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Inclusion of legume and oilseed crop in barley-based intercropping system for enhancing land utilization and productivity

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ABSTRACT

The experimentwasconducted at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar, during the Rabiseason of 2021-22 and 2022-23. It consisted of 11 treatments. Sole barley, Sole field pea, Sole linseed, barley + field pea (3:3), barley + field pea (4:4), barley + field pea (5:5), barley + field pea (6:6), barley + linseed (3:3), barley + linseed (4:4), barley + linseed (5:5) and barley + linseed (6:6). The experiment was laid out in randomized block design with three replications. All the yield attributes were recorded maximum under sole cropping of different crops when compared with their respective intercropping systems in various row ratios. Intercropping of barley with field pea (6:6) was found most economical as compared to barley+linseed and sole cropping of barley, field peaor linseed. The maximum barley equivalent yield of 71.37 and 66.09 q ha^{-1}was recorded in barley+fieldpeaintercropping having 6:6 or 5:5 rows, respectively. Barley crop produced significantly highest number of tillers/m^2(122.2) and test weight was 47.4g when grown as a sole crop followed by barley + field pea (6:6). Barley with field pea (6:6) fetched maximum net returns and B:C of 87111 Rs./ha and 3.39, respectively.Intercropping experiments face challenges related to complex management because it requires careful planning besides considering the crop compatibility and resource allocation.

Keywords: *Intercropping, barley, fieldpea, linseed, yield, economics, correlation and regression*

INTRODUCTION

Food and nutritional security are a prerequisite for ensuring national safety and human survival. The global human population is projected to cross nine billion in 2050. Thus, to fulfill the enhanced demands of an increasing population for food and feed, it is estimated that the current crop yield needs to be increased by 50% in 2030 and 100% in 2050. The continuous decline in cultivable lands due to urbanization and industrialization has limited the further expansion in the cultivation area of cereals and legumes. This situation is more serious in the developing countries (e.g., China, Pakistan, and India) that have more population and less cultivable land. Therefore, in the present scenario of limited resources (i.e., land and water) and climate change, it is important to develop new cropping systems (i.e., intercropping), which can increase crop yields by effectively using the limited resources without affecting the environment.

Thus, Intercropping is a traditional farming system that increases crop diversity to strengthen agroecosystem functions while decreasing chemical inputs and minimizing negative environmental effects of crop production, and makes it more sustainable [1] and[2].Intercropping of cereals with legumes can be helpful in increasing the resource use efficiency and climate resilience in this modern era of agriculture by stabilising the crop productivity while maintaining the ecological balance. Likewise, the intercropping mission under the National Mission on Edible Oils-Oilseeds aims to increase oilseed production by incorporating oilseeds into existing cropping systems to make better use of land. This strategy helps to boost oilseed yields without expanding cultivated land, thereby contributing to self-sufficiency in edible oils.Among the cereals, barley is a versatile crop having high fiber content, particularly beta-glucan, and it's a rich source of vitamins and minerals. It is a very hardy and nutrient-rich crop, in India, it has been grown in an area of 0.55mha with the production and productivity of 1.69mt and of 30q/ha during 2023-24 [3].

Pulses in the country face a significant demand-supply mismatch. The study projects that production will reach over 28 million tonnes by 2026. However, to meet the estimated demand of 32–33 million tonnes by 2030–31, production must grow at an annual rate of 3%. Given the volatility in output, this gap is expected to widen further. Consequently, low production levels are contributing to a decline in per capita availability.Inclusion of legumes, particularly pulses, helps in agricultural sustainability and conserves soil biodiversity [4]. Jensen *et al.* [5] estimated that on a global scale, intercropping can reduce the requirements for fossil-based fertilizer N by approx. 26% by increasing the nitrogen use efficiency (NUE) and thereby reducing the emission of N_2O. Further, the World Resources Institute projected that greenhouse gas (GHG) emissions rises from agricultural and allied activities. In addition, N_2O is emitted from agricultural fields, adding up to a total GHG emission of 703 Tg CO_2 equivalents, or 13.4% of total GHG emissions from agriculture [6]. So, the inclusion of pulses or legumes may be helpful in mitigating the effects of climate change also. The grain legume intercropped with cereals is a potent net land-saving option instead of sole cropping. In India, annual oilseed crops are cultivated across 26.67 million hectares, yielding approximately 30.06 million tonnes per year. Around 70% of this cultivation occurs under rainfed conditions [7].

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In recent years, the area under oilseed cultivation has generally declined, primarily due to their relatively lower profitability compared to competing crops, therefore, oilseed crops can be taken as an intercrop for the substantial resource use. Thus, the present study was planned to check the feasibility of fieldpea or linseed as an intercrop with barley-based cropping system with different row ratios.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar, during the *rabi* season of 2021-22 and 2022-23. Hisar is situated at 29°10' N latitude and 75° 46' E longitude and at an altitude of 215.2 m above the mean sea level. The maximum and minimum temperatures of 41.5 & 34.5 ^{0}C and 3.3 & 3.6 ^{0}C were recorded in the two subsequent years of study, respectively. Total rainfall received was 72.5 mm in the first year and 22.7 mm in the second year of experimentation. The experimental site was sandy loam in texture, having pH 7.9, EC 0.32 dS m^{-1} and organic carbon 0.46% with low available nitrogen (125 kg ha^{-1}), medium phosphorus (13.5 kg ha^{-1}) and medium potassium (290 kg ha^{-1}) status. The experiment consisted of 11 treatments,*viz*. Sole barley, Sole field pea, Sole linseed, barley + field pea (3:3), barley + field pea (4:4), barley + field pea (5:5), barley + field pea (6:6), barley + linseed (3:3), barley + linseed (4:4), barley + linseed (5:5) andbarley + linseed (6:6). The experiment was laid out in randomized block design with three replications. The crops were sown on 15th and 17th November during 2021-22 and 2022-23, respectively. Fertilizers were (60 kg N and 30 kg P_2O_5 ha^{-1}) applied through urea and DAP. The varieties used in the study were BH 946 (Barley), HFP 1428 (Field pea), and K 2 (Linseed). Different competition functions were calculated with the following formulas:

(A) Land equivalent ratio (LER): $\sum_{i}^{m} \frac{Yi}{Yij}$

Yi = individual crop yield under the intercropping system,
Yij = individual crop yield under the sole cropping system.

(B) Aggressivity (A): $Aab = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$

Yaa = yield of component 'a' as sole crop,
Ybb = yield of component 'b' as sole crop,
Yab = yield of component 'a'as intercrop grown in combination with component 'b,'
Yba = yield of component 'b' as intercrop grown in combination with component 'a,'
Zab = sown proportion of component 'a' in combination with 'b,'
Zba = sown proportion of component 'b' in combination with 'a'

(C) Relative crowding coefficient (RCC): $K = \frac{Yab \times Zab}{(Yaa - Yab) \times Zab} \times \frac{Yba \times Zab}{(Yb - Yba) \times Zba}$

Yaa = yield of component 'a' as sole crop,
Ybb = yield of component 'b' as sole crop,
Yab = yield of component 'a' as intercrop grown in combination with component 'b,'
Yba = yield of component 'b' as intercrop grown in combination with component 'a,'
Zab = sown proportion of component 'a' in combination with 'b,'
Zba = sown proportion of component 'b' in combination with 'a'

Area time equivalent ratio (ATER): $ATER = \frac{La \times Ta + Lb \times Tb}{T}$

Where, La and Lb are partial LER of component crops A and B, Ta and Tb are the durations of crops A and B, and T is the total duration of the intercropping system.

The yield attributes of different crops were recorded at harvest. The grain yield of the net plot was converted into q ha^{-1}. The yields of different intercrops/crops are converted into barley equivalent yield based on the price of the produce.

CEY (kg/ha)=Yield (main crop) + {Yield (intercrop) × Price (intercrop)/Price (main crop)}

Net returns (₹) were calculated by subtracting the cost of cultivation from gross returns on the basis of the market price of the economic product of the crop. The benefit/cost ratio was calculated by dividing gross returns by cost of production. The two years data were pooled and analyzed using appropriate analysis of variance (ANOVA). OPSTAT software available at the CCS HAU website was used to carry out statistical analysis.

RESULTS AND DISCUSSION

YIELD AND YIELD ATTRIBUTES

Grain yield of barley, fieldpea, and linseed was higher in sole cropping than the intercropped mixtures, irrespective of the row ratios, probably due to the absence of competition from the companioncrop. Among the various intercroppingsystems, a higher grain yield of barley was recorded when it was grown in the row ratio of (6:6) with fieldpea as an intercrop. The intercropping of barley+fieldpea recordeda higher yield as compared to barley+linseed when grown with the same row ratios. However, the significant yield increase was not noticed in barley when the row ratios were increased from 5 to 6 with fieldpea and linseed. The maximum grain yield of 32.67 qha^{-1} was recorded in barley+fieldpea (6:6), which was at par with barley+fieldpea (5:5), but significantly superior to rest of the intercropping combinations, including all the barley+linseed intercropping systems. Minimum grain yield was recorded in barley+linseed(3:3) row ratios. The yield reduced significantly with a reduction in row ratiosirrespective of intercrop combinations. Significantly higher barley equivalent yield of 71.37 q/ha was found in barley+fieldpea (6:6) intercropping system, which was at par with barley+fieldpea (5:5), but significantly higher than all other treatments. The yield enhancement in barley+fieldpea (6:6) was 7.98, 11.3, 45.3, and 55.79% as compared to barley+fieldpea (5:5), sole fieldpea, barley, and linseed, respectively. This might be due to the fact that appropriateintercropping ratios supplement the substantial amount of nitrogenand thereby increase the yields of the companion crop by improving the nutrient use. These results were also confirmed by Dhima*et al*. [8];Patel *et al*. [9]. Barley+linseed (6:6) intercropping system was found better in terms of barley equivalent yield (54.86 qha^{-1}) when compared with sole barley and linseed, but yielded 16.88% lower than sole fieldpea due to the higher seed production of fieldpea.All yield attributes of barley were varied significantly by the different treatments. Almost all the yield attributes were found to be maximum in sole cropping of barley, except the number of grans per earhead. Barley crop produced significantly highest number of tillers/m^2 when grown in sole cropping i.e. 488.8 which were29.2 more in numbers as compared to tillers/m^2 in barley under barley+fieldpea (6:6) row ratios. Tillers per m^2were affected significantly when row ratios were increased from3:3 to 6:6 irrespective of intercrop.Whereas, the number of grains per earheadin barley (48.57) were found to bemaximum with barley+fieldpea (6:6), which was at par with sole barley (48.33) and barley+field pea (5:5), however significantly superior to others.

Test weight of 47.4 g which was recorded highest found in sole barley; however all the intercropping systems were inferior in terms of 1000 grain weight of barley. The test weight of barley in intercropping systems having same row ratios were resulted at par despite of different crops as an intercrop. The data pertaining to correlation of grain yield of barley with its yield attributes (Table 3) indicate that test weight (r=0.903**, significant at 1% level), no. of grains per earhead (r = 0.722*, significant at 5% level), and tillers/m^2 (r = 0.887**, significant at 1% level), were highly significant and positively correlated with grain yield. This means grain yield was highly correlated with test weight followed by tillers/m^2 and then by no. of grains per earhead. The results of regression analysis depicted that variation in the barley equivalent yield had been explained 64% and 54% by the independent variables no. of grains perearhead and test weight (Fig.1 and 2) in the model, which showed that grain yield could be well estimated from the model using the above mentioned parameters.

In the case of intercrop, all the yield attributes were found to be maximum in sole cropping when compared with their intercropping with barley in different row ratios. The number of branches per plant was 2.36 and 4.49 in sole cropping of fieldpea and linseed, respectively. The number of pods per plant was 20.7 in field pea and 137.9 in linseed when sown in sole cropping. A number of seeds per pod was4.97 and 6.85, whereas the 100-seed weight (seed index) were 16.7 g and 0.6 g in fieldpea and linseed, respectively.

ECONOMICS

Barley+fieldpea (6:6) was found most remunerative with the Net returns of 87111 Rs. followed by barley+fieldpea (5:5). This might be due to the better availability and utilization of resources in the barley+fieldpea intercropping system as compared to barley+linseed (Table 2). Moreover, intercropping of barley with field pea,notwithstanding row ratios, fetched more returns as compared to sole cropping of barley (51,555 Rs./ha) or linseed (37,874 Rs./ha). Sole fieldpea (71,532 Rs./ha) cultivation has higher remuneration than sole cropping of barley and linseed due to its higher market price and yield than barley and linseed, respectively, which enhances profitability. However, in the barley+linseed intercropping system, only the 6:6 row ratio had higher returns than sole barley, but the rest of the treatments had lower returns.Variation in monetary returns in intercropping systems was also reported by Poddar*et al*. [10]. A significant variation was also found in the Benefit-cost ratio of different treatments. Maximum B:C of 3.39 was observed in barley+fieldpea (6:6) intercropping system which was at par with barley+fieldpea (5:5) but significantly superior over other treatments. Though there is not much difference in cost of cultivation between the treatments but variation was due to yield and prices of the respective crops. Sathiya*et al*. [11] reported thatfinger millet with black gram (4:1) combination resulted in a favourable benefit/cost ratio (2.84), convincingof its potential for improving profitability and sustainability.

LER and competitive functions

Variations in terms of LER was recorded among different intercropping systems (Table 4). Almost all treatments recorded higher LER over sole cropping, except intercropping in 3:3 row ratio, irrespective of crop and barley+linseed (4:4) treatment.

Among the various intercropping systems,barley+fieldpea (6:6) recorded the highest LER (1.27) which was at par with barley+fieldpea (5:5) and barley+linseed (6:6). Aggressivity, relative crowding coefficient(RCC) and area time equivalent ratio(ATER) of barley+fieldpea/linseed intercropping systems are presented in Table4. Aggressivity value measures the competitive ability of the component crops in an intercropping system. The result showed that barley was more competitive than the intercrops. Regardless of the intercropping system, there was a positive sign for barley and a negative sign for the intercrops, indicating that barley was dominant, while intercropswere suppressed. Though, the treatments were not significantly varied. The intercropping of barley withfieldpea at the row ratio of 5:5 and 6:6 was more advantageous, as the product of relative crowding coefficient (K) was more than 4 and it showed the high complementaryrelationship of the barley with fieldpea in these ratios. However, some other combinations also had the value >1, which showed positive correlation but not upto that extent. The value of Kwas,however,is significantly highest in 6:6 row ratio of barley+fieldpea(5.76) followed by barley+fieldpea (5:5) intercroppingsystem.In terms of ATER also, barley+fieldpea (6:6) intercropping system resulted in better utilization of area and time, with the highest value of 1.21, which was significantly superior to all other treatments except barley+fieldpea (5:5) may be due to the fact of more competition in narrow row ratios and long duration of linseed crop.

CONCLUSION

On basis of two years' pooled data, it can be concluded that, intercropping of barley with field pea (6:6) was found most remunerative and suitable, having LER, Net returns and B:C of 1.27, 87111 Rs./ha and 3.39, respectively. However, all the row ratios of barley +field pea exhibited the highest values for all the parameters as compared to sole barley cropping.

FUTURE SCOPE OF STUDY

Future studies could include other legume crops with different row ratios in barley to check their feasibility in varying agro-climatic conditions. Crop diversification, which is a need of today's era may also be fulfilled with the intercropping systems. It also strengthens agro-ecosystem functions while decreasing the use of chemical inputs and minimizing negative environmental effects of crop production and making it more sustainable. Intercropping of cereals with legumes or oilseed can be helpful in meeting the demand of pulses and oilseeds, increasing the resource use efficiency and climate resilience in this modern era of agriculture by stabilising the crop productivity while maintaining the ecological balance.

CONFLICT OF INTEREST

All authors declared that there is no conflict of interest.

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Table 1. Yield and yieldattributes of different crops as influenced by barley based intercropping system (Pooled data of two years)

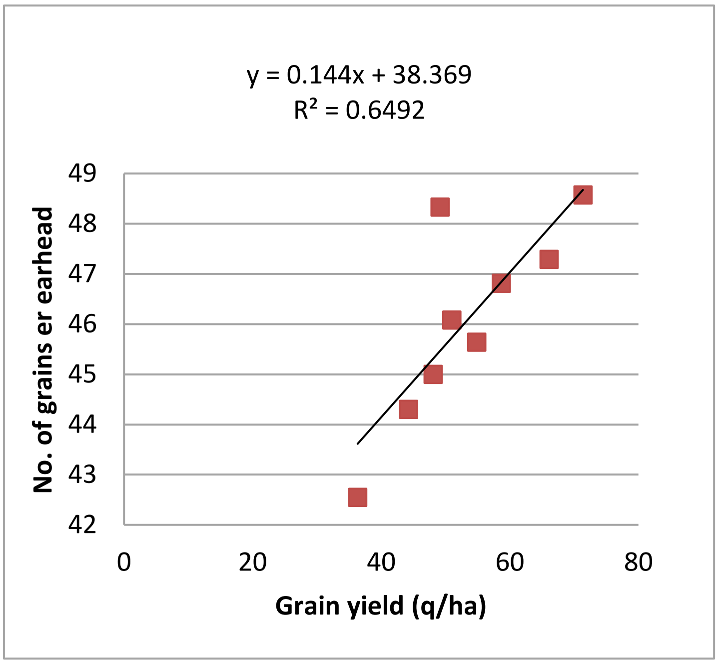
Treatments	Tillers/m²	No. of branches per plant	No. of pods/plant	No. of grains per earhead	No. of seeds per pod	1000 grain weight (g)	100 seed weight(g)	Grain yield (q ha⁻¹)		BEY (q ha⁻¹)
	barley	Intercrop	Intercrop	barley	Intercrop	barley	Intercrop	barley	Intercrop	system
Sole barley	488.8	-	-	48.33	-	47.4	-	49.12	-	49.12
Sole field pea	-	2.36	20.7	-	4.97		16.7	-	20.02	64.12
Sole linseed	-	4.49	137.9	-	6.85		0.6	-	13.44	45.81
barley + field pea (3:3)	375.6	1.86	17.5	46.08	3.96	44.4	14.9	26.03	7.78	50.95
barley + field pea (4:4)	399.2	1.88	18.5	46.81	4.19	45.3	15.3	26.77	9.96	58.67
barley + field pea (5:5)	426.0	2.00	18.8	47.29	4.45	46.1	15.7	29.58	11.40	66.09
barley + field pea (6:6)	459.6	2.08	19.8	48.57	4.58	47.2	16.1	32.67	12.08	71.37
barley + linseed (3:3)	336.8	2.5	94.9	42.55	4.82	42.9	0.4	20.76	4.57	36.33
barley + linseed (4:4)	365.2	2.75	104.2	44.30	5.57	43.8	0.5	23.15	6.19	44.23
barley + linseed (5:5)	386.8	3.37	117.3	45.00	6.03	44.8	0.5	24.93	6.79	48.05
barley + linseed (6:6)	426.4	3.68	126.9	45.64	6.38	45.5	0.6	27.60	7.99	54.86
SE (m)±	5.92			0.59		0.91		1.16		1.86
CD (P=0.05)	18.0	-	-	1.81	-	2.8	-	3.5	-	5.54

Table 2. Economics of different barley based intercropping systems. (Pooled data of two years)

	Cost of production (Rs. ha⁻¹)	Gross returns (Rs. ha⁻¹)	Net returns (Rs. ha⁻¹)	B:C
Sole barley	38330	89885	51,555	2.34
Sole field pea	34475	106007	71,532	3.07
Sole linseed	37470	75344	37,874	2.01
barley + field pea (3:3)	36403	89125	52,723	2.45
barley + field pea (4:4)	36403	101746	65,344	2.79
barley + field pea (5:5)	36403	114355	77,952	3.14
barley + field pea (6:6)	36403	123513	87,111	3.39
barley + linseed (3:3)	37900	63845	25,945	1.68
barley + linseed (4:4)	37900	77077	39,177	2.03
barley + linseed (5:5)	37900	83618	45,718	2.21
barley + linseed (6:6)	37900	95188	57,288	2.51
SE (m)±	-	-	3068	0.08
CD (P=0.05)	-	-	9114	0.25

Table 3. Correlation between grain yield of barley and its yield attributes

	Grain yield	Test weight	No. of grains per earhead	Tillers/m²
Grain yield	1			
Test weight	0.903**	1		
No. of gains/earhead	0.722*	0.937**	1	
Tillers/m²	0.887**	0.935**	0.864**	1



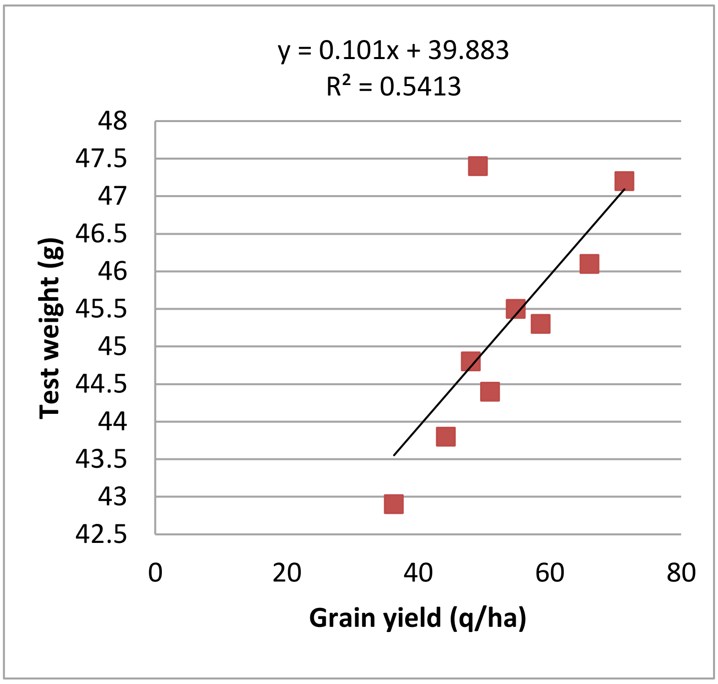


Fig. 1 & 2: Regression between barley grain equivalent yield and their respective yield attributes

Table 4. Effect of different barley based intercropping systems on competition functions

Treatments	LER	Aggressivity		RCC			ATER
		barley	Intercrop	barley	Intercrop	System	
sole barley	1.00	-	-	-	-	-	-
sole field pea	1.00	-	-	-	-	-	-
sole linseed	1.00	-	-	-	-	-	-
barley + field pea (3:3)	0.92	0.29	-0.29	1.13	0.87	0.98	0.88
barley + field pea (4:4)	1.04	0.11	-0.11	1.24	1.52	1.94	1.01
barley + field pea (5:5)	1.17	0.05	-0.05	1.62	3.59	4.87	1.14
barley + field pea (6:6)	1.27	0.11	-0.11	1.99	2.74	5.76	1.21
barley + linseed (3:3)	0.76	0.40	-0.40	0.74	0.75	0.54	0.75
barley + linseed (4:4)	0.93	0.32	-0.32	0.84	1.14	0.94	0.87
barley + linseed (5:5)	1.01	0.32	-0.31	0.95	1.65	1.56	0.94
barley + linseed (6:6)	1.16	0.38	-0.38	1.32	3.46	3.98	1.10
SE (m)±	0.04	0.11	0.11	0.21	0.88	0.84	0.05
CD (P=0.05)	0.13	NS	NS	0.65	NS	2.58	0.15

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