Range Management and Agroforestry 45 (2) : 321-328, 2024
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2024.v45.i2.18

Research article

Assessment of barley and berseem for feed-forage yield, land use efficiency and profitability under varying intercropping row ratios

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Received: 06th September, 2023 Accepted: 08th July, 2024

Abstract

An experiment was conducted during *rabi* season of 2020-21 to record the effect of different intercropping row ratios on feed and forage yield, land use efficiency and profitability. The experiment consisted of nine treatments *viz.* sole barley, sole berseem, intercropping of barley + berseem in 1:1, 2:1, 1:2, 2:2, 3:1, 1:3 and 3:3 row ratios. The experiment was laid out in a randomized block design with three replications. The results of the study revealed that in barley, maximum grain yield (3.46 t ha^{-1}) was recorded with sole barley, which was at par with 2:1 row ratios of barley + berseem intercropping. Intercropping of barley + berseem in 2:1 row ratio also recorded maximum dry fodder yield (6.27 t ha^{-1}), land equivalent ratio (1.21), relative crowding coefficient (3.73), phosphorus uptake (12.34 kg ha^{-1}), net return (Rs 45834 ha^{-1}) and benefit-cost ratio (2.44). Further, in forage berseem maximum green fodder yield (49.03 t ha^{-1}), crude protein (18.27%), TDN content (64.08%), dry matter intake (2.71%), digestible dry matter (66.41%) and relative feed quality (141.16%) were recorded with sole berseem treatment followed by 1:3 and 1:2 row ratio of intercropping.

Keywords: Dry matter intake, Economics, Fodder yield, Fodder quality, Grain yield

Introduction

Adequate feed and fodder are essential for enhancing livestock productivity but the growing gaps between requirement and availability warrant concern for sustaining animal productivity (Mahanta *et al.*, 2020). As per the estimates of the National Institute of Animal Nutrition and Physiology (NIANP), the deficit in the requirement and the availability of dry fodder, green fodder and concentrates during 2015 was to the extent of 21, 26 and 34%, respectively and it is likely to increase to 23, 40 and 38%, respectively by 2025 (Parmar and Misra, 2020). To bridge this gap there is an urgent need either to increase the area under feed and fodder production or to increase the productivity per unit area per unit time. Due to competition with the other agricultural crops and farmer's preference to grow food and cash crops, first approach of increasing the area under forage crops is not possible as the land available for cultivation of green fodder crops has also remained static at around 5% of the total cropped area for the last few decades (Roy *et al*., 2019). So, the only alternative to meet the feed and fodder requirement is to increase the yield of these crops per unit area per unit time. Therefore, an intercropping system that provides crop intensification both in time and space dimensions (Reddy, 2008) can be used as a tool for the production of adequate feed and fodder. Intercropping of cereal fodder crops with leguminous fodder crops appears to be a good approach for fodder production, efficient utilization of land resources, fodder quality and for providing stability to the system (Tripathi, 1989). Cereals and leguminous fodder crops are often intercropped to increase the productivity per unit area and the quality of the mixed forage crops (Ghosh *et al*., 2009).

Barley (*Hordeum vulgare* L.) is an important *rabi* season cereal crop of northern India, and it is of utmost importance for livestock feeding. After wheat and oats, barley is the third readily degradable cereal crop for ruminants and improves microbial nutrient assimilation by providing more synchronous release of energy and nitrogen (Nikkhah, 2012). Similarly, berseem (*Trifolium alexandrinum* L.) is also considered a prominent leguminous fodder crop of *rabi* season in India(Pradeep Behari *et al*., 2003) as it remains soft and

succulent at all stages of growth with better digestibility and palatability (Chaterjee and Das, 1989). Intercropping of barley with berseem provided higher dry fodder yield and crude protein as compared to sole planting (Sultan and Shafie, 2015). Forage quality indicators also suggested that intercropping of berseem with barley was superior as compared to oats (Ross *et al*., 2004). However, the intercropping practices of grain barley + forage berseem have not been evaluated extensively. Moreover, the identification of suitable intercropping combinations for this region is expected to help the farmers improve farm profitability and livestock productivity. Therefore, the present study was carried out to evaluate the suitable intercropping combination of barley and berseem for enhancing grain and forage yield, land use efficiency and net profitability in the region of Yamuna ravines of Uttar Pradesh.

Materials and Methods

Study area and soil site: A field experiment was conducted at the Agriculture farm of ICAR-Central Institute for Research on Goats, Makhdoom, Uttar Pradesh, during the *rabi* season of 2020-21 to record the effect of different intercropping row ratios on yield, intercropping indices and economics of grain barley and forage berseem. The mean weekly meteorological data recorded at the institute showed that the maximum and minimum temperatures during the crop growth period ranged between 19.9 to 35.6ºC and 3.9 to 14.6ºC, respectively. The mean relative humidity ranged between 52.7 to 81.4% and the total rainfall received during the crop-growing season was 27.5 mm. The soil of the experimental field was nearly neutral in reaction (pH 7.2) with EC of 0.28 dS m^{-1}. The soil was low in organic carbon (0.29%), medium in available nitrogen (243 kg ha^{-1}) and potassium (170 kg ha^{-1}); and high in available phosphorus (41 kg ha^{-1}).

Treatment details: The experiment consists of nine treatments *viz*., sole barley, sole berseem, intercropping of barley + berseem in 1:1, 2:1, 1:2, 2:2, 3:1, 1:3 and 3:3 row ratios. The experiment was laid out in a randomized block design with three replications. The field was allocated into 27 plots and each plot was 6 m x 3 m in size. All treatments were allocated in these small plots without any biases. Barley variety Narendra Barley-2 and berseem variety BB-2 were sown as per the treatment on 7th November 2020 by using the seed rate of 100 and 25 kg ha^{-1} in sole barley and sole berseem, respectively. Further, the crops were sown with row-to-row spacing of 25 cm in both sole as well as in intercropping combinations. All the intercultural operations, like thinning and weeding, were done manually.

Observations recording: Grain barley was harvested at 120 days after sowing (DAS), whereas forage berseem was harvested in three cuts, *i.e.,* first at 50 DAS, second at 40 days after the first cut, and third at 30 days after the second cut. Harvesting for green fodder was taken from the net plot, then weighed and converted into t ha^{-1} to obtain green fodder yield. The randomly collected green fodder samples were first dried in the sun and then transferred in a hot air oven for drying at a temperature of 65°C till constant weight. On the basis of these samples, the green fodder yields were converted into dry fodder yields and were expressed in t ha^{-1}. Grain yield was obtained after threshing and winnowing, and straw yield was calculated by subtracting the corresponding grain yield from the total plot yield.

Intercropping indices calculation: The intercropping indices were calculated from dry fodder yield of barley and berseem by using the following formulas: Land equivalent ratios (LER) = La+Lb, La =Yab/Yaa, Lb = Yba/Ybb where La and Lb were the land equivalent ratio of barley and berseem, respectively. Yaa and Ybb were yields as a sole crop of a (barley) and b (berseem) and Yab and Yba were yields as intercrops of barley and berseem, respectively. Aggressivity of barley (Aab) = {(Yab/Yaa × Zab) - (Yba/Ybb × Zba)} and of berseem (Aba) = {(Yba/Ybb × Zba) - (Yab/Yaa × Zab)}. Competitive ratio of barley (Cra) = (LERa/LERb) (Zba/Zab) and of berseem (Crb) = (LERb/LERa) (Zab/Zba). Relative crowding coefficient of barley (Kab) = (Yab × Zba)/(Yaa-Yab) Zab and of berseem (Kba) = (Yba× Zab)/(Ybb – Yba) Zba, where Zab, the proportion of intercrop area allocated to barley and Zba, the proportion of intercrop area allocated to berseem.

Nutrient analysis and fodder quality: Analysis of nutrients was carried out by using the digested samples by following methods: nitrogen by using the micro Kjeldahl method (AOAC, 2005), phosphorus by yellow color method (Richards, 1968) and potassium by flame photometer method (Richards, 1968). Crude protein content was determined by multiplying the N with the factor 6.25, and ether extract and ash contents were analyzed following the AOAC (2005) method. Total digestible nutrients (TDN), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV) and relative feed quality (RFQ) were estimated according to the following equations adapted from Horrocks and Vallentine (1999) whereas, relative feed quality (RFQ) adapted from Undersander *et al*. (2010): TDN = –1.291 × ADF + 101.35; DMI = 120/%NDF on dry matter basis; DMD = 88.9 – (0.779 × ADF); RFV = DMD × DMI × 0.775; RFQ = [(DMI, % of BW) x (TDN, % of DM)]/ 1.23.

Economics and statistical analysis: Further, to find out the most profitable treatment, the economics of different treatments were worked out in terms of net return (Rs ha^{-1}) and B: C ratio. Net return = Gross return (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1}) and B:C ratio = Gross return (Rs ha^{-1})/cost of cultivation (Rs ha^{-1}). All the data were subjected to statistical analysis by adopting an appropriate method of analysis of variance as described by Gomez and Gomez (1984).

Results and Discussion

Grain and forage yield: Intercropping of grain barley and forage berseem with varying row ratios had a significant effect on grain and straw yield of barley and green and dry fodder yield of berseem (Table 1)**.** The highest grain yield (3.46 t ha^{-1}) of barley was recorded in sole barley treatment. However, intercropping of barley + berseem in 3:1 (3.25 t ha^{-1}) and 2:1 (3.11 t ha^{-1}) row ratios was also recorded at par grain yield with sole barley treatment. In forage berseem highest green fodder yield (49.03 t ha^{-1}) was recorded with sole berseem treatment. Further, the highest dry fodder yield of berseem (2.66, 1.76 and 1.27 t ha^{-1} in I, II and III cuts, respectively) and barley *i.e.,* straw yield (4.96 t ha^{-1}) were recorded with sole beseem and sole barley treatment, respectively. However, highest total dry fodder yield (6.27 t ha^{-1}) of the barley + berseem intercropping system was recorded in 2:1 row ratio, which was statistically at par with the treatments of sole berseem and intercropping row ratio of 1:1, 1:2, 2:2, 3:1 and 3:3. The increase in total dry fodder yield in 2:1 row ratio was 26.41% over sole barley treatment. The higher grain yield of barley in 2:1 and 3:1 row ratios with a lower proportion of barley crop in these treatments as compared to sole barley might be owing to better utilization of space and light interception coupled with the nutrient contribution of leguminous fodder to cereal. Kumar and Narmadha (2021) reported that among the intercropping of grain maize with forage legumes, sole maize crop recorded the highest grain yield, although normal and paired row intercropping of maize + pilipesera and maize + lucerne recorded at par value of grain yield with sole maize treatment. Redfeara *et al*. (1999) reported that intercropping of sorghum with forage soybean produced lower soybean dry matter accumulation thus less forage yield as compared to monocropping of soybean. Hassan *et al.* (2017) also reported that yields of legume components are significantly depressed by grass components in intercropping. Ninama *et al*. (2022) and Ganvit *et al.* (2018) reported the highest total dry fodder yield of oats and lucerne with 2:1 row ratio of oat + lucerne intercropping, which was significantly superior to sole oat and sole lucerne and it confirmed the results of this experiment.

Competitive performance: Intercropping treatments of grain barley and forage berseem showed variation in their competitive performance (Table 2). All the intercropping combinations of barley + berseem recorded a total land equivalent ratio (LER) value of more than 1. This indicated the yield advantage of mixing these crops in all these intercropping treatments. The highest value of LER (1.21) was recorded in 2:1 row ratio of barley + berseem intercropping combination followed by in 3:1

Table 1. Effect of different intercropping combinations on fodder and grain yield of berseem and barley

Treatment	Green fodder yield (t ha^{-1})				Grain yield (t ha^{-1})	Dry fodder yield (t ha^{-1})				
	Berseem				Barley	Berseem			Barley*	Total
	I Cut	II Cut	III Cut	Total		I Cut	II Cut	III Cut		
Sole Barley	-	-	-	-	3.46	-	-	-	4.96	4.96
Sole Berseem	25.30	14.27	9.47	49.03	-	2.66	1.76	1.27	-	5.69
Barley + Berseem (1:1)	14.20	9.00	5.20	28.40	1.97	1.32	1.01	0.65	2.96	5.93
Barley + Berseem (2:1)	11.57	4.53	3.53	19.63	3.11	1.11	0.53	0.47	4.16	6.27
Barley + Berseem (1:2)	15.23	10.10	7.60	32.93	1.25	1.55	1.14	0.98	2.00	5.66
Barley + Berseem (2:2)	13.93	9.07	5.07	28.07	1.88	1.29	1.03	0.62	2.88	5.82
Barley + Berseem (3:1)	8.93	3.27	2.57	14.77	3.25	0.86	0.37	0.32	4.29	5.84
Barley + Berseem (1:3)	17.57	11.30	7.90	36.77	1.01	1.77	1.29	1.03	1.48	5.57
Barley + Berseem (3:3)	13.77	9.00	5.00	27.77	1.85	1.28	1.00	0.61	2.85	5.74
SEM	0.83	0.56	0.42	1.23	0.13	0.09	0.08	0.06	0.19	0.20
CD (P<0.05)	2.52	1.69	1.27	3.73	0.39	0.27	0.23	0.18	0.58	0.61

*Barley straw yield used as dry fodder yield

Table 2. Effect of different intercropping combinations on land use efficiency and competitive performance (calculated on dry fodder yield basis)

Treatment	LER			Aggressivity		CR		RCC		
	Barley	Berseem	Total	Barley	Berseem	Barley	Berseem	Barley	Berseem	Total
Barley + Berseem (1:1)	0.60	0.52	1.12	0.08	-0.08	1.15	0.88	1.57	1.10	1.72
Barley + Berseem (2:1)	0.84	0.37	1.21	0.05	-0.05	1.15	0.88	3.11	1.20	3.73
Barley + Berseem (1:2)	0.40	0.64	1.05	0.08	-0.08	1.27	0.82	1.39	0.93	1.30
Barley + Berseem (2:2)	0.58	0.52	1.10	0.03	-0.03	1.13	0.90	1.42	1.08	1.54
Barley + Berseem (3:1)	0.86	0.27	1.14	0.01	-0.01	1.06	0.95	2.62	1.14	2.99
Barley + Berseem (1:3)	0.30	0.72	1.02	0.06	-0.06	1.27	0.87	1.32	0.90	1.19
Barley + Berseem (3:3)	0.58	0.51	1.08	0.02	-0.02	1.13	0.89	1.40	1.04	1.45

LER: Land equivalent ratio; CR: Competitive ratio; RCC: Relative crowding coefficient

row ratio (1.14). The value of 1.21 indicated that almost 21% more land would be required to plant the sole crops to produce the same quantity of the yield of the intercropping pattern. The greater LER might be due to a greater resource use and resource-complementary nature of component crops. The results were in close confirmation with Ganvit *et al.* (2018) and Ninama *et al*. (2022), who reported that the highest value of LER was recorded with 2:1 row ratio of oat + lucerne intercropping. The negative values of aggressivity for forage berseem indicated their poor competitiveness than the grain barley, which has positive aggressivity in all the intercropping combinations. The higher values of aggressivity of grain barley in 1:1, 2:1, 1:2 and 1:3 row ratio of barley + berseem intercropping combination showed its greater dominance over other intercropping combinations. Higher values of the competitive ratio of barley also indicated that it was more competitive to berseem. Barley + berseem (1:2 and 1:3 row ratio) recorded a competitive ratio of 1.27 it means barley produced 1.27 times as much as the expected yield and it was 1.27 times as competitive. These results were in close confirmation with Javanmard *et al.* (2014), who reported that in mixed cropping of barley + grass pea (75:25 and 50:50 seeding ratio) and barley + vetch (75:25 seeding ratio), barley was the dominant species as measured by the positive value of aggressivity and in most cases, the competitive ratio of legumes decreased as the proportion of barley increased in the mixtures. Further, all the intercropping combinations were more advantageous than sole planting systems because the product of the relative crowding coefficient of both the component crops was more than one due to their complementary relationship. The higher values of the relative crowding coefficient of barley were obtained from 2:1 row ratio (3.11) of barley + berseem intercropping combinations followed by 3:1 row ratio (2.62), indicating greater advantage from these intercropping combinations, which was further evident from their respective higher values of product crowding coefficient (barley crowding coefficient x berseem crowding coefficient) of 3.73 and 2.99, respectively. The results were in close confirmation with Javanmard *et al.* (2014), who reported that the value of the relative crowding coefficient was significantly influenced by the mixing of different seeding ratios of barley + grass pea and barley + vetch.

Nutrient content and uptake: Nitrogen, phosphorus and potassium content and uptake of barley grain and straw were significantly influenced by different intercropping combinations and sole cropping systems (Table 3). The highest value of nitrogen, phosphorus and potassium content in barley grain (1.87, 0.331 and 0.553%) and straw (0.292, 0.115 and 1.84%), respectively, were recorded with 1:3 row ratio of barley + berseem intercropping. However, intercropping row ratios of 1:2, 1:1, 2:2, 3:3 and 2:1 were recorded statistically at par value of nitrogen, phosphorus and potassium content in barley grain and straw. Significantly higher contents of nitrogen, phosphorus and potassium in intercropping as compared to sole cropping in barley grain and straw might be attributed to the fact that the inclusion of a legume with cereal intercropping restores the soil fertility as it lessens the depletion of soil N, P and K compared to sole cropping of cereals. These results were in close confirmation with Gecaitė *et al.* (2021), who reported that intercropping of forage legumes with oats significantly influenced the content of nutrients accumulated in oats grain. Further, the highest value of nitrogen and potassium uptake in barley grain (56.47 and 16.41 kg ha^{-1}) and straw (11.98 and 73.51 kg ha^{-1}), as well as total uptake (68.45 and 89.92 kg ha^{-1}) were recorded in sole barley treatment. Intercropping of barley + berseem in 2:1 row ratio recorded the highest value of phosphorus uptake in barley grain (9.15 kg ha^{-1}), straw (3.89 kg ha^{-1}) and total uptake (13.04 kg ha^{-1}). However, sole barley and intercropping row ratio of 2:1 and 3:1 were recorded statistically at par value of nitrogen, phosphorus and potassium uptake in barley grain, straw and in total. The results of nitrogen and

Table 3. Effect of different intercropping combinations on nutrient content and uptake of grain barley

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Sole Barley	1.63	0.241	0.262	0.067	0.476	1.48	56.47	11.98	68.45	9.01	3.33	12.34	16.41	73.51	89.92
Barley + Berseem (1:1)	1.73	0.270	0.302	0.099	0.518	1.69	34.03	7.97	42.00	5.94	2.88	8.82	10.19	49.84	60.03
Barley + Berseem (2:1)	1.71	0.264	0.294	0.093	0.505	1.63	53.24	11.01	64.25	9.15	3.89	13.04	15.72	67.97	83.70
Barley + Berseem (1:2)	1.85	0.289	0.325	0.112	0.547	1.8w2	23.14	5.77	28.91	4.06	2.25	6.31	6.84	36.16	43.00
Barley + Berseem (2:2)	1.77	0.276	0.311	0.105	0.529	1.74	33.22	7.95	41.17	5.84	3.03	8.88	9.94	50.13	60.06
Barley + Berseem (3:1)	1.67	0.252	0.279	0.087	0.495	1.55	54.25	10.75	65.00	9.09	3.70	12.79	16.10	66.21	82.31
Barley + Berseem (1:3)	1.87	0.292	0.331	0.115	0.553	1.84	18.84	4.31	23.15	3.34	1.71	5.04	5.58	27.54	33.11
Barley + Berseem (3:3)	1.79	0.282	0.318	0.108	0.538	1.77	33.27	8.06	41.33	5.90	3.09	8.99	9.97	50.43	60.40
SEM	0.06	0.010	0.012	0.007	0.016	0.07	2.91	0.63	3.00	0.49	0.32	0.66	0.74	3.82	4.14
CD (P<0.05)	0.17	0.030	0.038	0.022	0.048	0.22	8.81	1.92	9.10	1.47	0.96	2.00	2.24	11.60	12.56

potassium uptake were in close confirmation with Gao *et al.* (2019), who reported that sole maize and sole peanut had greater N and K uptake than intercropped maize and peanut, respectively. Ramanakumar and Bhanumurthy (2001) reported that intercropping of maize and cowpea resulted in more phosphorus uptake of the system than sole cropping.

Proximate constitutes and fodder quality: Sole and intercropping combinations had a significant effect on proximate constitutes and fodder qualities of forage berseem (Table 4). Sole berseem treatment recorded significantly the highest value of crude protein (18.27%), ether extract (3.69%) and total ash (15.49%) content in forage berseem. However, intercropping row ratios 1:3, 1:2, 1:1, 2:2, 3:3 and 1:1 were recorded at par values of crude protein, ether extract and total ash content in forage berseem. The mean crude protein content of berseem in intercrops with oats was less than in berseem sole crops, indicating that competition by oats reduced the crude protein content of berseem (Ross *et al*., 2005). Legumes contain more crude protein than cereals and when mixed with cereals, the crude protein content of mixtures remains lower than legume monoculture (Stout *et al*., 2001). The results were in close confirmation with Mohsenabadi *et al.* (2008), who reported that in barley and vetch intercropping, crude protein content of vetch decreased over sole cropping of vetch. Further, a comparative analysis of different sole and intercropping treatments revealed that the highest value of TDN content in forage berseem (64.08%) was found with sole berseem treatment. However, treatment sole berseem and intercropping combinations of 1:3, 1:2, 1:1, 2:2 and 3:3 were recorded at par values of TDN content. The results were in close confirmation with Yilmaz *et al.* (2015) who reported that in legume + barley intercropping TDN content decreased as the rate of barley increased. The highest value of dry matter intake (2.71%) and digestible dry matter (66.41%) in forage berseem was recorded with sole berseem treatment. However, treatment sole berseem and intercropping combinations of 1:3, 1:2, 1:1, 2:2 and 3:3 were recorded at par values of dry matter intake and digestible dry matter. NDF and ADF were used to predict the dry matter intake and digestible dry matter, respectively. Dry matter intake was negatively correlated with NDF, whereas digestible dry matter was negatively correlated with ADF. Horrocks and Vallentine (1999) also reported that where NDF was high, forage quality and dry matter intake were low. The results were in close confirmation with Yilmaz *et al.* (2015), who reported that in legume + barley intercropping, dry matter intake increased as at the rate of legume increased. Similarly, the highest value of relative feed value (110.33%) and relative feed quality (141.16%) in forage berseem was recorded with sole berseem treatment. However, treatment sole berseem and intercropping combinations of 1:3 and 1:2

Table 4. Effect of different intercropping combinations on proximate constitute and fodder qualities of berseem (calculated on the basis of mean values of all three cuttings)

Treatment	CP (%)	EE (%)	Ash (%)	TDN (%)	DMI (%)	DDM (%)	RFV (%)	RFQ (%)
Sole Berseem	18.27	3.69	15.49	64.08	2.71	66.41	110.33	141.16
Barley + Berseem (1:1)	17.33	3.45	14.58	62.28	2.59	65.33	105.10	131.23
Barley + Berseem (2:1)	16.77	3.06	13.84	61.35	2.52	64.76	101.96	125.60
Barley + Berseem (1:2)	18.02	3.62	15.21	63.26	2.63	65.92	107.03	135.20
Barley + Berseem (2:2)	17.46	3.48	14.68	62.48	2.60	65.44	105.65	132.24
Barley + Berseem (3:1)	16.59	3.01	13.73	60.92	2.50	64.51	101.18	124.13
Barley + Berseem (1:3)	18.18	3.66	15.32	63.59	2.64	66.11	107.96	136.63
Barley + Berseem (3:3)	17.57	3.51	14.75	62.81	2.61	65.64	106.24	133.30
SEM	0.34	0.08	0.36	0.63	0.04	0.38	1.53	2.23
CD (P<0.05)	1.03	0.24	1.08	1.92	0.12	1.16	4.64	6.76

CP: Crude protein; EE: Ether extract; TDN: Total digestible nutrients; DMI: Dry matter intake; DDM: Digestible dry matter; RFV: Relative feed value; RFQ: Relative feed quality

Table 5. Effect of different intercropping combinations on economics of barley and berseem cultivation

Treatment	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
Sole Barley	65273	34498	2.12
Sole Berseem	49033	11281	1.30
Barley + Berseem (1:1)	65840	33575	2.04
Barley + Berseem (2:1)	77720	45834	2.44
Barley + Berseem (1:2)	56873	23532	1.71
Barley + Berseem (2:2)	63900	31635	1.98
Barley + Berseem (3:1)	75287	43065	2.34
Barley + Berseem (1:3)	55947	21889	1.64
Barley + Berseem (3:3)	63060	30795	1.95
SEM	2093	2093	0.07
CD (P<0.05)	6275	6275	0.20

B:C ratio: Benefit cost ratio

recorded at par values of relative feed value and quality. Relative feed value (RFV) is an index that is used to predict the intake and energy value of forage, which is derived from DMD and DMI (Lithourgidis *et al;* 2006). Differences in the digestibility of the fiber fraction could result in a difference in animal performance when forages with a similar RFV are fed. Therefore, the relative feed quality (RFQ) index has been developed to overcome this difference. This index takes into consideration the differences in digestibility of the fiber fraction and can be used to more accurately predict animal performance and match animal needs (Jeranyama and Garcia, 2004).

Economics: The economics of grain and forage production were also significantly influenced by different intercropping combinations of barley + berseem (Table 5). The highest gross return (Rs 77720 ha^{-1}), net return (Rs 45834 ha^{-1}) and benefit: cost ratio (2.44) were obtained with 2:1 row ratio of grain barley and forage berseem intercropping combination followed by 3:1 row ratio. Similar results were also reported by Arif *et al.* (2024), who recorded the highest gross return, net return and benefit: cost ratio with 2:1 row ratio of fodder oats + berseem intercropping combination followed by 3:1 row ratio. Ganvit *et al.* (2018) and Ninama *et al*. (2022) also reported that 2:1 row ratio of oats + lucerne intercropping recorded the highest net returns and benefit-cost ratio as compared to other intercropping ratios and sole cropping of oats and lucerne. Langat *et al.* (2006) and Sharma *et al*. (2008) observed that intercropping row ratios significantly influenced monetary returns and benefit-cost ratios in forage crops.

Conclusion

Results of the study confirmed that intercropping of grain barley with forage berseem significantly influenced the grain yield and nutrient content in barley and the land use efficiency of the system. Maximum values of dry fodder yield, land equivalent ratio, relative crowding coefficient, phosphorus uptake, net return and benefit-cost ratio were recorded with intercropping of 2:1 row ratio of barley + berseem combination. However, the maximum value of grain yield, nitrogen and potassium uptake was recorded by sole cropping of barley, which was at par with 2:1 row ratio of barley + berseem intercropping combination. Hence, this investigation recommends two rows of barley + one-row berseem (2:1) intercropping combination for obtaining the maximum value of grain and dry fodder yield, profitability, and land use efficiency from barley and berseem intercropping.

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