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Evaluation of *toria* (*Brassica campestris*) and lentil (*Lens culinaris*) varieties in intercropping system with wheat (*Triticum aestivum*) under rainfed conditions

NARENDRA KUMAR*, VED PRAKASH, B.L. MINA, K.A. GOPINATH AND A.K. SRIVASTVA

Division of Natural Resource Management, Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand 263 601

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2003-04 and 2004-05 at Almora to evaluate the varietal performance of lentil (*Lens culinaris* Medikus) and *toria* (*Brassica campestris* L. var. black *toria*) with wheat (*Triticum aestivum* L. emend. Fiori & Paol.) intercropping system. Intercropping of wheat + lentil and wheat + *toria* showed an added advantage over sole and mixed cropping. In intercropping systems, lentil yield was higher with 'VL Masoor 4' (0.35 t/ha) than with 'VL Masoor 120'. Similarly, 'VL Toria 2' gave higher yield (0.35 t/ha) than 'VL Toria 1'. The highest wheat-equivalent yield (5.87 t/ha), net return (Rs 19,651/ha), benefit : cost ratio (2.1), monetary advantage (5,172) and land-equivalent ratio (1.26) were obtained under wheat + lentil ('VL Masoor 4') intercropping, followed by wheat + *toria* 'VL Toria 2'. Negative values of aggressivity under intercrop showed that wheat was dominant, and lentil and *toria* were the dominated crops in the systems. Competitive ratio and relative crowding coefficient of wheat was higher under intercropping of wheat with lentil 'VL Masoor 120' and *toria* 'VL Toria 1'. Relative crowding coefficient of the system was highest for wheat + lentil ('VL Masoor 4') (5.72), followed by wheat + *toria* ('VL Toria 2') (4.77). Thus lentil 'VL Masoor 4' and *toria* 'VL Toria 2' were found suitable under intercropping system with wheat in comparison with other varieties.

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 their varieties, and also the cropping system. Intercropping is the oldest technique of growing crops, which provides an insurance against aberrant weather and helps in the maximization of productivity and profitability by efficient utilization of resources. Intercropping, which involves component crops of different growth pattern for extended use of resources, is a viable option for rainfed condition. Generally short-duration pulses and oilseeds are selected as one of the component crops in cereal-based intercropping systems because of their ability to adapt well under such situations. 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). 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. They grow these crops mainly in mixed cropping system in improper way, which is one of the reason for low productivity of these crops in the region. Competitive ability of intercrops varies with the genotypes. The variety that performs better under sole cropping may not perform the same way under intercropping system (Srivastava *et al.,* 2007). Two improved varieties of lentil and *toria* are available for cultivation under hill condition. But the information on their compatibility as intercrops with wheat is still lacking. Hence the present investigation was aimed to study the compatibility of different varieties of lentil and *toria* with wheat under intercropping system.

***Corresponding author** (Email: naren1_agro@yahoo.co.in)

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) season of 2003-04 and 2004-05 at the experimental farm, Hawalbagh (29º36' N, 79º40' S and 1250 m altitude) of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. The area has a typical subtropical climate, with severe cold winter, hot and dry summer and rainy season. Long-term average annual rainfall in the area is 1,020 mm. The total rainfall received during the crop season of 2003-04 and 2004-05 was 197 and 367 mm, respectively. During 2003-04 long dry spell was observed. Some rainfall

was received in January, whereas during 2004-05 well distributed rainfall was received.

Soil at the site was sandy clay-loam, slightly acidic in reaction (pH 6.4) and medium in organic C (0.6%), and low in available N (168 kg/ha) and medium in available P (18.4 kg/ha) and K (179 kg/ha). Promising varieties 'VL Masoor 4' and 'VL Masoor 120' of lentil and 'VL Toria 1' and 'VL Toria 2' of *toria* were evaluated with wheat 'VL Gehun 804'. The experiment was laid out in randomized block design with three replications. The treatments consisted of T_1, wheat sole 'VL Gehun 804 ; T_2, lentil sole 'VL Masoor 4'; T_3, 'lentil sole 'VL Masoor 120'; T_4, *toria* sole 'VL Toria 1'; T_5, *toria* sole 'VL Toria 2'; T_6, wheat + lentil 'VL Masoor 4'; T_7, wheat + lentil 'VL Masoor 120'; T_8, wheat + *toria* 'VL Toria 1'; T_9, wheat + *toria* 'VL Toria 2'; T_{10}, wheat + lentil 'VL Masoor 4' in mixed cropping ; and T_{11}, wheat + *toria* 'VL Toria 1' in mixed cropping. In the intercropping system 2:1 row ratio of wheat and lentil or *toria* was used, whereas in mixed cropping two-third of recommended seed rate of wheat (100 kg/ha) and one-third of lentil (40 kg/ha) or *toria* (5 kg/ha) was mixed together and broadcast over prepared land followed by planking. The crops were sown during the last week of October. 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, intercropping and mixed 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 were harvested at maturity. Wheat-equivalent yield was worked out on the basis of existing market 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 6,400 for wheat grains, Rs 1,500 for wheat straw, Rs 15,250 for lentil grains, Rs 2,500 for lentil straw and Rs 16,650 for *toria* grains. The inputs costs used for calculation of net returns were: Rs 100/manday, Rs 11/kg N, Rs 23/kg P, Rs 8/kg K and Rs 5,000/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 inter- and mixed-cropping 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* 'VL Toria 1'. This might be due to better competitive ability of *toria* than of lentil with wheat. Significant reduction in effective tillers/m^2 was observed due to mixed cropping 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. Higher reduction under mixed cropping was mainly due to poor germination, whereas under wheat + *toria* intercropping because of crop competition. Reduction was 37 and

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 (t/ha)		Straw yield (t/ha)		Harvest index (%)		WEY (t/ha)
					Wheat	Lentil/ *toria*	Wheat	Lentil/ *toria*	Wheat	Lentil/ *toria*	
Wheat sole	98.5	397	1.77	40.5	3.33		6.58		33.6		4.88
Lentil sole ('VL *Masoor* 4')						1.04		2.24		31.6	3.34
Lentil sole ('VL *Masoor* 120')						1.12		2.64		29.9	3.70
Toria sole ('VL *Toria* 1')						1.18		3.21		26.9	3.04
Toria sole ('VL *Toria* 2')						1.10		3.35		25.0	2.87
Wheat + lentil ('VL *Masoor* 4')	95.0	348	1.85	40.3	3.06	0.35	6.94	0.92	30.7	27.6	5.87
Wheat + lentil ('VL *Masoor* 120')	96.6	340	1.85	38.8	3.08	0.23	7.14	0.57	30.1	28.7	5.52
Wheat + *toria* ('VL *Toria* 1')	85.2	312	1.63	35.4	3.04	0.32	6.77	0.95	31.0	25.1	5.45
Wheat + *toria* ('VL *Toria* 2')	88.4	320	1.58	37.2	3.04	0.35	6.95	1.27	30.4	21.6	5.56
Wheat + lentil ('VL *Masoor* 4')*	89.8	252	1.93	40.7	2.92	0.18	7.29	0.52	28.3	25.5	5.27
Wheat + *toria* ('VL *Toria* 1')*	91.7	240	1.84	39.6	2.83	0.19	6.83	0.70	29.1	20.6	4.90
SEm±	3.7	27	0.11	2.3	0.19	0.05	0.34	0.17	0.9	0.8	0.23
CD (P=0.05)	11.5	82	0.34	NS	NS	0.16	NS	0.49	2.9	2.4	0.67

* Mixed cropping

20% due to mixed cropping and intercropping, respectively with *toria* over sole wheat. No significant variation in ear length, and grains/ear was observed either due to inter-or mixed cropping, whereas grain weight/ear showed significant variation. Data of grain weight/ear showed 9.3% reduction under *toria* intercropping than sole cropping of wheat. The reduction in 1,000-grain weight was higher under wheat + *toria* intercropping than under wheat + lentil. In wheat + lentil intercropping, higher values of yield attributes were obtained in 'VL Masoor 4' than in 'VL Masoor 120'. Similarly, in wheat + *toria* intercropping, higher values of yield attributes were obtained with 'VL Toria 2' than with 'VL Toria 1'. The reduction was more in *toria* intercropping because of higher competition among *toria* and wheat for resources, viz. light, space and nutrients, in comparison with wheat + lentil intercropping (Srivastava and Bohra, 2006).

During the first year of study wheat yield was less than during the second year owing to poor rainfall. However, lentil and *toria* had good growth and yield in both the years. Wheat yield was higher under sole cropping, followed by intercropping, and lowest under mixed cropping. In the sole crops, 'VL Masoor 120' and 'VL Toria 1' performed better than 'VL Masoor 4' and 'VL Toria 2' respectively. In contrast, under intercropping systems 'VL Massor 4' and 'VL Toria 2' gave higher grain and straw yields than 'VL Masoor 120' and 'VL Toria 1'. 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 mixed cropping systems (Table 1). Mean reduction of 14.6 and 9% was obtained in harvest index of wheat under mixed and intercropping, respectively in comparison with sole wheat. Similarly, reduction in harvest index of lentil and *toria* was observed under mixed and intercropping in comparison with their sole cropping. Reduction in harvest index of wheat, lentil and *toria* was higher under mixed cropping than under intercropping. The reduction in harvest index under mixed and intercropping might be due to competition between wheat and intercrops.

Intercropping of lentil and *toria* with wheat showed significant advantage in terms of wheat-equivalent yield over sole and mixed cropping of wheat, lentil and *toria* (Table 1). The highest WEY was obtained under wheat + lentil 'VL Masoor 4' intercropping (5.87 t/ha), followed by wheat + *toria* 'VL Toria 2' intercropping (5.56 t/ha) and lowest under sole cropping of 'VL Toria 2' (2.87 t/ha). In wheat + lentil intercropping, higher WEY was obtained under wheat + 'VL Masoor 4'. However, higher WEY was obtained in wheat + 'VL Toria 2'. These results showed that 'VL Masoor 4' and 'VL Toria 2' were more compatible under intercropping system with wheat in comparison with 'VL Masoor 120' and 'VL Toria 1' respectively. Banik (1996) also reported higher value of wheat-equivalent yield under wheat + lentil.

Economics

Intercropping had higher economic advantage over sole and mixed cropping (Table 2). However, in lentil intercropping system, wheat + 'VL Masoor 4' intercropping gave higher net return and benefit:cost (B:C) ratio. In case of net return, intercropping of wheat + 'VL Masoor 4' had advantage of 12.9% over wheat + 'VL Masoor 120' intercropping. Similarly, intercropping of wheat + 'VL Toria 2' showed advantage of 4% in net return in comparison with wheat + 'VL Toria 1'. Similarly, B: C ratio was higher in wheat + lentil 'VL Masoor 4' and wheat + *toria* 'VL Toria 2' in comparison with wheat + lentil 'VL Masoor 120' and wheat + *toria* 'VL Toria 1' respectively. These results also indicate that 'VL Masoor 4' and 'VL Toria 2' were more suitable for intercropping. Srivastava and Bohra (2006) also reported higher net returns and B : C ratio under intercropping than under sole cropping.

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

Treatment	Cost of production (x 10^3 Rs/ha)	Net returns (x 10^3 Rs/ha)	B : C ratio
T_1	17.41	13.80	1.79
T_2	15.05	6.35	1.42
T_3	15.05	8.62	1.57
T_4	13.80	5.66	1.41
T_5	13.80	4.55	1.33
T_6	17.94	19.65	2.10
T_7	17.94	17.41	1.97
T_8	17.58	17.28	1.99
T_9	17.58	17.99	2.03
T_{10}	16.98	16.76	1.99
T_{11}	16.58	14.81	1.89
SEm±		1.72	0.09
CD (P=0.05)		4.91	0.26

Treatment details are given in Materials and Methods.

Monetary advantage (Table 3) was higher under intercropping systems than under mixed cropping. In intercropping, wheat + lentil 'VL Masoor 4' gave higher value of monetary advantage (5,172), followed by wheat + *toria* 'VL Toria 2' (4,608) and lowest in mixed cropping of wheat + *toria* (658). This might be due to cumulative effect of yield and higher prices of lentil and *toria*. In terms

Table 3. Effect of different cropping systems on competitive ratio (CR), relative crowding coefficient (RCC), aggressivity (A) and land-equivalent ratio (LER) (mean of 2 years)

Treatment	CR		RCC			A		LER	Monetary advantage (x 10^3 Rs/ha)
	Wheat	Intercrop	Wheat (Kw)	Intercrop (Ki)	System (K=Kw x Ki)	Wheat	Intercrop		
Wheat + lentil ('VL *Masoor* 4')	1.37	0.73	5.52	1.04	5.72	0.35	-0.35	1.26	5.17
Wheat + lentil ('VL *Masoor* 120')	2.26	0.45	5.92	0.52	3.08	0.76	-0.75	1.13	2.64
Wheat + *toria* ('VL *Toria* 1')	1.68	0.60	6.09	0.74	4.51	0.54	-0.54	1.18	3.80
Wheat + *toria* ('VL *Toria* 2')	1.44	0.69	5.10	0.94	4.77	0.71	-0.71	1.22	4.61
Wheat + lentil ('VL *Masoor* 4')*	2.48	0.41	3.48	0.43	1.50	0.79	-0.79	1.10	2.02
Wheat + *toria* ('VL *Toria* 1')*	2.71	0.39	2.78	0.40	1.11	0.78	-0.78	1.02	0.66

*Mixed cropping

of monetary advantage, 'VL Masoor 4' and 'VL Toria 2' were more suitable for intercropping than 'VL Masoor 120' and 'VL Toria 1'.

Competition functions

Competitive ratio (CR) of wheat was higher in mixed cropping than in intercropping, whereas that of intercrop was higher under intercropping than under mixed cropping (Table 3). In the intercropping systems, wheat + lentil 'VL Masoor 120' and wheat + *toria* 'VL Toria 1' gave higher values of CR than wheat + lentil 'VL Masoor 4' and wheat + *toria* 'VL Toria 2' respectively. In contrast, intercrops showed higher values of CR under wheat + lentil 'VL Masoor 120' and wheat + *toria* 'VL Toria 1'. It showed that wheat + lentil 'VL Masoor 4' and wheat +*toria* 'VL Toria 2' intercropping are more suitable than others. 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 intercropping systems than under mixed cropping. This showed the advantage of intercropping over mixed cropping. The higher values of RCC of the system were obtained in wheat + lentil 'VL Masoor 4' and wheat + *toria* 'VL Toria 2' than in wheat + lentil ' VL Masoor 120' and wheat + *toria* 'VL Toria 1'. Aggressivity values of intercropping and mixed cropping were greater than zero, indicating yield advantage over sole cropping. Aggressivity data revealed that in intercropping systems wheat was dominant crop, and lentil and *toria* were the dominated crops.

Intercropping of wheat with lentil and *toria* proved superior to mixed and sole cropping in terms of land-equivalent ratio (LER). Highest LER was obtained with wheat + lentil 'VL Masoor 4' intercropping (1.26), followed by wheat + *toria* 'VL Toria 2' (1.22) and lowest values was recorded in mixed cropping of wheat + *toria* (1.02). The LER values were also higher under intercropping of wheat with lentil 'VL Masoor 4' and *toria* 'VL Toria 2' in comparison with lentil 'VL Masoor 120' and *toria* 'VL Toria 1'. All the intercropping indices showed that lentil 'VL Masoor 4' and *toria* 'VL Toria 2' were the suitable varieties for intercropping with wheat.

Thus it was concluded that intercropping of wheat with lentil and *toria* is more advantageous than mixed and sole cropping. Also, lentil 'VL Masoor 4' and *toria* 'VL Toria 2' are more compatible for intercropping with wheat than 'VL Masoor 120' and 'VL Toria 1' respectively.

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