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Productivity 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 in randomized block design with 11 treatments replicated thrice, to evaluate the intercropping of Indian mustard (Brassica juncea L.) and chickpea (Cicer arietinum) with barley (Hordeum vulgare L.). Results revealed that sole barley gave the highest grain as well as straw yield, which was significantly superior as compared to all other treatments except barley + chickpea (6:1). Seed and straw yields of barley was reduced in barley + mustard intercropping system as compared to barley + chickpea because mustard was found to be more competitive and dominant over barley. Among the intercropping treatments, barley + chickpea (6:2) was found most economical and efficient intercropping system with the highest barley-equivalent yield (BEY, 7.46 t/ha), effective-yield total (EYT, 6.91 t/ha), land-equivalent ratio (LER, 1.41), net returns (₹ 84,200/ha) and benefit: cost ratio (B:C, 4.15). Among different row patterns, on the basis of assessment of competition and yield advantage values, barley intercropped with either of the intercrop at 6:2 row ratio performed better. Hence barley + chickpea (6:2) intercropping system can be a best option to get more monetary returns and resource-use efficiency.

Key Words: Barley, Chickpea, Mustard, Oats, Yield, Land equivalent ratio, Effective yield total, Barley equivalent yield, Economics

Introduction

Barley (*Hordeum vulgare L.*) is a cereal grain, member of family 'Poaceae', which serve as a major animal feed crop since biblical time. It ranks next to wheat, rice and maize among cereals in its spread and is cultivated in all continents. Barley is a nutritious crop. The barley grain contains 65-68% starch, 10-17% protein, 2-3% free lipids, 4-9% â-glucans and 1.5-2.5% minerals Total dietary ranges from 11-34% containing soluble dietary fibre with 3-20% (Das and Kaur, 2016). Intercropping is an advanced agro-technique and is consider being an effective and potential means of increasing crop productivity, particularly for farmers having marginal and small holdings. It provides an efficient utilization of environmental resources, decreases the cost of production, provides higher financial stability for farmers, decrease the pest damage, inhibits the weed growth more than monocultures and improves soil fertility through fertilizers and increase yield and quality (Singh *et al*., 2016).

Legume intercropping systems play a significant role in the efficient utilization of resources and cereal legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping by increasing production per unit area. Moreover, various intercropping patterns of legumes and non-legumes (legumes with cereals and oilseeds) have a central feature of many agricultural systems in India (Meena and Kumhar, 2017). Intercropping establishes a beneficial relationship between component crops, increasing grain yield, stability and efficient resource utilization hence causes the weed suppression (Singh *et al*., 2014).

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

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resulting in 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 and Singh *et al*., 2017). These two crops also play an important role in protecting the environment from the risk associated with high-input agriculture. In general intercropping is being looked as an efficient and most economical production system in India as it not only increases the production per unit area and time but also improves the resource use efficiency and economic standard of the growers. 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 mustard and chickpea in different replacement series.

Materials and Methods

A field experiment was carried out at Agricultural Research Farm, Raja Balwant Singh College, Bichpuri, Agra, ($27^0$2' N and 77^0 9' E, 163.4 m above mean sea level) during the winter (*rabi*) seasons of 2011–12 and 2012–13 in a randomized block design, replicated thrice with 11 treatments viz. Barley+mustard (6:1, 6:2 and 6:3), Barley+chickpea (6:1, 6:2 and 6:3), barley (sole), mustard (sole), gram (sole), oat (sole) and barley (sole dual purpose). The total rainfall received during the crop season was 80.5 mm in 2011–12 and 58.0 mm in 2012–13. Soil of the field was sandy loam, slightly alkaline in *p*H (8.2), low in organic carbon (0.36%), available nitrogen (191 kg/ha) and medium in available phosphorus (30 kg P_2O_5/ha) and rich in available potassium (316 kg K_2O/ha). Sole barley and component crops in every intercropping system were sown at 20 and 30 cm row-to-row spacing, respectively. While sole mustard, chickpea, oat and barley (dual purpose) were sown at 45, 30 20 and 20 cm row-to-row distance, respectively. In intercropping treatments barley rows were replaced with 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, 'RSG 888' of chickpea, 'Laxmi' of mustard, 'Kent' of oats and 'RD 2552' of dual purpose barley were used in the study. The sowing of the experiment was done on 24 and 28 November during 2011–12 and 2012–13, using a seed rate of 100, 5, 80, 100, 75 kg/ha for barley, mustard, chickpea, barley (dual purpose) and oats, respectively. The barley, Indian mustard, chickpea, barley (dual purpose), oats were harvested and cut for fodder (dual purpose barley and oats) at 127, 116, 136, 136, 139 and 60 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 and sole crop of mustard was applied. The fertilizer schedule used for sole crop of chickpea was 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 33 and 67 days after sowing (DAS).

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, chickpea and oat/barley green fodder considered in the study was 11.50, 34.0, 34.0 and 0.75, respectively. Cost of cultivation, gross and net returns under different treatments work out on the basis of prevailing cost of different inputs. Power and labour for different operations, i.e. ploughing, sowing, weeding, plant protection, harvesting, and threshing were calculated per hectare basis as per normal rates prevalent at the Agricultural Research farm, Raja Balwant Singh College, Bichpuri, Agra. The cost of fertilizers, plant protection chemicals and seeds etc. were taken from the market rates. Net return (/ha) and benefit cost ratio were calculated. 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), effective yield total (EYT) and barley-equivalent yield (BEY) which gave more desirable competitive ability for the crops over other indices were calculated using the formula given by Willey and Rao (1980). 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 attributes and yield of base crop

Barley + chickpea intercropping with 6:2 row-ratio produced significantly more effective shoots per metre row length, although this remained statistically

at par with some of the row ratio treatments, namely barley + chickpea (6:1), barley + chickpea (6:3) and sole barley dual purpose (Table 1). Significantly higher spike length and spikelets/spike were recorded with barley + chickpea (6:2) followed by barley + chickpea (6:1). The maximum grains/spike and weight of grains/spike were obtained under barley + chickpea (6:2), which was significantly superior over all other sole and ratio treatments except barley + chickpea (6:1). Although the highest value of 1000-grains weight was noted with barley + chickpea (6:2) but this was failed to its superiority over barley + chickpea (6:1) and barley + chickpea (6:3) and also representing an increase of 3.5 and. 5.3% than sole barley and barley + mustard (6:2), respectively in this regard. This could be ascribed to the inter-generic competition between the component crops or possible under and above ground resources, viz. space, nutrients moisture. These results support the findings of Singh *et al.* (2016). Among the sole and intercropping systems, sole barley gave the highest biological yield, which was significantly superior as compared to all other treatments except (barley + chickpea 6:1) and being 11.5 and 29.2% higher biological yield than barley + chickpea (6:1) and barley + mustard (6:1), respectively. Grain as well as straw yield of barley was reduced drastically in barley + mustard intercropping as compared to barley + chickpea intercropping. Among the intercropping systems, the lowest barley grain and straw yields were obtained with barley + Indian mustard (6 : 3), while barley + chickpea (6 : 1) was found with highest grain (4.39 t/ha) and straw yield (6.66 t/ha), which were 10.4 and 10.0%, 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 *et al.* (2015) and Singh *et al.* (2017), who reported that sole barley gave significantly higher yield than intercropping.

Yield attributes and yield of intercrops

As compared to inter cropped with barley, the number of siliquae/plant of mustard were differed significantly, but sole mustard was found statistically at par with barley + mustard (6:1). The maximum weight of siliquae/plant and seeds/siliqua were obtained with sole mustard followed by barley + mustard (6:1) and representing an increase of 12.5 and. 7.4% than barley + mustard (6:3). Sole mustard recorded significantly more weight of seeds/plant and 1000-seeds weight over all other treatments except barley + mustard (6:1). The increase in weight of seeds/plant and 1000-seeds weight was 8.2 and 7.5% with sole mustard than barley + mustard (6:3),

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

Treatments	Effective shoots/ m row length	Spike length (cm)	Spikelets/ spike	Grains/ spike	Weight of grains/spike	1000-grains weight	Bio-mass yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Barley + Mustard (6:1)	78.5	6.8	22.5	22.5	1.7	39.9	9.53	3.77	5.76
Barley + Mustard (6:2)	78.4	6.6	22.5	22.2	1.7	39.5	9.33	3.68	5.65
Barley + Mustard (6:3)	77.2	6.5	22.4	22.0	1.4	39.0	9.21	3.61	5.60
Barley + Chickpea (6:1)	80.8	7.6	23.5	22.9	2.4	40.9	11.04	4.39	6.66
Barley + Chickpea (6:2)	81.3	7.9	24.6	23.1	2.7	41.6	10.88	4.32	6.56
Barley + Chickpea (6:3)	79.6	7.3	23.3	22.8	2.1	40.7	9.90	3.92	5.98
Sole Barley	78.9	7.0	23.0	22.5	1.8	40.2	12.31	4.90	7.40
Sole Oat	78.0	6.9	22.9	22.3	1.7	36.0	8.69(17.27)*	2.36	6.33
Sole Barley (dual purpose)	79.2	7.2	23.1	22.7	1.9	40.6	9.19(15.13)*	3.60	5.59
SEm±	0.7	0.1	0.4	0.1	0.1	0.3	0.46	0.19	0.27
CD (P=0.05)	2.2	0.4	1.2	0.3	0.4	1.0	1.37	0.57	0.82

*Values in parenthesis of fodder yield

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

Treatments	Siliquae/ pods/plant	Weight of siliquae/ pods /plant (g)	Seeds/ siliqua/ pod	Weight of seeds/ plant (g)	1000-seeds weight (g)	Bio-mass yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Barley + Mustard (6:1)	262.3	36.8	14.0	19.0	5.6	2.55	0.71	1.84
Barley + Mustard (6:2)	255.9	35.3	13.8	18.6	5.4	2.81	0.77	2.04
Barley + Mustard (6:3)	240.1	33.6	13.5	18.2	5.3	3.00	0.82	2.18
Sole Mustard	270.0	37.8	14.5	19.7	5.7	5.25	1.41	3.84
SEm±	2.7	0.7	0.2	0.3	0.1	0.37	0.14	0.25
CD (P=0.05)	8.2	2.1	0.6	1.0	0.2	1.14	0.42	0.76
Barley + Chickpea (6:1)	38.5	12.1	1.8	8.1	113.7	2.43	0.99	1.44
Barley + Chickpea (6:2)	39.5	13.3	2.0	9.0	115.1	2.62	1.07	1.55
Barley + Chickpea (6:3)	40.3	13.8	2.1	9.5	115.8	2.81	1.14	1.67
Sole Chickpea	39.0	12.9	1.9	8.7	115.6	5.01	2.02	2.99
SEm±	0.4	0.2	0.05	0.3	0.3	0.31	0.15	0.21
CD (P=0.05)	1.1	0.7	0.16	0.8	0.9	0.94	0.45	0.62

respectively. Among different intercropping treatments with barley, pods/plant and weight of pods/plant were significantly higher in barley + chickpea (6:3) as compared to all other treatments except barley + chickpea (6:2). Barley + chickpea intercropping (6:3) row-ratio being at par with barley + chickpea (6:2), produced significantly more seeds/pod and also resulted 9.5 and 14.3% more seeds/pod over sole chickpea and barley + chickpea (6:1), respectively. Significantly higher weight of seeds/plant and 1000-seeds weight were recorded with barley + chickpea (6:3) followed by sole gram and barley + gram (6:2) and representing an increase of 17.3 and 18.1% than barley + chickpea (6:1). This could be attributed to variations in the magnitude of competition among component crops grown in various proportions. These findings support those reported by Singh *et al.* (2017), who reported higher yield attributes of barley, when intercropped with chickpea compared to other crops. An intercropping reduced the biological, seed and straw yields significantly compared with sole crop. Sole mustard produced significantly higher yields over all row ratios. Marked reduction of 51.3, 50.1% and 57.5% was observed in mustard biological, seed and straw yields, respectively in barley + mustard (6:1) compared to sole mustard. Similarly, biological, seed and straw yields were reduced to 51.5, 50.9% and 51.8%, respectively, in barley + chickpea (6:1) compared to sole chickpea. Among the intercropping systems, the highest biological and 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.* (2016) and Singh, *et al.* (2016) who reported greater competition ability of barley when intercropped with chickpea.

Barley-equivalent yield

Barley + chickpea (6:2) showed significantly higher barely-equivalent yield (BEY) over all other sole and intercropping systems except barley + chickpea (6:1) intercropping system (Table 3). Among the intercropping systems, barley intercropped with mustard at all row ratios gave significantly higher BEY over all sole cropping systems. The increment in the barley-equivalent yield due to barley + chickpea (6:2) over barley + chickpea (6:3), barley + mustard (6:1), sole barley, sole barley (dual purpose) and sole oats was tune of 2.6, 27.3, 51.3, 62.9 and 114.4 per cent, respectively.

Effective yield total

Amongst different intercropping with barley, highest effective yield total (6.90 t/ha) was recorded with

Table 3: BEY, EYT and LER as affected by intercropping of Indian mustard and chickpea with barley (pooled data of 2 years)

Treatments	Barley equivalent yield (t/ha)	Effective yield total (t/ha)	Land equivalent ratio
Barley + Mustard (6:1)	5.86	6.24	1.27
Barley + Mustard (6:2)	5.95	6.36	1.30
Barley + Mustard (6:3)	6.02	6.46	1.32
Barley + Chickpea (6:1)	7.30	6.78	1.38
Barley + Chickpea (6:2)	7.46	6.91	1.41
Barley + Chickpea (6:3)	7.27	6.67	1.36
Sole Barley	4.93	4.93	1.00
Sole Oat	3.48	3.48	1.00
Sole Barley (dual purpose)	4.58	4.58	1.00
SEm±	0.06	0.04	-
CD (P=0.05)	0.18	0.12	-

Table 4: Economics of barley as influenced by intercropping with mustard and chickpea (pooled data of 2 years)

Treatments	Cost of cultivation(x10^3 ₹ /ha)	Gross income(x 10^3/ha)	Net income(x 10^3/ha)	B :C ratio
Barley + Mustard (6:1)	25.7	87.4	61.7	3.40
Barley + Mustard (6:2)	25.5	88.4	62.9	3.46
Barley + Mustard (6:3)	25.4	89.3	63.9	3.52
Barley + Chickpea (6:1)	26.5	108.9	82.4	4.12
Barley + Chickpea (6:2)	26.8	110.9	84.1	4.15
Barley + Chickpea (6:3)	26.9	107.4	80.5	3.99
Sole Barley	26.0	78.6	52.6	3.02
Sole Mustard	24.6	53.5	28.9	2.18
Sole Chickpea	28.2	79.1	50.9	2.80
Sole Oat	27.5	74.4	46.9	2.70
Sole Barley (dual purpose)	26.2	69.5	43.3	2.65
SEm±	-	0.3	0.4	-
CD (P=0.05)	-	1.0	1.2	-

barley + chickpea (6:2), which was significantly higher over all other intercropping systems and represented an increase of 3.4 and 10.6% over barley + chickpea (6:3) and barley + mustard (6:1), respectively. The lowest effective yield total was obtained by barley + gram (6:1).

Land-equivalent ratio

Intercropping advantage measured in terms of land-equivalent ratio (LER) in intercropping systems revealed that LER for all intercropping treatments greater than, indicating an advantage of intercropping compared to the sole crop (Table 3). The highest LER (1.41) was found with barley + chickpea (6:2) followed by barley + chickpea (6:1) with LER (1.38), which indicates that 41% more area would be required by a sole cropping system to equal the yield of intercropping system. LER of barley was increased as the proportion of intercrop of mustard increased from 6:1 to 6:3. LER of barley was lower in barley + mustard as compared to barley + chickpea intercropping. The lowest LER of intercrop was recorded with barley + mustard 6:1 row pattern of intercropping which indicates that there was an advantage for barley in this intercropping system. 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.

Economics

The higher cost of cultivation was incurred on sole chickpea crop, while the lowest amount was spent on sole mustard. However, all the intercropping systems of mustard had lesser cost of cultivation as compared to all sole cropping systems except sole mustard. Among the intercropping treatments, barley

+ chickpea (6:2) was obtained highest gross return, which was 41.1% higher than sole barley and it was also significantly higher over all other treatments. Net returns had also followed same trend as that of gross return. The highest and lowest net returns were found with barley + chickpea (6:2) and sole mustard, respectively. Barley + chickpea intercropping systems were observed with higher benefit: cost ratio (3.99–4.15) than barley + mustard intercropping systems (3.40-3.52) at 6:1 to 6:3 row arrangements (Table 4). Barley + chickpea (6:2) was observed with the highest B:C ratio (4.15), which was 37.4% higher than sole barley. The additional net profit was obtained by barley + gram (6:2) Rs. 1700 to Rs. 55200 as compared to all other treatments.

It was concluded that intercropping of barley + chickpea (6:2) 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 net return (84200/ha) and benefit: cost (4.15). Among the different row patterns, 6:2 ratio of barley + 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 + chickpea (6:2) can be a very useful management strategy not only to meet out the food requirements but also to increase profitability.

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