>Toria</i>	
Wheat sole	97.2	385	1.92	38.6	3.2		9.85		32.5		4.65
Lentil sole						1.14		3.80		30	2.91
<i>Toria</i> sole						1.22		4.40		27.7	3.05
Wheat + lentil (1:1)	95.4	265	1.85	36.8	2.65	0.4	8.52	1.28	31.1	31.3	4.91
Wheat + <i>toria</i> (1:1)	84.0	225	1.60	33.4	2.26	0.41	7.46	1.72	30.3	23.8	4.44
Wheat + lentil (2:1)	93.0	340	1.80	38.5	2.95	0.31	9.77	1.28	30.2	24.2	5.24
Wheat + <i>toria</i> (2:1)	88.5	313	1.65	38.0	2.71	0.3	9.12	1.49	29.7	20.2	4.90
S _{Em} ±	4.2	25	0.14	2.1	0.21	0.05	0.38	0.18	0.8	0.7	0.25
CD (P=0.05)	12.6	74	NS	NS	0.61	0.15	1.1	0.54	2.4	2.1	0.75

WEY, Wheat equivalent yield

viz. light, space and nutrients, in comparison with wheat + lentil intercropping as earlier reported by Srivastava *et al.* (2007). Wheat yield was higher under sole cropping, followed by intercropping, and lowest under wheat + toria 1:1 intercropping. The trends in straw yield of wheat, lentil and toria were similar to their respective grain yields.

Banik *et al.* (2000) also reported similar findings. Harvest index of wheat was higher under sole cropping, followed by intercropping with lentil and toria, and significantly higher than wheat + toria 2:1 intercropping system (Table 1) with a mean reduction of 8.6 per cent. Similarly, reduction in harvest index of toria was also observed under intercropping in comparison with their sole cropping. Reduction in harvest index of lentil and toria was higher under 2:1 intercropping than under 1:1 intercropping. Intercropping of lentil and toria with wheat had significant advantage in terms of wheat-equivalent yield over sole crop except wheat + toria 2:1 ratio intercropping (Table 1). The highest WEY was obtained under wheat + lentil 2:1 ratio intercropping (5.24 tonnes/ha), followed by wheat + lentil 1:1 intercropping (4.91 tonnes/ha) and lowest under sole cropping of lentil (2.91 tonnes/ha). Similarly, in wheat + toria intercropping, higher WEY was obtained in wheat + toria 2:1 ratio than 1:1 ratio. These results showed that lentil and toria were more compatible under 2:1 intercropping system with wheat with comparison to 1:1.

Economics

Intercropping had higher economic advantage over sole

Table 2 Economics of wheat, lentil and toria intercropping system (pooled data of two years)

Treatment	Cost of production ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	B : C ratio
Wheat sole	19.32	31.31	1.62
Lentil sole	17.81	13.96	0.78
Toria sole	15.90	17.38	1.09
Wheat + lentil (1:1)	19.53	33.98	1.74
Wheat + toria (1:1)	19.40	29.02	1.50
Wheat + lentil (2:1)	20.33	36.77	1.81
Wheat + toria (2:1)	20.15	33.28	1.65
SEm \pm		1.52	0.09
CD ($P=0.05$)		4.56	0.26

Table 3 Effect of different cropping systems on competitive ratio (CR), relative crowding coefficient (RCC), aggressivity (A), land-equivalent ratio (LER) and monetary advantage index (MAI) (mean of two years)

Treatment	CR		RCC		System	A		LER	MAI ($\times 10^3$ ₹/ha)
	Wheat	Intercrop	Wheat	Intercrop		Wheat	Intercrop		
Wheat + lentil (1:1)	2.36	0.42	4.82	0.54	2.60	0.19	-0.19	1.18	6.63
Wheat + toria (1:1)	2.10	0.48	2.40	0.51	1.22	0.05	-0.05	1.04	1.29
Wheat + lentil (2:1)	1.70	0.59	5.90	0.75	4.41	0.57	-0.57	1.19	7.21
Wheat + toria (2:1)	1.72	0.58	2.77	0.65	1.80	0.53	-0.53	1.09	2.95

cropping (Table 2). Wheat + lentil under 2:1 intercropping recorded higher net returns and benefit:cost (B:C) ratio. Similarly, wheat + toria 2:1 intercropping indicated 14.7% higher net returns with comparison to wheat + toria 1:1 intercropping. The highest net returns (Rs 36 770) and B:C ratio (1.81) were observed with wheat + lentil 2:1 intercropping followed by wheat + lentil 1:1 intercropping indicating superiority of lentil as intercrop as observed by Srivastava *et al.* (2007). Monetary advantage index was higher under 2:1 inter-cropping systems than under 1:1 intercropping irrespective of lentil or toria (Table 3). Among intercroppings, wheat + lentil 2:1 had higher monetary advantage index (7 207), followed by wheat + lentil 1:1 (6 627) and lowest was with wheat + toria 1:1 intercropping (1 288).

Competition functions

Competitive ratio (CR) of wheat and intercrops were higher in 1:1 ratio than in 2:1 intercropping (Table 3). Relative crowding coefficient (RCC) and aggressivity (A) values indicated wheat as dominant species in intercropping situation. Relative crowding coefficient (RCC) of the system was greater than one, in all the treatments indicating yield advantage compared with their monocultures due to mutual cooperation. The RCC of wheat, intercrop and system were higher under wheat + lentil intercropping system than under wheat + toria inter-cropping system irrespective of 2:1 or 1:1 inter-cropping ratio. Higher values of RCC of the system were obtained in wheat + lentil 2:1 followed by wheat + lentil 1:1. Aggressivity values in intercroppings were greater than zero, indicating yield advantage over sole cropping. Further, aggressivity data also revealed dominance of wheat crop.

Wheat with lentil proved superior to wheat with toria intercropping in terms of land-equivalent ratio (LER). Highest LER was obtained with wheat + lentil 2:1 intercropping (1.19), followed by wheat + lentil 1:1 intercropping (1.18) and lowest values was recorded in wheat + toria 1:1 intercropping (1.04).

Nutrient balance

It was observed that raising of wheat + lentil (1:1) had enhanced the available soil N (192.6 kg/ha) status, however it was found non-significant compared to other sole wheat/lentil/toria or different intercropping pattern of these crops

Table 4 Soil nutrient status and moisture-use indices as influenced by sole and intercropping systems (average data of two years)

Treatment	Available nutrients after harvest of crops (kg/ha)			Actual gain/loss over initial status (kg/ha)			Con- sumptive efficiency use (mm)	Water-use (kg/ ha-mm)	Rate of moisture use (mm/day)	Moisture extraction pattern (%)		
	N	P	K	N	P	K				0-15 cm	15-30 cm	30-45 cm
	Wheat sole	184.3	17.6	174.8	9.3	0.3				-8.2	220.0	27.1
Lentil sole	191.6	17.6	178.9	16.6	0.3	-4.1	185.0	9.7	1.2	52.8	28.3	18.9
Toria sole	182.4	17.4	172.6	7.4	0.1	-10.4	208.3	10.3	1.7	58.2	31.5	10.3
Wheat + lentil (1:1)	192.6	17.8	168.8	17.6	0.5	-14.2	242.4	25.8	1.4	58.8	29.3	11.9
Wheat + toria (1:1)	188.4	18.0	164.5	13.4	0.7	-18.5	253.5	22.6	1.4	53.2	30.2	16.6
Wheat + lentil (2:1)	189.9	18.2	166.3	14.9	0.9	-16.7	240.5	27.6	1.4	58.0	27.4	14.6
Wheat + toria (2:1)	186.2	18.1	170.0	11.2	0.8	-13.0	238.4	25.5	1.3	56.5	31.1	12.4
SEm±	6.5	0.6	5.9									
CD (P=0.05)	NS	1.8	NS									

(Table 4). Similarly, the highest gain of available soil N (17.6 kg/ha) over initial status was observed under the same intercropping system. This unaccountable N might have come through symbiotic nitrogen-fixation. The available soil P status (18.2 kg/ha) under the plots of wheat + lentil (2:1) was found to be significantly higher than all other treatments. The increased level available soil P may be due to more root proliferation of wheat and lentil crop under 2:1 intercropping system. There might be some release of P in the labile pool of soil due to intercropping. The available soil K after harvest of crops was found to be similar to each other treatments. However, a negative K balance was calculated over initial status under all treatments which indicates K mining.

Water-use efficiency

Water-use efficiency (WUE) in terms of yield of individual crops showed marked variation due to intercropping system (Table 4). Intercropping of wheat + lentil/toria recorded higher WUE than sole lentil and toria. This might be attributed to proportionately higher grain yield of both the crops than amount of water used for individual crop yield. Wheat intercropped with lentil and toria utilized more water for evapotranspiration and metabolic activities. Maximum WUE was recorded with wheat + lentil under 2:1 (27.6 kg/ha-mm) and wheat + lentil under 1:1 row ratio (25.8 kg/ha-mm). This could be due to higher productivity in terms of wheat-equivalent yield under these row proportions. Similarly, consumptive use of water was also recorded higher under intercropping systems than in lentil/wheat/toria sole. The rate of moisture use was higher in sole toria and similar to one another under all intercropping systems. It could be attributed to the fact that toria took less days to mature than wheat/lentil. In general, the crops extracted greater amount of soil moisture from the top 0-15 cm soil layer than from 15-30 and 30-45 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 wheat sole, lentil sole and wheat + toria (1:1) intercropping system 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.* 2011).

Thus, intercropping of wheat with lentil 2:1 is more advantageous than with toria and sole cropping.

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