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Compatibility, Growth and Production Potentials of Mustard/Lentil Intercrops

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Abstract: An experiment was conducted to analyse the interspecies compatibility and production potentials of mustard and lentil in intercrop association. The experiment comprised four planting systems viz., sole mustard, sole lentil, single row (1:1 i.e., one row of mustard followed by one row of lentil) and double row (1:2 i.e., one row of mustard followed by two rows of lentil) intercropping. The stands height and number of branches (primary and secondary) per plant were maximum and minimum in sole and single row intercropped plants, respectively. Higher leaf area index and total dry matter production was observed in sole cropped mustard or lentil while those were lower in 1:2 intercropped mustard or 1:1 intercropped lentil plants. Maximum seed yield, 1.26 t ha^{-1} (or 1.30 t ha^{-1}) was harvested from sole crop of mustard (or lentil) which was about 40 and 48% (or 34 and 12%) higher than that of the mustard (or lentil) yield obtained from single and double row intercrop mixtures, respectively. Combined seed yield from double row mixture was the maximum (1.8 t ha^{-1}) and was respectively 11, 30 or 28% higher than that obtained from single row intercropped stands, sole mustard or lentil. Single and double row intercropping systems respectively resulted 25 or 41% increase in land equivalent ratios. Area time equivalency ratio was also increased by about 14 and 31%, respectively for single and double row intercropping systems. The competitive ratio of each population is approached to be unity in both intercropping systems reflecting the proper balance of the natural resources between associated species resulted better yield. The results suggest that mustard and lentil populations are well compatible in intercrop association and 1:2 row ratio mixture would be better for their profitable production.

Key words: Competitive ratio, intercropping, land equivalent ratio, lentil, mustard

INTRODUCTION

Intercrop association simply intercropping can be defined as the production or growing of two or more crops simultaneously in the same piece of land (Ofori and Stern, 1987). It is a simple but inexpensive strategy and has been recognized as a potentially benefited technology for increase crop production (Awal *et al*., 2006). It is an age-old practice of crop production in Bangladesh, India, China, Taiwan, Sri Lanka, Malaysia, Hong Kong, Vietnam, Africa and Latin America. It can ensure substantial yield advantages as compared to sole cropping (Rao and Singh, 1990).

Crop compatibility is the most essential factor for a feasible intercropping system. Thus, the success of any intercropping system depends on the proper selection of crop species where competition between them for light, space, moisture and nutrients is minimum (Fukai and Trenbath, 1993). Competition in an intercrop mixture can be reduced considerably through judicious selection of crops and also by changing plant population with spatial orientation of either of the crops. A careful selection of crops could reduce competition to a considerable extent (Ofori and Stern, 1986). On the other hand, selection of proper crop species in an intercropping could enhance the scope of increasing in overall production per unit of land and time (Midmore, 1993). As all the crops do not grow well as mixed crops, a careful study is necessary to find out the suitability of different crops to be grown as intercrops.

Mustard (*Brassica napus* L.) belonging to the family Cruciferae whereas the lentil (*Lens esculenta* M.) to the Legominosae, both are important crops; the former is a valuable oil seed crop while the latter is a high protein human and livestock feed. The combination of a non-leguminous species with a leguminous one might be expected to generate yield advantages over sole cropping (Trenbath, 1974), since their canopy architectures are different: mustard grows with tall whereas lentil with short stature canopies. Research reports on the compatibility as intercrops between mustard and lentil are quite scanty although these crops are extensively

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cultivated throughout the world. Therefore, the present study was undertaken to assess the compatibility of mustard and lentil plants in intercrop association and to evaluate spatial intercropping systems for their profitable production.

MATERIALS AND METHODS

Experiment site: The experiment was conducted at the Filed Laboratory of the Crop Botany Department, Bangladesh Agricultural University, Mymensingh (24°25"N latitude and 90°50"E longitude, 18 masl), Bangladesh during the winter cropping season from November 2007 to March 2008. Recommended fertilizer doses of N, P_2O_5, K_2O, S and B were applied in the plots corresponding to 106, 67, 30, 36 and 1.1 kg ha^{-1}, respectively. At the time of final land preparation, 50% of the total N and entire doses of the other fertilizers were applied. The remaining 50% of the N were top dressed before flowering of mustard plants. A crop of tall stature, mustard (var. BINA Sorisha-3) was chosen as dominant/principal crop and that of a short stature crop, lentil (var. BINA Masur-3) was chosen as subordinate/companion crop to reduce spatial competition in the intercropping system. The seeds of mustard and lentil were sown by hand on 26 November 2007 in rows oriented east to west (E–W) direction as per treatments. Weeding, thinning, plant protection measures and other cultural practices were performed to optimise growth and development of the crops.

Experimental treatments and design: The experiment comprised four treatments viz., sole cropping of mustard and lentil and two spatial intercropping systems namely single (1:1) and double row (1:2) intercropping. Line to line distance was 25 cm for each sole (mustard or lentil) cropping. In 1:1 intercropping, mustard or lentil lines were raised alternatively keeping 25 cm spacing between two lines for each. So, the distance between two consecutive lines of mustard or lentil became 25 cm i.e., both partners had an equal population pressure. In 1:2 intercropping, two lentil lines were grown in between two mustard lines of 40 cm distance and so, the distance between two lentil lines became 13.33 cm. Plant to plant distance in a line either for mustard or lentil was 10 cm. Unit plot size for each treatment was 5×4 m. The treatments were laid-out in a randomized complete block design with four replicates.

Sampling for growth analysis and data collection: The samplings for growth analysis were started from 35 DAS following destructive harvesting method and continued at 10 days intervals till maturity of mustard on 85 DAS or lentil on 105 DAS. At each harvest date, ten plants were extracted carefully keeping maximum roots with them from each sole (mustard or lentil) or intercropped (5 mustard and 5 lentil plants) plots. The harvested plants were separated into roots, stems, leaves and harvestable sinks (i.e., siliqua or pod). The plant parts were oven dried at 80°C until constant weight and their corresponding dry weights were recorded separately. The data were recorded on plant height, number of primary branches (branches originated from the main stem) and secondary branches (branches originated from primary branches) per plant and yield. The plant height was recorded with a graduated meter scale placed vertically from the ground level to the top of the shoot of mustard or lentil plants. A representative sample of leaves from each harvested plot was taken and their leaf area was measured with an Electronic Area Meter (LI 3000, USA). Then the total leaf area of the plants from a replication was calculated as (LA/LDW)×total leaf dry weight, where, LA and LDW are the area and dry weight of representative leaf sample, respectively. The Leaf Area Index (LAI) was then calculated as the (leaf area/ground area) m^2 m^{-2} basis.

Computation of production potential parameters: The following parameters were computed from the data obtained at physiological maturity of crops:

- **Harvest Index (HI):** The HI was calculated following (Donald and Hamblin, 1976):

$$HI = (\text{Economic yield}/\text{Biological yield})\times 100 \quad (1)$$

where, economic and biological yields respectively represent the seed yield and total dry weight.

- **Land Equivalent Ratio (LER):** The LER was calculated following (Ofori and Stern, 1987; Keating and Carberry, 1993):

$$LER = L_i+L_j = (Y_{ij}/Y_{ii})+(Y_{ji}/Y_{jj}) \quad (2)$$

where, Y is the yield per unit area, Y_{ii} and Y_{jj} are sole crop yields of the component crops i and j and Y_{ij} and Y_{ji} are intercrop yields. The partial LER values, L_i and L_j, represent the ratios of the yields of crops i and j when grown as intercrops, relative to sole crops.

- **Area Time Equivalency Ratio (ATER):** The ATER was calculated as (Ofori and Stern, 1987):

$$ATER = (L_i t_i+L_j t_j)/T \quad (3)$$

where, t_i and t_j are the durations (days) for crops i and j and T is the duration (days) of the whole intercrop system.

- **Competitive Ratio (CR):** The CR was calculated as (Dhima *et al*., 2007):

$$CR = \{(Y_{ij}/Y_{ii})\times(Y_{ji}/Y_{jj})^{-1}\}(S_i/S_j) \quad (4)$$

where, S_i is the relative space occupied by species i and that of S_j by species j in the intercrop mixture.

The collected data on various parameters were compiled and statistically analysed and the mean differences were adjudged by LSD and Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Stand height: The height of mustard stands increased rapidly and that of lentil being slowly with time (Fig. 1) and those varied significantly under different cropping systems. Height of mustard plant population was about three-folds higher than that of lentil resulting distinctly two vertical tiers of canopy in the intercropping systems. Stands of mustard or lentil were found tallest in sole cropped plots but those were shorter in single row (1:1) intercropped plots than the double row (1:2) intercropping system. This variation in plant height under different cropping systems might be attributed for the availability of natural resources like nutrient, moisture, light, space etc. Generally, sole cropped plants grown with less competition for those resources than that of the plants grown under single or double row intercropping (Jolliffe, 1988) which favoured crop growth to establish tall stature plant under sole cropping. Awal *et al.* (2007) reported taller stands in sole crop of barley or peanut as compared to the plants grown with intercropping which commensurate the present results.

Production of primary and secondary branches per plant: The number of branch production in mustard or lentil crops slowly increased with season (Table 1). Mustard or lentil stands with sole cropping produced the maximum number of primary branches followed by the plants with double and single row intercropping (Table 1). For example at final harvest, sole mustard (or lentil) plant produced 6.58 (or 14.9) primary branches/plant which was about 19 and 15% (or 20 and 13%) higher than the primary branches produced by the same plants grown under single and double row intercropping systems, respectively.

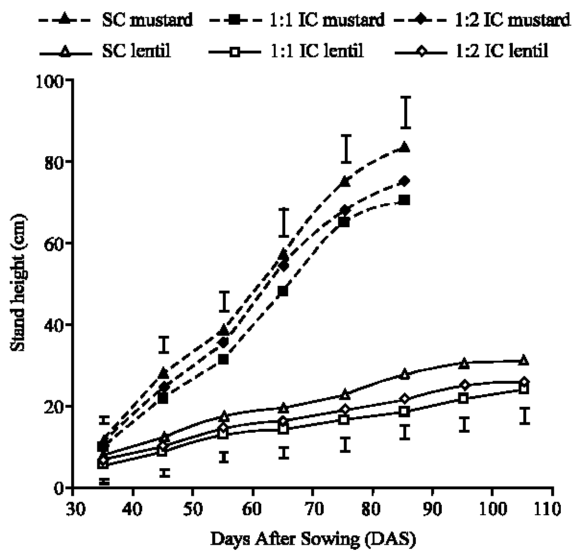

Fig. 1: Seasonal time-course of plant height of mustard and lentil under different cropping systems. Vertical bars (upper for mustard whereas lower for lentil) indicate the LSD ($p<0.05$) among the cropping systems. SC and IC, respectively represent sole crop and intercrop

The seasonal pattern and inter-treatmental variation for secondary branch production in mustard and lentil followed the same pattern as of primary branch production (Table 1). Such greater No. of branches in sole cropped plants might be due to the contribution of more available spaces for horizontal spreading of the plants along with less competition for nutrient, moisture and sunlight (Shackel and Hall, 1984).

Green leaf area index: Leaf Area Index (LAI), a measure of leafiness and photosynthetic area of a crop depends on the leaf growth, leaf number, leaf senescence and plant population per unit area. Initial low LAI in all the treatments rapidly increased to a maximum at about 65 DAS in mustard and at 75 DAS in lentil followed by a sharp decline with the advancement of maturity (Fig. 2). Both of mustard and lentil stands with sole crop population maintained greater LAI throughout the growth period. However, mustard plants with 1:1 intercropping or lentil plants with 1:2 intercropping generated the higher LAI over their companion partners. The reduction of LAI in each species under intercropping is a common phenomenon in crop plants (Reddy and Willey, 1981). It is notable from Fig. 2 that mustard and lentil stands attained their peak LAIs on different time which ignores the burden of excessive green foliage at a time resulting better compatibility of the mixture (Awal *et al*., 2006).

Table 1: Seasonal time-course of production of primary and secondary branches per plant in mustard and lentil plants under sole and intercropping systems

Plant traits/ cropping systems	Days After Sowing (DAS) 35	45	55	65	75	85	95	105
No. of primary branches plant^{-1}								
Mustard								
Sole crop	–	2.26±0.21a	3.44±0.32a	5.38±0.52a	6.20±0.54a	6.58±0.58a		
Single row (1:1) intercrop	–	1.59±0.12b	2.98±0.26b	3.28±0.25c	4.15±0.31c	5.31±0.45b		
Double row (1:2) intercrop	–	2.06±0.15a	3.34±0.27ab	4.30±0.39b	5.00±0.36b	5.60±0.52b		
$LSD_{0.05}$		0.26	0.37	0.72	0.78	0.87		
Lentil								
Sole crop	1.70±0.15a	3.15±0.29a	4.28±0.38a	6.73±0.66a	8.25±0.80a	12.85±1.14a	14.13±1.14a	14.90±1.36a
Single row (1:1) intercrop	0.63±0.045b	1.78±0.17c	3.13±0.22b	4.28±0.33c	6.78±0.56b	10.05±0.86b	10.93±0.99b	11.88±1.01b
Double row (1:2) intercrop	1.78±0.15a	2.45±0.21b	3.95±0.34a	4.90±0.47b	8.13±0.67a	10.48±0.91b	12.23±1.03ab	13.0±1.15ab
$LSD_{0.05}$	0.90	0.40	0.65	0.42	1.19	1.46	1.95	2.30
No. of secondary branches plant^{-1}								
Mustard								
Sole crop	–	–	1.23±0.10a	3.25±0.26a	3.53±0.30a	4.30±0.39a		
Single row (1:1) intercrop	–	–	0±0.00c	1.96±0.18b	2.23±0.17b	3.30±0.32b		
Double row (1:2) intercrop	–	–	0.38±0.03b	2.98±0.26a	3.30±0.29a	3.73±0.28ab		
$LSD_{0.05}$			0.12	0.48	0.51	0.61		
Lentil								
Sole crop	–	1.75±0.13a	2.63±0.22a	3.70±0.34a	8.75±0.71a	11.45±1.02a	12.25±1.22a	14.00±1.20a
Single row (1:1) intercrop	–	0.60±0.06c	1.55±0.13c	2.30±0.22b	4.45±0.44c	8.10±0.67b	8.58±0.760b	9.35±0.830c
Double row (1:2) intercrop	–	1.18±0.10b	2.10±0.18b	3.35±0.31a	7.50±0.67b	9.70±0.88b	11.83±1.04a	12.05±1.04b
$LSD_{0.05}$		0.08	0.36	0.55	0.74	1.75	2.06	1.38

Values followed by ± indicate the SD of treatment means (n = 4). In a column, values having dissimilar letter(s) under each LSD group different significantly

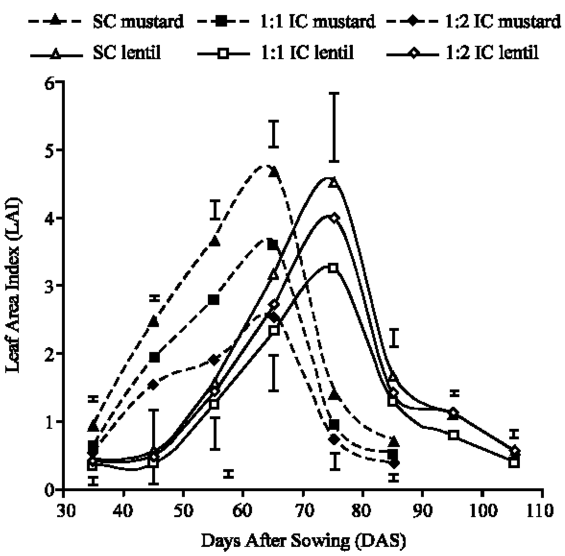

Fig. 2: Seasonal time-course of Leaf Area Index (LAI) of mustard and lentil plants under different cropping systems. Vertical bars (upper for lentil whereas lower for mustard) indicate the LSD ($p<0.05$) among the cropping systems. SC and IC, respectively represent sole crop and intercrop

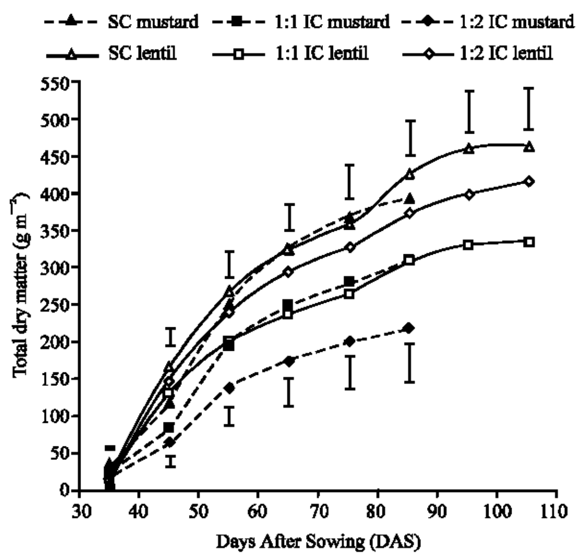

Fig. 3: Seasonal time-course of total dry matter accumulation in mustard and lentil plants under different cropping systems. Vertical bars (upper for lentil whereas lower for mustard) indicate the LSD ($p<0.05$) among the cropping systems. SC and IC, respectively represent sole crop and intercrop

Accumulation of Total Dry Matter (TDM): Initial little accumulation of TDM gradually increased with the advancement of season for both of mustard and lentil (Fig. 3). The mustard and lentil plants under sole cropping accumulated the maximum amount of TDM throughout the growth period. The order of variation of TDM accumulation in mustard and lentil populations under single and double row intercropping almost followed the order found in LAI development.

The total DM production of a crop depends on the size of the photosynthetic system and its activity as well

Table 2: Economic yield, biological yield and harvest index of mustard, lentil and combined mixture with different cropping systems

Crops/cropping systems	Economic yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Mustard			
Sole crop	1.26±0.18aB	4.03±0.30aB	31.05±5.19a
Single row (1:1) intercrop	0.76±0.10b	3.11±0.30b	24.25±5.91b
Double row (1:2) intercrop	0.65±0.07b	2.19±0.06c	29.73±3.88ab
$LSD_{0.05}$	0.22	0.39	3.55
Lentil			
Sole crop	1.30±0.07aB	3.94±0.10aC	34.02±1.61a
Single row (1:1) intercrop	0.85±0.06c	2.81±50.13c	30.22±1.39b
Double row (1:2) intercrop	1.15±0.02b	3.38±0.12b	33.02±1.25a
$LSD_{0.05}$	0.11	0.19	2.65
Combined mixture (mustard+lentil)			
Single row (1:1) intercrop	1.60±0.15AB	5.92±0.35A	-
Double row (1:2) intercrop	1.80±0.13A	5.57±0.10A	-
$LSD_{0.05}$	0.37	0.87	

Values followed by ± indicate the SD of treatment means (n = 4). In a column, values having dissimilar smaller or capital letter(s) (i.e., sole and combined intercrops) different significantly

as the length of growing period when photosynthesis takes place (Evans, 1975). The DM accumulation is positively correlated with LAI (Ziaei and Sepaskhah, 2003). Initially, there was an incomplete canopy cover in all the treatments resulting minimum DM accumulation and that of highest DM accumulation during full vegetative growth was due to the maximum utilization of natural resources (Keating and Carberry, 1993; Morris and Garrity, 1993a, b) and the result is in conformity with Harris *et al.* (1987) in sorghum/groundnut intercropping.

Seed yield or economic yield: Seed yield of sole mustard (1.25 t ha^{-1}) was about 40 and 48% higher than that of mustard plants with 1:1 and 1:2 intercropping, respectively (Table 2). Similar result was also found for lentil with different cropping systems. The highest seed yield by the sole cropped mustard or lentil plants might be attributed due to more vigourous growth with favorable space, sunlight, air and nutrients availability or less interspecific competition (Chang and Shibles, 1985; Willey, 1990; Helenius and Jokinen, 1994) and the results are supported well by the findings of Reddy and Willey (1981), Harris *et al.* (1987) and Tefera and Tana (2002) in pearl millet/groundnut and sorghum/groundnut intercropping. In the other word, yield reduction of components crops in an intercropping mixture is a common phenomenon (Agegnehu *et al.*, 2006; Xu *et al.*, 2008).

There was significant variation of seed yield among the combined (mustard+lentil) intercropping systems with that of the sole cropping (Table 2). The 1:2 combined mixture generated maximum production (1.80 t ha^{-1}) which was about 11, 30 and 28% higher yield than that of the yield obtained from 1:1 combined intercropping and sole mustard and lentil, respectively. Seed yield obtained in this study indicates that mustard/lentil intercrop association has overwhelming superiority over sole cropping, where, 1:2 intercropping system represents the best performance. The result of combined yield is in full conformity with Willey (1990) in sorghum/pigeonpea and millet/groundnut intercropping.

Biological yield: At physiological maturity, greater biological yield, 4.03 t ha^{-1} (or 3.94 t ha^{-1}) was obtained from sole mustard (or lentil) plants which was about 28 and 46% (or 29 and 14%) higher than the mustard (or lentil) stands grown with 1:1 and 1:2 intercropping systems, respectively (Table 2). The 1:1 combined intercropping system produced the maximum biological yield (5.92 t ha^{-1}) which was about 32 and 34% higher biological yield produced by the plants with sole mustard and lentil, respectively. Although the 1:1 combined intercropping system produced the higher biological yield but lower harvest index (discussed later) both of mustard and lentil plants resulted lower economic yield than the economic yield obtained from double row system. The literature supported the biological yield is yet available for mustard/lentil intercropping but the results are commensurable with Awal *et al.* (2007) in barley/peanut intercropping.

Harvest index: Harvest index found in the mustard plants with sole cropping was about 22% higher than the HI of mustard plants grown with 1:1 intercropping (Table 2). In lentil, maximum HI was found in sole cropped or double row intercropped plants which was significantly higher than the lentil grown with 1:1 intercropping. Harvest index is an important parameter which indicates the efficiency of mobilization of photosynthate to the harvestable part of a crop. Higher harvest index generally corresponds to higher grain yield. In this study, sole crop plants not only produced larger amount of photosynthates but also transferred that efficiently to the seeds resulting higher yield. The lower HI in the mustard or lentil plants grown with intercropping especially single row system can be explained for deficiency of available solar radiation throughout the canopy (Awal *et al.*, 2006) and the results are supported well by the findings of Tsubo *et al.* (2001) in maize/bean intercropping.

Land Equivalent Ratio (LER): Single and double row intercropping gave 25 or 41% more seed yield (LER = 1.25 or 1.41) than growing the mustard and lentil separately (Table 3). Therefore, the yield advantage was 25 or 41% for the practice of single or double row intercropping and the results are supported by the findings of Marshall and Willey (1983), Santalla *et al.* (2001) and Tefera and Tana (2002).

Table 3: Land Equivalent Ratio (LER), Area Time Equivalency Ratio (ATER) and Competitive Ratio (CR) of the partner stands in the intercrop association

Crop in mixtures	Single row (1:1) intercropping			Double row (1:2) intercropping		
	LER	ATER	CR	LER	ATER	CR
Mustard	0.60±0.09b	0.49±0.07c	0.92±0.17b	0.52±0.12c	0.42±0.10c	1.20±0.34a
Lentil	0.65±0.07b	0.65±0.07b	1.10±0.17a	0.88±0.06b	0.88±0.06b	0.88±0.23b
Combined intercrop	1.25±0.13a	1.14±0.12a	-	1.41±0.10a	1.31±0.08a	-
$LSD_{0.01}$	0.185	0.148	0.192*	0.051	0.143	0.187

Values followed by ± indicate the SD of treatment means (n = 4). In a column, values having dissimilar letter(s) different significantly at p<0.01 (*p<0.05)

Area Time Equivalency Ratio (ATER): The single and double row combined intercrop stands generated 14 and 31% higher ATER, respectively than sole stands although the component's ATER in each intercropping system was declined (Table 3). Due to the land occupation time by the partner stands was different, the ATER would provide better estimate than LER and it permits an evaluation of crops on a yield per day basis (Ofori and Stern, 1987). Higher LER and ATER obtained from double row intercropping would indicate its best performance over single row intercropping.

Competitive ability among the associated populations: Competitive Ratio (CR) of mustard and lentil populations under the different intercropping systems was computed and the result is shown in Table 3. The lentil population strongly competed over mustard in single row intercropping system, however, opposite result was true for double row intercropping. Efficiency of intercrop production might be increased by minimizing the interspecies competition between the component populations for growth limiting factors (Dhima *et al.*, 2007). The CR both in single (0.92-1.10) and double row intercropping (0.88-1.20) approached unity which indicates that the genotypes used and the agronomic/management practices applied in the experiment effectively balanced the natural resources between mustard and lentil populations resulted better yield and the findings are very close to the result of Awal *et al.* (2007) in barley/peanut intercrop association.

It can be concluded from the present study that mustard and lentil populations are well compatible in intercrop association and their 1:2 row ratio mixture i.e., one row of mustard followed by two rows of lentil, would be better for profitable production of these crops.

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