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Performance of lentil (*Lens culinaris* M.) and mustard (*Brassica juncea* L.) intercropping under rainfed conditions

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Abstract

Crop compatibility is the most essential factor in a feasible intercropping system. Thus the success of any intercropping system depends on the selection of crop species which competes for light, space, moisture and nutrients between them. The combination of a non-leguminous species with a leguminous one might be expected to generate yield advantages over sole cropping since their canopy architectures are different. Thus a field experiment was conducted on intercropping of lentil and mustard in varying row ratios viz., sole Lentil, sole Mustard, Lentil + Mustard (1:1), Lentil + Mustard (2:1), Lentil + Mustard (4:1), Lentil + Mustard (6:1), Lentil + Mustard (2:2), Lentil + Mustard (4:2), Lentil + Mustard (6:2) and Lentil + Mustard (4:4) during the winter season of 2009-10 and 2010-11 to assess the compatibility of lentil and mustard plants in intercrop association and to evaluate spatial intercropping systems for their profitable production. The competitive behavior of component crops in different intercropping systems was determined in terms of land equivalent ratio (LER), relative crowding coefficient (RCC), aggressivity, competitive ratio (CR) and monetary advantage index (MAI). The result revealed that lentil + mustard under 6:1 and 6:2 intercropping system were found to be more economical and had highest monetary advantage index (193.93 and 184.33). The lowest competitive ratio for lentil and mustard were 0.44 and 2.27 respectively. Among the different row ratios of lentil and mustard, 6:1 has the highest aggressivity value (0.205) for both lentil and mustard followed by 4:2 (0.162) and the lowest in 4:4 (0.003) showing that mustard was a better competitor in 6:1 than 4:4. The relative crowding co-efficient of lentil was greater than in all the treatments except 1:1 row ratio indicating yield advantage compared with their monoculture due to mutual cooperation. Lentil + mustard intercropping under 4:2 recorded the highest land equivalent ratio (1.35). The available nitrogen (N), phosphorus (P) and potassium (K) after the harvest of crops were significantly improved under 6:1 row ratio of lentil + mustard. Similarly, water use efficiency was also higher (3.75 kg ha^{-1} mm^{-1}) under 6:1 and 6:2 (3.73 kg ha^{-1} mm^{-1}) than sole lentil (2.38 kg ha^{-1} mm^{-1}) and mustard (3.41kg ha^{-1} mm^{-1}). It might be due to proportionately higher grain yield of both the crops than the amount of water used for individual crop yield. Moisture depletion from deeper layers were observed under sole mustard and lentil + mustard (1:1) intercropping system due to moisture stress in the upper 0-30 cm soil profile, compelling the root to go deeper in search of moisture.

Keywords: lentil; mustard; intercropping; aggressivity; competitive ratio; land equivalent ratio.
Abbreviations: N_Nitrogen; P_Phosphorus; K_potassium; B:C_Benefit:Cost; LER_Land Equivalent Ratio; MAI_Monetary Advantage Index; RCC_Relative crowding coefficient; CR_Competition ratio.

Introduction

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 increased crop production (Awal et al., 2006). The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height and nutrient requirement based on the complementary utilization of growth resources by the component crops. Better use of nutrients can be possible due to differences in rooting pattern which may also occur due to mutual avoidance of different root system (Trenbath, 1974). Greater uptake of different nutrients and better use of water by intercropping are also possible. The complementarity may be temporal when the growth patterns of component crops differ in time so that the crops make their major demands on resources at different times. By temporal use of resources, yield advantages have been obtained with crops having marked differences in maturity period (Willey and Osiru, 1972). It can ensure substantial yield advantage as compared to sole cropping (Rao and Singh, 1990). The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture Dhima et al., 2007;

Muoneka et al., 2007; Carrubba et al., 2008; Launay et al., 2009; Mucheru-Muna et al., 2010). The selection of an appropriate intercropping system in each case is quite complex as the success of intercropping systems depend much on the interactions between the component species, the available management practices, and the environmental conditions. Crop compatibility is the most essential factor in 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 minimized (Fukai and Trenbath, 1993). 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). Yield advantage occurs because growth resources such as light, water, and nutrients by the intercrop over time and space as a result of differences in competitive ability for growth resources between the crops in characteristics such as rates of canopy development, final canopy size, photosynthetic adaptation of canopies to irradiance conditions and rooting depth (Midmore, 1993; Tsubo et al., 2001). Normally, complementary use of resources occurs when the component species of an intercrop use quantitatively different resources or they use the same resources at different places or at different times (Tofinga et al., 1993). In ecological terms, resource complementarity minimizes the niche overlap and the competition between crop species and permits crops to capture a greater range and quantity of resources than the sole crops. Thus selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system as well as plant density and arrangement. With the above facts the experiment was conducted to analyse the interspecies compatibility and production potentials of mustard and lentil in intercropped association. Lentil (*Lens culinaris* M.) belongs to the family leguminosae whereas the mustard (*Brassica juncea* L.) to the cruciferae, both are important crops. The former is a high protein human and livestock feed while the latter is valuable oilseed crop. The combination of a leguminous species with a non-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. The competitive behavior of component crops in different intercropping systems was determined in terms of relative crowding coefficient, aggressivity, and competitive ratio. With the above facts the present investigation was carried out to assess the compatibility of lentil and mustard plants in intercrop association and to evaluate spatial intercropping systems for their profitable production.

Results and Discussion

Effect of intercropping system on yield of component crops

Seed yield of sole lentil (4.33 t ha^{-1}) and sole mustard (1030 t ha^{-1}) were higher than their intercropping system. The highest seed yield of the sole cropped lentil or mustard might be attributed due to more vigorous growth with favourable space, sunlight, air and nutrient 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 pearlmillet/groundnut and sorghum/groundnut intercropping 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 (lentil + mustard) intercropping system with that of the sole cropping (Table1). Among the different row ratios of lentil with mustard, 6:1 row ratio gave the highest yield (424 kg ha^{-1}) which was at par with that of 6:2 (405 kg ha^{-1}), 4:2 (387 kg ha^{-1}) and sole lentil (433 kg ha^{-1}) . The lowest lentil seed yield (273 kg ha^{-1}) was observed in 1:1 row ratio. The reduction in yield due to intercropping was more pronounced in mustard as compared to lentil because of higher requirement of moisture and nutrients of mustard than lentil. The inherent ability of leguminous crops like pea and french bean to fix the atmospheric nitrogen induced the higher crop yield and helped the plant to provide more macro and micro elements through the increment in biological properties of soil (Angas et al., 2006 and Gill et al., 2008). The highest lentil equivalent yield (549 kg ha^{-1}) was obtained under lentil + mustard 6:1 row ratios followed by 6:2 (541 kg ha^{-1}) and the lowest under sole mustard (334 kg ha^{-1}). These results showed that lentil and mustard were more compatible under 6:1 and 6:2 row ratio intercropping system in comparison to the rest treatments. Similar results were also reported by Tuti et al. (2012).

Effect of intercropping system of economics of component crops

Intercropping had a higher economic advantage over sole cropping (Table1). Lentil + mustard under 6:1 and 6:2 intercropping recorded higher net returns (286AUD, 278AUD) and benefit: cost ratio (1.63 and 1.62) than the other row ratios indicating superiority of lentil as intercrop. Similar observations were also reported by Srivastava et al. (2007). The monetary advantage index was also higher in lentil + mustard intercropping under 6:1 row ratio than the rest treatments. Among intercroppings, lentil + mustard 6:1 had a higher monetary advantage index (193.93) followed by 6:2 (184.33) and the lowest was with 4:4 (127.58). The higher the MAI value the more profitable is the cropping system (Ghosh, 2004).

Competition functions

Effect of intercropping system on the competitive ratio (CR)

The competitive ratio is an important tool to know the degree to which one crop competes with the other. Competitive ratio of lentil and mustard populations under different intercropping system was computed and the results were shown in Table 2. Among the different row ratios of lentil and mustard intercropping, 6:1 shows the lowest value of competitive ratio (0.44) for lentil and highest (2.27) for mustard. These results suggested that among intercropping systems of lentil and mustard, the row ratio 6:1 proved to be a better competitor as compared to other row ratios. The mustard population strongly competed over lentil in 6:1 row ratio intercropping system. But the lentil population strongly competed over mustard in 2:2 row ratio. Efficiency of intercropped production might be increased by minimizing the interspecies competition between the component populations for growth limiting factors (Dhima et al., 2007). It is evident from the competitive ratio that 4:1 was the most suitable row ratio intercropping for lentil and mustard.

Effect of intercropping system on aggressivity

An aggressivity value of zero indicates that component crops

Table 1. Yield and economics of lentil and mustard intercropping system (pooled data).

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)		Net return in AUD	B:C ratio	Lentil Equivalent Yield (LEY)
	Lentil	Mustard	Lentil	Mustard			
Sole Lentil	433[b]	-	1030[b]	-	167[b]	1.40[b]	433[b]
Sole Mustard	-	724[c]	-	1784[b]	64[a]	1.16[a]	334[a]
Lentil + Mustard (1:1)	273[a]	458[b]	594[a]	1153[b]	178[b]	1.37[b]	487[b]
Lentil + Mustard (2:1)	360[b]	324[a]	823[ab]	769[a]	217[bc]	1.46[bc]	511[b]
Lentil + Mustard (4:1)	398[b]	284[a]	871[ab]	725[a]	241[bc]	1.51[b]	530[b]
Lentil + Mustard (6:1)	424[b]	268[a]	900[ab]	652[a]	286[c]	1.63[c]	549[b]
Lentil + Mustard (2:2)	287[a]	433[b]	674[a]	1113[b]	182[bc]	1.38[b]	489[b]
Lentil + Mustard (4:2)	387[b]	313[a]	850[ab]	792[a]	265[bc]	1.58[bc]	533[b]
Lentil + Mustard (6:2)	405[b]	290[a]	956[ab]	709[a]	278[c]	1.62[bc]	541[b]
Lentil + Mustard (4:4)	264[a]	452[b]	586[a]	1162[b]	194[bc]	1.43[bc]	475[b]
S. Em.±	25.11	27.58	84.19	102.61	34.34	0.07	25.44
CD (P= 0.05)	75.28	82.67	252.42	307.63	102.06	0.22	75.60

* Means followed by same superscripts within the same column are not significantly different at the 5% . level of probability based on Duncan's Multiple Range Test.
*(-) Indicates the sole of component crop which is not included in the calculation of yield.

Table 2. Effect of different row ratios intercropping systems of lentil and mustard on Competitive ratio (CR), Relative Crowding Coefficient (RCC), Aggressivity, Land equivalent ratio (LER) and Monetary advantage index (MAI) (pooled data)

Treatment	Competitive ratio (CR)		Relative Crowding Coefficient (RCC)		Aggressivity		Land equivalent ratio (LER)	Monetary advantage index (MAI)
	Lentil	Mustard	Lentil	Mustard	Lentil	Mustard		
Lentil + Mustard (1:1)	1.00	1.01	0.70	1.91	-0.008	0.008	1.00	138.21
Lentil + Mustard (2:1)	0.94	0.27	2.84	0.85	-0.036	0.036	1.00	151.55
Lentil + Mustard (4:1)	0.61	0.11	5.47	0.66	-0.162	0.162	1.27	174.39
Lentil + Mustard (6:1)	0.44	2.27	7.29	0.59	-0.205	0.205	1.28	193.93
Lentil + Mustard (2:2)	1.13	0.94	1.97	1.51	0.036	-0.036	1.32	139.79
Lentil + Mustard (4:2)	1.09	1.00	5.25	0.81	0.007	-0.007	1.35	182.22
Lentil + Mustard (6:2)	0.79	1.29	4.91	0.68	-0.044	0.044	1.27	184.33
Lentil + Mustard (4:4)	1.03	1.09	2.05	1.95	-0.003	0.003	1.34	127.58

Table 3. Soil nutrient status and moisture extraction pattern as influenced by sole and different row ratio intercropping of lentil and mustard (pooled data).

Treatment	Available nutrients after harvest of crops (kg/ha)			Moisture extraction pattern (%)		
	N	P	K	0-15cm	15-30cm	30-45cm
Sole lentil	191.76 ±36.94[e]	18.34±3.54[c]	178.23±34.30[c]	52.45	37.67	9.88
Sole mustard	165.58 ±31.46[a]	16.34 ±3.21[a]	176.11 ±33.89[a]	50.56	35.78	13.66
Lentil + Mustard (1:1)	176.56 ±33.66[b]	16.45 ±3.17[a]	175.22 ±33.72[a]	55.56	30.67	13.77
Lentil + Mustard (2:1)	178.85 ±34.25[b]	17.69 ±3.41[a]	175.46 ±33.77[a]	53.89	32.88	13.23
Lentil + Mustard (4:1)	189.45±36.36[d]	17.89±3.45[b]	177.66 ±34.19[bc]	52.66	37.11	10.23
Lentil + Mustard (6:1)	193.12 ±36.97[e]	18.42 ±3.55[c]	178.42 ±34.34[c]	51.88	34.56	13.56
Lentil + Mustard (2:2)	185.77 ±35.82[c]	17.85 ±3.44[b]	177.42 ±34.14[b]	55.89	31.55	12.59
Lentil + Mustard (4:2)	188.12 ±35.85[cd]	18.02 ±3.47[c]	176.47 ±33.96[ab]	54.65	32.76	12.56
Lentil + Mustard (6:2)	189.11 ±36.47[d]	18.24 ±3.51[c]	177.67 ±34.19[bc]	55.45	32.56	11.99
Lentil + Mustard (4:4)	187.65 ±35.95[c]	18.22±3.51[c]	176.34 ±33.94[ab]	52.78	33.64	13.58

* N, P and K values are means with ±SE. * Means followed by same superscripts within the same column are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

are equally competitive. In any other situation, both crops will have the same numerical value, but the sign of the dominant species will be positive and that of dominated negative. The greater the numerical value, the bigger the differences between actual and expected yields. The data shown in Table 2 revealed that the component crops did not compete equally. The results suggest that among the different row ratios of lentil and mustard, 6:1 has the highest aggressivity value for lentil and mustard were + 0.205 and – 0.205 respectively. It showed that mustard was dominated by lentil.

Effect of intercropping system on relative crowding coefficient (RCC)

Most of the expected yield of mustard was lower, as the coefficient were less than 1, whereas the lentil gave more yield than expected under all the different row ratio intercropping except 1:1. It revealed that the relative crowding coefficient of the lentil was greater than 1, in all the treatments except 1:1 row ratio indicating yield advantage compared with their monoculture due to mutual cooperation. Higher value of RCC for lentil was obtained from 6:1 followed by 4:1 row ratio. Similar results were also reported by Tuti et al. (2012).

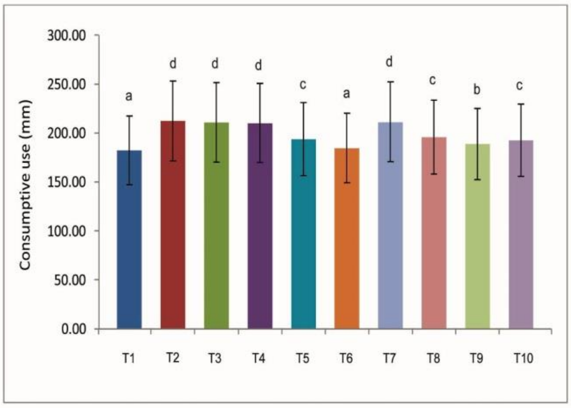

Fig 1. Effect of different row ratio intercropping of lentil and mustard on consumptive use of water. Vertical bars at the top of the shaded bars indicate the standard error. Means followed by the same letters are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

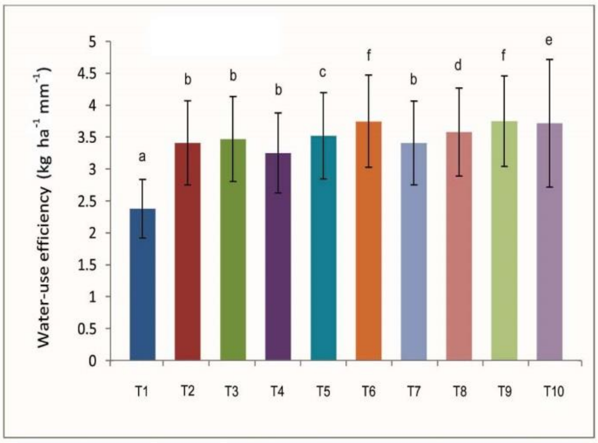

Fig 2. Effect of different row ratio intercropping of lentil and mustard on water use efficiency. Vertical bars at the top of the shaded bars indicate the standard error. Means followed by the same letters are not significantly different at the 5% level of probability based on Duncan's Multiple Range Test.

Effect of intercropping system on land equivalent ratio (LER)

Lentil + mustard intercropping as 4:2 row ratio recorded the highest LER value (1.35) (Table 2) followed by 4:4 (1.34). The requirement of the relative land area under the row ratio of 4:2 and 4:4 were higher to achieve the yields obtained under other row ratios. It might be attributed to the development of the better complementary relationship, leading to better use of growth resources. The result confirms the findings of Schultz et al., 1982 and Mandal et al., 1987, 1990.

Effect of intercropping system on nutrient balance

It was observed that rising of lenlil + mustard in 6:1 row ratio enhanced significantly the available soil N (191.76 kg ha^{-1}) status. The increase in N might be due to symbiotic nitrogen-fixation as lentil belongs to the family leguminoseae. The lowest soil N status (165.58 kg ha^{-1}) was recorded from sole mustard as mustard cannot fix atmospheric nitrogen. The available soil P status (18.34 kg ha^{-1}) under 6:1 was found to be significantly higher than all other treatments. The increased level of available soil P may be due to more root proliferation of lentil and mustard under 6:1 intercropping system. There might be some release of P in the labile pool of soil due to intercropping. The available K after the harvest of crops was found to be higher in 6:1 and the lowest under1:1. Similar results were also reported by Tuti et al. (2012). Midmore (1993) also reported that improved resource use is given in most cases a significant yield advantage, increase the uptake of other nutrients such as P, K, micronutrients and provides better rooting ability and better ground cover.

Effect of intercropping system in consumptive use

Consumptive use of water of lentil and mustard intercropped was lesser than that of the sole mustard (Fig. 1). The highest consumptive use (212.42 mm) was observed under sole mustard whereas the lowest (182.30 mm) in sole lentil. It could be attributed to the fact that mustard needs more water for growth and development than lentil. This indicates that intercropping of mustard with lentil is advantageous for soil-moisture utilization under rainfed condition. For better utilization of soil moisture, lentil and mustard intercropping appeared superior to its sole crops. However, lentil produced more grain yield /unit water when grown as a sole crop than as an intercrop. Similar results were also reported by Jana et al. (1995).

Effect of intercropping system on water use efficiency

Water use efficiency (WUE) in terms of yield of individual crops showed marked variation due to intercropping system (Fig. 2). Intercropping of lentil with mustard at row ratios of 6:1 and 6:2 recorded higher WUE (3.75 kg ha^{-1} mm) and (3.73 kg ha^{-1} mm) respectively than sole lentil (2.38 kg ha^{-1} -mm) and mustard (3.41 kg ha^{-1} mm). This might be attributed due to proportionately higher grain yield of both the crops than the amount of water used for individual crop yield. Lentil intercropped with mustard utilized more water for evapotranspiration and metabolic activities. Morris and Garrity (1993) also reported that higher water use efficiency was obtained with the improved resource were used.

Moisture extraction

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 as intercropping systems (Table 3). 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 the maximum extraction of soil moisture from this profile. Moisture depletion from deeper layers by mustard sole, lentil + mustard (1:1) and lentil + mustard (4:4) intercropping system might be due to moisture stress in the upper 0-30 cm soil profile, compelling the root to go deeper in search of moisture. It explains the reason behind greater depletion of soil moisture from the deeper soil profile (Sigh et al., 2011). Similar results were also reported by Tuti et al., 2012.

Materials and Methods

Plant material used for the intercropping

i. Lentil: The lentil variety L – 4076 was used for this experiment.

ii. Mustard: The mustard variety used for the intercropping was JD – 6.

Experimental site and soil characteristics

The experiment was undertaken at the Research Farm, College of Agriculture, Central Agricultural University, Imphal, India (24°45′ N, 93°56′ E; altitude 774.5m above mean sea level) during the winter season of 2010-11 and 2011-12. The soil was clay loam in texture with a pH of 5.5, low in organic carbon (0.48%), available nitrogen (210 kg ha^{-1}), available P_2O_5 (17.5 kg ha^{-1}) and available K_2O (186 kg ha^{-1}). The total rainfall received during the cropping seasons (November - April) were 10.3mm and 8.5 mm respectively.

Treatments

The experiment consists of ten treatments viz., T_1 – Lentil sole, T_2 – Mustard sole, T_3 – Lentil + Mustard (1:1), T_4 - Lentil + Mustard (2:1), T_5 - Lentil + Mustard (4:1), T_6 - Lentil + Mustard (6:1), T_7 - Lentil + Mustard (2:2), T_8 - Lentil + Mustard (4:2), T_9 - Lentil + Mustard (6:2) and T_{10} - Lentil + Mustard (4:4). The experiment was laid out in randomized block design with three replications. The recommended seed rates were 40 kg ha^{-1} for lentil and 5 kg ha^{-1} for mustard. The crops were sown during the first week of November in both the years and harvested in April. The recommended dose of fertilizer for lentil and mustard were 20, 40 and 40 kg NPK ha^{-1} and 60, 30 and 40 kg NPK ha^{-1} respectively. All the recommended fertilizers for lentil were applied at the time of sowing. Half the dose of N and full dose of P and K were applied for mustard. The remaining half of N was applied into two equal doses at 30 and 60 days after sowing. Nitrogen, phosphorus and potash were applied in the form of urea, single superphosphate and muriate of potash respectively. The crops of lentil and mustard were sown at a row spacing of 25 cm in sole as well as intercropping except for sole mustard (30 cm). Plant to plant distance in a line either for mustard or lentil was 10 cm. It was a replacement series intercropping. The treatments were laid out in a randomized block design with three replications. The crops were kept weed free by hand weeding at 20 days after sowing. Three life saving irrigations were given just after sowing, at flowering and pod formation stages.

Sampling for growth analysis and data collection.

Biometric observations were recorded at the time of maturity. At each harvest, ten plants were extracted carefully from each sole (lentil or mustard) or intercropped (5 mustard and 5 lentil plants) plots. Seed and stover yield were recorded. The competition behaviour of component crops across different intercropping systems was determined in terms of the relative crowding coefficient (De Wit, 1960), aggressivity (Mc Gilchrist, 1965), competitive ratio (Willey and Rao, 1980), land equivalent ratio (Willey, 1979) and monetary advantage index (Ghosh, 2004).

Chemical analysis

Analysis of soil properties like soil pH (Jackson, 1973) and organic carbon (Walkley and Black, 1935), available N (Jackson, 1973), available P (Watanabe and Olsen, 1965) and available K (Jackson, 1973) were carried out by using standard methods.

Data analysis

All the data were subject to analysis of variance (ANOVA) for three replications in randomized block design by using MSTAT C software (CIMMYT, Mexico City). The least significant difference (LSD) was calculated in comparing the treatment means at the 5% level of probability based on Duncan's Multiple Range Test.

Conclusion

The present study indicated that intercropping of lentil and mustard affects the yield of individual species and the economics of the cropping system. Results obtained from competition indices and the economics of the lentil + mustard mixtures indicated a significant advantage from intercropping which was attributed to better economics and land use efficiency than the other row ratios. It can be concluded that intercropping of lentil and mustard in 6:1 and 6:2 row ratios were found to be better for profitable production. The lentil + mustard intercropping under 6:1 and 6:2 had a yield advantage of intercropping for exploiting the resources of the environment compared with the other row ratios used in this study.

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