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Research Paper

Land, biological and economic evaluation of intercropping systems involving barley (*Hordeum vulgare*), Indian mustard (*Brassica juncea*) and chickpea (*Cicer arietinum*) under different spatial arrangements

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2011–12 and 2012–13 at Hisar, Haryana, in randomized block design with 9 treatments replicated thrice, to evaluate the intercropping of Indian mustard [*Brassica juncea* (L.) Czernj & Cosson] and chickpea (*Cicer arietinum*) with barley (*Hordeum vulgare* L.) in replacement series. Results revealed that seed and straw yields of barley was reduced in barley + Indian mustard intercropping system as compared to barley + chickpea because Indian mustard was found to be more competitive and dominant over barley, as evident from higher partial relative crowding coefficient (RCC), competitive ratio (CR), actual yield loss (AYL) and positive aggresivity (A) values of Indian mustard in all the planting patterns compared to barley and chickpea. Among the intercropping treatments, barley + Indian mustard (6 : 3) was found most economical and efficient intercropping system with the highest barley-equivalent yield (BEY, 7.93 t/ha), land-use efficiency (LUE, 135%), area-time equivalent ratio (ATER, 1.34), land-equivalent ratio (LER, 1.36), land-euivalent coefficient (LEC, 0.44), crowding coefficient (K, 5.82), actual yield loss (AYL, + 1.10), intercropping advantages index (IAI, + 3624.3), monetary advantage index (MAI, + 17,975.4), income-equivalent ratio (IER, 1.24), system productivity index (SPI, 65.4), relative net returns index (RNRI, 1.27), monetary-equivalent ratio (MER, 1.33), net returns (₹56,321/ha), benefit: cost rato (B:C, 3.41) and profit margin (71%). Among different row patterns, on the basis of total crop-performance ratio (CPR) values, barley intercropped with either of the intercrop at 6:3 row ratio performed better. Hence barley + Indian mustard (6:3) intercropping system can be a best option to get more monetary returns and resource-use efficiency.

Key words **:** Aggresivity, Barley, Chickpea, Crop equivalent ratio, Indian mustard, Intercropping, Land-equivalent ratio, Monetary advantage index, Relative crowding coefficient

India is having only 2.8% of the world's land area but we have to feed 17% of the global population and 11% livestock. Moreover, nearly 50% of our farmers cultivating less than 1 ha area, and nearly 33% population of our country suffering from poverty and hidden hunger. Thus India will have to produce about 281 million tonnes (mt) food grain, 53.7 mt oilseeds, 22 mt pulses, 127 mt vegetables and 86 mt fruits to meet out the demand for increasing population by 2020–21 with quality under diminishing natural recourse base and changing climate (Singh, 2014). Consequently, India has high population pressure on land and other natural recourses and bio-diversity is under severe pressure to meet its food and development needs. There is a need for more broad-based, more inclusive and more sustainable approach; and there is need to produce more without depleting our natural resources any further. Intercropping is an age-old practice of growing two or more crops simultaneously on the same piece of land. Intercropping has been recognized as a potentially beneficial system of crop production and evidences indicate that it can provide substantial yield advantage over sole cropping (Seth *et al*., 2016). To stabilize crop production and to provide insurance mechanism against aberrant weather situations, intercropping could be a viable agronomic practice of risk minimizing, increasing farmers' profit and subsistence oriented, energy efficient and sustainable venture (Faroda *et al.,* 2007; Singh *et al.,* 2016).

Barley, grown under rainfed cultivation (49% area), often meets with scanty rainfall before sowing and prolonged spell of no rain shower after sowing, resulting in

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failure or poor stand and yield. Under such conditions intercropping of some deep-rooted crops like chickpea and Indian mustard along with barley is advantageous. Indian mustard and chickpea occupy a prominent position at national level and are valued for their importance in nutritional security, soil amelioration and sustainable crop production (DAC, 2014). These two crops also play an important role in protecting the environment from the risk associated with high-input agriculture.

It was widely recognized that intercropping system, designed on scientific basis growing cereals, legumes and oilseeds together holds a great promise in increasing the land productivity compared to sole cropping under Indian conditions. However, spatial arrangement and plant population in an intercropping system have important effects on the balance of competition between component crops and their overall productivity. Therefore, the present investigation was planned to augment the possibility of increasing production potential of barley-based intercropping systems with Indian mustard and chickpea in different replacement series.

MATERIALS AND METHODS

A field experiment was carried out at wheat and barley research area of the Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (29°10'N, 75°46'E and 215.2 m above mean sea-level) during the winter (*rabi*) season of 2011–12 and 2012–13 in a randomized block design, replicated thrice with 9 treatments (Table 1). The total rainfall received during the crop season was 47.7 mm in 2011–12 and 113.8 mm in 2012–13. Soil of the field was sandy loam, slightly alkaline in *p*H (7.8), low in organic carbon (0.38%), available nitrogen (188 kg/ha) and medium in available phosphorus (23 kg/ha) and rich in available potassium (256 kg/ha). Sole barley and component crops in every intercropping system were sown at 22.5 cm row-to-row spacing. While sole Indian mustard and chickpea were sown at 30 cm row-to-row distance. In intercropping treatments barley rows were replaced with Indian mustard or chickpea as per planting pattern varying from 6:1 to 6:3. The gross plot size was 5.4 m × 8.0 m. Varieties such as 'BH 902' of barley, 'RG 888' of chickpea and 'Laxmi' of Indian mustard were used in the study. The sowing of the experiment was done on 19 and 24 November during 2011–12 and 2012–13, respectively using a seed rate of 87.5 kg/ha for barley, 50 kg/ha for chickpea and 5 kg/ha for Indian mustard. The barley, Indian mustard and chickpea were harvested at 143, 148 and 160 days after sowing (DAS), respectively during both the years. The fertilizer dose of 60 : 30 kg N and P_2O_5/ha for sole as well as intercropped barley was applied. The fertilizer schedule used for sole crops of Indian mustard and chickpea was 80:30 and 20:40 kg N and P_2O_5/ha respectively. The proportionate fertilizer dose of the respective intercrop was applied depending upon their planting pattern in the intercropping. Two irrigations were applied at 45 and 85 days after sowing (DAS). The remaining standard recommended crop-management practices were followed as per the package of practices of CCS Haryana Agricultural University, Hisar, India.

The economic yield of different crops was converted into barley-equivalent yield (BEY) based on the market price. The price (₹/kg) of barley, Indian mustard and chickpea considered in the study was 11.05, 29.94 and 30.50 respectively. The benefit of planting patterns and the effect of competition between the main crop and intercrops used in this experiment was calculated using different competition indices. Land-equivalent ratio (LER), relative crowding coefficient (RCC), measure of the relative dominance of one species over the other in the intercropping, aggressivity (A), to determine the competitive relationship between component crops in intercropping, area-time equivalent ratio (ATER), barley-equivalent yield (BEY) and competitive ratio (CR), which gives more desirable competitive ability for the crops over other indices were calculated using the formula given by Willey and Rao (1980). The actual yield loss (AYL) and intercropping advantage index (IAI) were calculated as suggested by Banik *et al.* (2006). Since none of the above competition indices provide any information on the economic advantage of the intercropping system, the monetary advantage index (MAI) was calculated according to Singh and Bohra (2012). Additionally, relative net return index (RNRI) as given by Jain and Rao (1980), land-equivalent coefficient (LEC) and monetary equivalent ratio (MER) as prescribed by Adetiloye (1983), land-use efficiency (Ram *et al*., 2012), combination coefficient (Okigbo, 1979) and crop performance ratio (Yahuza, 2011) were also calculated. The response to different treatments was similar during both the years of study, hence the data were pooled and analyzed statistically.

RESULTS AND DISCUSSION

Yield

Compared to chickpea, an intercropping of Indian mustard in barley reduced the barley effective tillers/m^2 significantly over sole barley (Table 1). The decrease in effective tillers in barley was observed with proportional increase of intercrops from 6 : 1 to 6 : 3. This could be attributed to variations in the magnitude of competition among component crops grown in various proportions. Grains/ear head in barley were non-significant, higher number of grains was found under barley intercropped with chickpea than barley intercropped with Indian mustard. Increase in

1,000-seed weight owing to various intercropping systems was not perceptible. These findings support those reported by Megawer *et al.* (2010), who reported higher yield attributes of barley, when intercropped with chickpea compared to other crops.

Sole barley gave significantly higher seed and straw yields than all the intercropping systems except barley + chickpea (6 : 1) for straw yield. Among the intercropping systems, straw as well as seed yield of barley was reduced more drastically in barley + Indian mustard intercropping as compared to barley + chickpea intercropping. Among the intercropping systems, the least barley seed and straw yields were obtained with barley + Indian mustard (6 : 3), while barley + chickpea (6 : 1) was found with highest seed (4.31 t/ha) and straw yield (7.04 t/ha), which were 10.2 and 4.9%, respectively, less as compared to sole barley crop. More effective tillers/m^2 coupled with higher population of barley in 6 : 1 row ratio could be the reason for higher seed yield of barley in barley + chickpea (6 : 1) (Table 1). These results confirm the findings of Antti Tuulos *et al.* (2015), who reported that sole barley gave significantly higher yield than intercropping.

An intercropping reduced the seed and straw yields significantly compared with sole crop (Table 1). The intercropping of barley with either intercrop at 6 : 1 row ratio recorded significantly the lowest yield than other row ratio. Marked reduction of 79.4% and 77.9% was observed in mustard seed and straw yields, respectively, in barley + Indian mustard (6 : 1) compared to sole Indian mustard. Similarly, chickpea seed and straw yields were reduced to 94.0% and 82.8%, respectively, in barley + chickpea (6 : 1) compared to sole chickpea. Among the intercropping systems, the highest seed as well as straw yields of both intercrops were obtained at 6 : 3 row ratio due to more proportion of crop in intercropping. These results are in line with those previously reported by Megawer *et al.* (2010), who reported greater competition ability of barley when intercropped with chickpea.

Barley-equivalent yield

Sole Indian mustard showed significantly higher barely-equivalent ratio (BEY) than all other sole and intercropping systems, while it was statistically at par with barley + Indian mustard (6 : 3) intercropping system (Table 2). Among the intercropping systems, barley intercropped with Indian mustard at all row ratio was found with higher BEY than barley + chickpea. Among the intercropping treatments barley + Indian mustard (6 : 3) was found with highest BEY, which was significantly higher than all intercropping treatments. Similar trend of result was observed by Ahlawat *et al.* (2005), who also reported that sole Indian mustard showed significantly higher crop-equivalent yield.

Land-use evaluation

Land-equivalent ratio: Intercropping advantage measured in terms of land-equivalent ratio (LER) in intercropping systems revealed that total LER for all intercropping treatments except barley intercropped with either of intercrops in 6 : 1 row pattern were greater than unity, indicating an advantage of intercropping compared to the sole crop (Table 2). The highest LER (1.36) was found with barley + Indian mustard (6 : 3) followed by barley + chickpea (6 : 3) with LER (1.20), which indicates that 36% more area would be required by a sole cropping system to equal the yield of intercropping system (Midya *et al.*, 2005). Partial LER of barley was more than intercrops in all the planting patterns except barley + Indian mustard

Table 1. Yield and yield attributes of barley as influenced by intercropping with Indian mustard and chickpea (pooled data of 2 years)

Treatment	Seed yield (t/ha)			Straw yield (t/ha)			Barley		
	Barley	Mustard	Chickpea	Barley	Mustard	Chickpea	Effective tillers/m^2	Grains/ear head	1,000-seeds weight(g)
Barley sole	4.81	–	–	7.40	–	–	328	43	46
Indian mustard sole	–	1.60	–	–	5.21	–	–	–	–
Chickpea sole	–	–	1.21	–	–	4.25	–	–	–
Barley + Indian mustard (6 : 1)	3.53	0.33	–	6.11	1.15	–	300	42	44
Barley + Indian mustard (6 : 2)	2.90	0.88	–	5.45	3.05	–	292	42	43
Barley + Indian mustard (6 : 3)	2.48	1.35	–	4.85	4.49	–	282	42	43
Barley + chickpea (6 : 1)	4.31	–	0.07	7.04	–	0.73	313	43	45
Barley + chickpea (6 : 2)	4.03	–	0.27	6.36	–	1.63	308	43	45
Barley + chickpea (6 : 3)	3.75	–	0.51	5.67	–	2.03	306	43	45
SEm±	0.11	0.01	0.02	0.25	0.18	0.15	7	0.5	0.8
CD (P=0.05)	0.34	0.02	0.07	0.77	0.64	0.52	23	NS	NS

(6:3) intercropping system. Partial LER of barley was decreased as the proportion of intercrops increased from 6 : 1 to 6 : 3. Partial LER of barley was lower in barley + Indian mustard as compared to barley + chickpea intercropping. The lowest partial LER of both intercrops was recorded with 6 : 1 row pattern of intercropping which indicates that there was an advantage for barley in this intercropping system and a disadvantage for intercrops. These findings are in the agreement with those of Dhaka *et al.* (2014), who concluded that LER values greater than one indicated yield advantage of intercropping.

Land-equivalent coefficient: Land-equivalent coefficient (LEC) was developed to access the interaction and production potentials of intercropping (Table 2). The LEC greater than 0.25 indicated yield advantage. The value of LEC obtained (Table 2) also followed a trend similar to that of LER, showing that with maximum LEC (0.44) barley + Indian mustard (6 : 3) intercropping system was found most advantageous over the sole cropping of component crops. These results are in accordance with findings of Mbah and Ogidi (2012). Area-time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of intercropping systems (Table 2). Intercropping treatments having ATER values more than 1 showed advantage over sole planting. Barley + Indian mustard (6 : 3) treatment was found with highest ATER value, showing 34% advantage over sole planting. Land-use efficiency (LUE) (Table 2) had similar trend as LER and ATER. The LUE was significantly affected by the intercropping systems. Maximum LUE (135.2%) was recorded with barley + Indian mustard (6 : 3) intercropping system followed by barley + chickpea (6:3) with LUE value of 116.2%. As compared to barley + chickpea intercropping, barley + Indian mustard intercropping at all row ratios were found more effective in using land as a resource.

Biological potential evaluation

Relative crowding coefficient: Relative crowding coefficient (RCC) is an index, which is based on the plant density of each crop in the intercropping system (Table 3). The product of RCC values (K) was more than 1 (1.23–5.82) in all the intercropping systems except barley intercropped with either of intercrop in 6 : 1 row pattern, which indicate the definite yield advantage owing to intercropping. The maximum K value was found with barley + Indian mustard (6 : 3) followed by barley + chickpea (6 : 3). Partial RCC of barley was less than 1 and also less than Indian mustard partial RCC, which indicated Indian mustard as dominant and more competitive than barley in all planting patterns, while reverse trend was observed with

Table 2. Land-use indices, intercropping advantage index (IAI), actual yield loss (AYL) and barley-equivalent yield (BEY) as affected by intercropping of Indian mustard and chickpea with barley (pooled data of 2 years)

Treatment	Land use evaluation indices						IAI			AYL			BEY
	LER			LEC	ATER	LUE	Barley	Intercrop	System	Barley	Intercrop	Total	(t/ha)
	Barley	Intercrop	Total										
Barley sole	1.00	0.00	1.00	1.00	–	–	–	–	–	–	–	–	5.01
Indian mustard sole	0.00	1.00	1.00	1.00	–	–	–	–	–	–	–	–	8.15
Chickpea sole	0.00	1.00	1.00	1.00	–	–	–	–	–	–	–	–	3.21
Barley + Indian mustard (6 : 1)	0.74	0.21	0.94	0.15	0.92	92.9	–170.3	1,736.5	1,566.2	–0.15	0.58	0.43	5.75
Barley + Indian mustard (6 : 2)	0.60	0.55	1.15	0.33	1.13	114.5	–215.5	3,603.1	3,387.6	–0.19	1.20	1.01	6.65
Barley + Indian mustard (6 : 3)	0.52	0.84	1.36	0.44	1.34	135.2	–196.5	3,820.8	3,624.3	–0.18	1.28	1.10	7.93
Barley + chickpea (6 : 1)	0.90	0.06	0.96	0.05	0.86	91.0	–5.9	–1,647.7	–1,611.8	0.03	–0.54	–0.51	5.03
Barley + chickpea (6 : 2)	0.84	0.22	1.06	0.19	0.97	101.7	132.9	–353.8	–221.0	0.12	–0.10	0.02	5.25
Barley + chickpea (6 : 3)	0.78	0.42	1.20	0.33	1.12	116.2	263.2	439.0	702.2	0.24	0.14	0.38	5.65
SEm±	0.02	0.01	0.02	0.01	0.02	2.46	33.6	159.9	157.3	0.03	0.05	0.06	0.11
CD (P=0.05)	0.06	0.02	0.06	0.03	0.07	7.87	107.2	510.2	502.2	0.09	0.16	0.18	0.34

LER, Land equivalent ratio; LEC, land-equivalent coefficient, ATER, area time equivalent ratio; LUE, land-use efficiency

barley + chickpea intercropping. Among the intercrops, chickpea was found with lower values of partial RCC compared to Indian mustard, which showed that Indian mustard was more competitive than chickpea when intercropped with barley. Similar results were also reported by Khan *et al*. (2012), who reported higher RCC for Indian mustard compared to barley.

Aggresivity: The results of aggresivity (A) confirmed with those of LER and RCC. The A values given in Table 3 showed that Indian mustard was the dominant crop with positive A values in intercropping systems over the barley, which had negative A values, while in barley + chickpea intercropping, barley was dominant over chickpea. Relative dominance of Indian mustard over barley was increased with increase in number of rows from 1 to 3. While dominance of barley over chickpea intercrop was decreased with increase in proportion of chickpea. Dominated nature of chickpea and dominant behaviour of Indian mustard to barley intercrop as shown by RCC and A values, was also observed from competitive ratio (CR) (Table 3). Values of CR for intercropped barley were lower than Indian mustard but higher than chickpea, which revealed that in intercropping, Indian mustard was more competitive over barley. The highest CR value for barley was observed with barley + chickpea (6 : 1) intercropping system. While for mustard highest CR value (2.77) was found with barley + Indian mustard (6 : 3) intercropping system. With increasing proportion of intercrops from 1 to 3 rows in intercropping with barley, the competitiveness of intercrops also increased and the highest competitiveness of intercrop was observed with 6 : 3 intercropping pattern of barley with either of intercrops. These results are in harmony with those of Abu-Bakar *et al*. (2014), who concluded that owing to higher values of CR barley was dominant and chickpea was dominated in intercropping.

Competition coefficient: Competition coefficient (CC) values of Indian mustard (1.59–3.67) were higher than barley (0.11–0.58) in barley + Indian mustard intercropping (Table 3). While reverse trend was found in barley + chickpea intercropping. Where barley CC (0.80–2.41) values were higher than chickpea. Crop-performance ratio (CPR) values for barley intercropped with Indian mustard at all row ratios were less than 1, which showed that barley in the intercropping with Indian mustard performed less efficiently compared to the sole crop (Table 3). On the other hand, Indian mustard as an intercrop performed better than it's sole crop. However, the total CPR was not efficient than sole crop. While barley intercropped with chickpea performed more efficiently as than sole crop. Maximum performance by Indian mustard and chickpea as intercrop was shown at barley intercropping with either intercrop at 6 : 3 row pattern. On the basis of total CPR values, barley intercropped with either of intercrop at 6 : 3 row ratio had given best performance. Similar results were also represented by Yahuza (2011).

Actual yield loss: Actual yield loss (AYL) showed that Indian mustard as an intercrop was more dominant than barley at all row ratios as values of partial AYL of barley was negative, whereas Indian mustard had positive values (Table 2) probably due to the negative effects of Indian mustard on barley (Singh and Bohra, 2012). It was also revealed that in barley + chickpea intercropping, barley was dominant over chickpea, because the partial AYL of barley was greater than partial AYL of chickpea. Partial AYL shows the yield loss or gain by its sign as well as its value. Thus there was 128% (AYL= + 1. 28) increase in yield of mustard in barley + Indian mustard (6 : 3) as compared to it's sole crop. In contrast, in barley + chickpea (6 : 1) and barley + chickpea (6 : 2), the ALY for chickpea was –0.54 and –0.10, respectively, indicating yield loss of 54 and 10%, respectively, compared to it's sole crop. In all the intercropping systems total ALY values were positive (+0.02 to +1.10) except barley + chickpea (6 : 1), indicating an advantage from intercropping over pure stands. Maximum yield advantage of 110% was obtained

Table 3. Biological potential evaluation indices as affected by intercropping of Indian mustard and chickpea with barley (pooled data of 2 years)

Treatment	RCC			A		CR			CC		CPR		
	Barley	Intercrop	K	Barley	Intercrop	Barley	Intercrop	Total	Barley	Intercrop	Barley	Intercrop	System
Barley + Indian mustard (6 : 1)	0.43	1.73	0.74	–0.73	0.73	0.54	1.87	2.41	0.58	2.43	0.85	1.58	0.88
Barley + Indian mustard (6 : 2)	0.33	3.68	1.23	–1.40	1.40	0.37	2.74	3.11	0.27	3.67	0.77	2.20	0.94
Barley + Indian mustard (6 : 3)	0.63	9.14	5.82	–1.45	1.45	0.36	2.77	3.13	0.11	1.59	0.75	2.28	1.06
Barley + chickpea (6 : 1)	1.78	0.43	0.68	0.57	–0.57	2.36	0.45	2.81	2.46	0.78	1.03	0.46	1.01
Barley + chickpea (6 : 2)	2.24	0.85	1.87	0.24	–0.24	1.27	0.80	2.07	1.18	0.59	1.06	0.88	1.10
Barley + chickpea (6 : 3)	2.08	1.26	2.63	0.09	–0.09	1.08	0.92	2.01	0.80	0.48	1.12	1.15	1.06
SEm±	0.56	0.21	0.46	0.06	0.06	0.17	0.06	0.15	0.15	0.41	0.05	0.05	0.03
CD (P=0.05)	1.73	0.68	1.46	0.20	0.20	0.55	0.19	0.47	0.49	1.32	0.16	0.16	0.09

RCC, relative crowding coefficient; A, aggressivity; CR, competitive ratio; CC, competition coefficient; CPR, crop performance ratio

from barley + Indian mustard (6:3) having AYL value of +1.10.

Intercropping advantage index: Intercropping advantage index (IAI) followed the same trend as that of AYL values, indicated that barley + Indian mustard (6 : 3) with IAI value +3,624.3 was most advantageous intercropping system (Table 2). The intercropping system having negative IAI values showed an economical disadvantage. The lowest total IAI value of –16,11.8 showed that barley + chickpea (6 : 1) lead to highest loss. These results confirmed the findings of Dhima *et al*. (2007).

Economical evaluation

Monetary advantage index: Monetary advantage index (MAI) values were positive in all intercropping systems except barley intercropped with either of intercrop at 6 : 1 row ratio, which showed a definite yield advantage in these intercropping systems compared to sole crop (Table 4). Barley + Indian mustard (6 : 3) was found with the highest MAI, closely followed by barley + chickpea (6:3). These results were also supported the findings of Ghosh (2007), who found that when LER and K values were higher, significant economic benefit was also expressed with higher MAI.

Income-equivalent ratio: The Income equivalent ratio (IER) was significantly influenced by intercropping systems (Table 4). The IER is similar in concept to LER, except that yield is measured in terms of net income rather than crop yield. Barley intercropped with either intercrop at 6 : 3 row ratio was found with IER values more than unity (1.01 to 1.24), which showed an economical advantage from these intercropping system over pure stand. The highest IER value of 1.24 was observed with barley + Indian mustard (6 : 3). On the other hand, IER value below one (0.81 to 0.94) found with barley intercropped with either intercrop at 6 : 1 row ratio and barley + chickpea (6:2) had shown economical disadvantage of these intercropping over pure stands. Similar results were also reported by Dhaka *et al*. (2014), who reported that the IER, in general, declined with increasing proportions of base crop in intercropping system.

System productivity index: Barley + Indian mustard (6 : 3) intercropping system was found with highest system productivity index (SPI) value 65.4, which was significantly higher than all other treatments (Table 4). Barley intercropped with chickpea at all row ratios was found with lower SPI values (37.5 to 43.2) than barely + Indian mustard intercropping systems. Indian mustard as an intercrop with barley at 6 : 2 and 6 : 3 row ratio with relative net return index (RNRI) value of 1.10 and 1.27, respectively, were found profitable compared to sole barley as values were more than 1 (Table 4). Barley + chickpea in-

Table 4. Economical evaluation indices as affected by intercropping of mustard and chickpea with barley (pooled data of 2 years)

Treatments	Cost of cultivation ($\times 10^3$₹/ha)	Gross returns ($\times 10^3$₹/ha)	Net returns ($\times 10^3$₹/ha)	Benefit: cost ratio	RNRI	PM	Net returns /day (₹)	MER	SPI	MAI (₹/ha)	IER
Barley sole	23.7	65.9	42.2	2.77	--	0.64	295.2	-	-	--	--
Indian Mustard mustard sole	22.5	51.7	29.2	2.30	--	0.56	197.7	-	-	--	--
Chickpea sole	23.0	41.3	18.3	1.79	--	0.44	114.4	-	-	--	--
Barley + Indian Mustard mustard (6 : 1)	23.6	60.4	36.7	2.56	0.92	0.61	248.6	0.87	45.2	--3,079.4	0.81
Barley + Indian Mustard mustard (6 : 2)	23.4	70.1	46.7	2.99	1.10	0.67	315.7	1.11	55.5	7,834.1	1.03
Barley + Indian Mustard mustard (6 : 3)	23.3	79.6	56.3	3.41	1.27	0.71	380.5	1.33	65.4	17,975.4	1.24
Barley + Chickpea chickpea (6 : 1)	23.6	64.0	40.3	2.70	0.90	0.63	252.0	0.96	43.2	--2,202.3	0.89
Barley + Chickpea chickpea (6 : 2)	23.6	66.2	42.6	2.81	0.84	0.64	266.5	1.01	40.3	3,019.2	0.94
Barley + Chickpea chickpea (6 : 3)	23.5	69.4	45.9	2.95	0.78	0.66	287.3	1.09	37.5	9,679.7	1.01
SE m ±	-	1.3	1.3	0.05	0.02	0.01	8.59	0.03	1.22	1,310.1	0.03
CD (P= 0.05)	-	3.9	3.9	0.17	0.08	0.03	25.9	0.11	3.90	4,181.4	0.10

RNRI, Relative net return index; MER, Monetary equivalent ratio; SPI, System productivity index; MAI, Monetary advantage index; IER, Income equivalent ratio; PM, Profit margin

tercropping were found uneconomical as all RNRI values were less than 1. The highest RNRI was found with barley + Indian mustard (6:3).

The higher cost of cultivation was incurred on sole barley crop, while the lowest amount was spent on sole Indian mustard. In intercropping systems cost of cultivation was higher than sole Indian mustard and chickpea but it was less than sole barley. Among the intercropping treatments, barley + Indian mustard (6 : 3) was obtained with the highest gross return, which was 20.7% higher than sole barley and it was also significantly higher than all treatments. Net returns had also followed same trend as that of gross return. The highest and lowest net returns were found with barley + Indian mustard (6 : 3) and sole chickpea respectively.

Barley + Indian mustard intercropping systems were observed with higher benefit: cost (2.99–3.41) than barley + chickpea intercropping systems (2.81–2.95) at 6 : 2 and 6 : 3 row arrangements (Table 4). Barley + Indian mustard (6 : 3) was observed with the highest B:C (3.41), which was 18.8% higher than sole barley. Barley intercropped with either of intercrop at all row ratio except 6 : 1, was found with monetary equivalent ratio (MER) values more than 1, which indicate the monetary advantage over sole cropping (Table 4). The maximum MER was observed with barley + Indian mustard (6 : 3). Barley intercropped with either of intercrop at 6 : 1 row arrangement was found uneconomical as the MER values were less than 1 (0.87–0.96). Mbah and Ogidi (2012) also reported that in all the intercropping combinations, MER was above unity, an indication that it was more advantageous to grow the crops in mixture than sole cropping. Net returns per day had also followed the same trend as that of B:C and net returns and maximum per day return of ₹380.5 and the highest profit margin (PM) of 71% was obtained with barley + Indian mustard (6 : 3).

It was concluded that intercropping of barley + Indian mustard (6 : 3) proved the best option owing to relative yield advantage, economic return, optimum and efficient use of available resources because of to its maximum values of different land use, biological potential and economical evaluation indices. System recorded land-use efficiency of 135%, 34–36% relative advantage over sole crop, monetary advantage index (+17,975.4), net return (₹56,321/ha), benefit: cost (3.41) and ₹380/day return. Among the different row patterns, 6 : 3 ratio of barley + Indian mustard or chickpea was found most economical. Therefore, in the current scenario of growing population pressure, changing climate and the need to produce diverse products from the ever shrinking land holdings, intercropping of barley + Indian mustard (6:3) can be a very useful management strategy not only to meet out the food requirements but also to increase profitability for farmers.

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