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Research article

Enhancing productivity, profitability and land use efficiency of fodder oats (*Avena sativa* L.) and berseem (*Trifolium alexandrinum* L.) by intercropping

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Abstract

A field experiment was conducted during *Rabi* season of 2020-21 at ICAR-Central Institute for Research on Goats, Makhdoom, to study the effect of different intercropping row ratios on yield, intercropping indices and economics of fodder oats and berseem. The experiment consists of nine treatments *viz.,* sole oats, sole berseem, oats + berseem (1:1 row ratio), oats + berseem (2:1 row ratio), oats + berseem (1:2 row ratio), oats + berseem (2:2 row ratio), oats + berseem (3:1 row ratio), oats + berseem (1:3 row ratio), oats + berseem (3:3 row ratio). The experiment was laid out in a randomized block design with three replications. Results of the study revealed that maximum values of total green fodder yield (66.70 t ha^{-1}), land equivalent ratio (1.32), monetary advantage index (12411), total phosphorus uptake (22.04 kg ha^{-1}), net return (Rs 51307 ha^{-1}) and benefit: cost ratio (2.33) were recorded with 2:1 row ratio of oats + berseem intercropping combination. However, the maximum value of total nitrogen (178.33 kg ha^{-1}) and potassium (208.84 kg ha^{-1}) uptake was recorded by sole cropping of berseem, which was at par with 2:1 row ratio of oats + berseem intercropping combination. It was concluded that two rows oats + one row of berseem (2:1) intercropping combination performed best in terms of yield, land use efficiency and profitability of fodder oats and berseem.

Keywords: Aggressivity, B: C ratio, Intercropping, LER, MAI, Nutrient uptake

Introduction

Animal husbandry is an important component of Indian agriculture, which influences the rural agricultural economy, leading to sustainable agriculture. As per the 20th livestock census (2019), the total livestock population in India is 536.76 million, which is 4.8% higher than the previous livestock census of 2012. Although the population of livestock increased over the previous census but, grazing lands are gradually diminishing due to pressure on the land for agricultural and non-agricultural uses. Further, the land available for the 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). This creates a gap between the requirement and availability of green fodder for livestock. Thus, it is an urgent need to increase the quantity and quality of the cultivated fodder crops on the same piece of land to fulfill the fodder requirement of increasing livestock population (Singh *et al*., 2022; Kumar *et al*., 2023). The intercropping system, which provides crop intensification both in time and space dimensions (Reddy, 2008) can be used as a tool to bridge this gap of fodder requirement and availability for enhancing animal productivity. 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).

In northern India oats (*Avena sativa* L.) and berseem (*Trifolium alexandrinum* L.) are the prominent forage crops during the winter season (Pradeep Behari *et al*., 2003). Oats, due to its quick growth, provide palatable, succulent and nutritious fodder to livestock (Dangi, 2020). Berseem remains soft and succulent at all stages of growth with better digestibility and palatability (Chatterjee and Das, 1989) and thus provides good quality green fodder. Oats also form an excellent combination when grown with other winter fodder legumes such as berseem, lucerne *etc.* Intercropping of oat and lucerne with different row ratios recorded significant variations in forage yield, land use efficiency and economics. Maximum green fodder yield, land equivalent ratio and the benefit-cost ratio were recorded with 2:1 row ratio of oats + lucerne intercropping (Ganvit *et al*., 2018). The intercropping practices of oats + berseem have not been evaluated extensively in the region of Yamuna ravines. Also, the identification of suitable intercropping combinations for this region helps the farmers for improving farm profitability and livestock productivity. Therefore, the present study was carried out to evaluate the suitable intercropping combination of oats and berseem for enhancing forage yield, land use efficiency and net profitability in the region of Yamuna ravines of Uttar Pradesh.

Materials and Methods

Study area and soil: An experiment was conducted at Agriculture Farm of ICAR-Central Institute for Research on Goats (CIRG), Makhdoom, India, during the *rabi* season of 2020-21 to study the effect of different intercropping row ratios on yield, intercropping indices and economics of fodder oats and 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 16.0ºC, 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 7.4) with EC of 0.29 dS m^{-1}. The soil was low in organic carbon (0.26%) and available nitrogen (240 kg ha^{-1}); and medium in available phosphorus (39 kg ha^{-1}) and potassium (168 kg ha^{-1}).

Treatment details and sowing: The experiment consisted of nine treatments *viz.* sole oats, sole berseem, oats + berseem (1:1 row ratio), oats + berseem (2:1 row ratio), oats + berseem (1:2 row ratio), oats + berseem (2:2 row ratio), oats + berseem (3:1 row ratio), oats + berseem (1:3 row ratio), oats + berseem (3:3 row ratio). The experiment was laid out in a randomized block design with three replications. The field was allocated into 27 plots and each plot was 6m ×3m in size. All treatments were allocated in these small plots without any biasness. Oats variety Kent and berseem variety BB-2 were sown as per the treatment on 7^{th} November 2020 by using the seed rate of 100 and 25 kg ha^{-1} in sole oats 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. A total of six irrigations were applied to the crops during the cropping period.

Observations recording: Three cuts of crops were taken; first cutting at 50 days after sowing (DAS) and subsequent cuts at 40 days intervals. Harvesting for green fodder was taken from net plot then weighed and converted into t ha^{-1} to obtain green fodder yield. For calculating the crop equivalent yield, the yield of one crop is converted into the yield equivalent of another crop by using the ratio of prices of the two crops *e.g.*

$$\text{Oats equivalent yield (t/ha)} = \frac{\text{Berseem yield (t/ha) x Prices of Berseem}}{\text{Prices of Oats}}$$

Intercropping indices calculation: The intercropping indices were calculated by using the following formulas:

$$\text{Land equivalent ratios (LER)} = La + Lb, \text{La} = \frac{\text{Yab}}{\text{Yaa}}, \text{ Lb} = \frac{\text{Yba}}{\text{Ybb}}$$

$$\text{Aggressivity of oats (Aab)} = \left\{\left(\frac{\text{Yab}}{\text{Yaa}} \times \text{Zab}\right) - \left(\frac{\text{Yba}}{\text{Ybb}} \times \text{Zba}\right)\right\}$$

$$\text{Aggressivity of berseem (Aba)} = \left\{\left(\frac{\text{Yba}}{\text{Ybb}} \times \text{Zba}\right) - \left(\frac{\text{Yab}}{\text{Yaa}} \times \text{Zab}\right)\right\}$$

$$\text{Competitive ratio of oats (Cra)} = \left(\frac{\text{LERa}}{\text{LERb}}\right)\left(\frac{\text{Zba}}{\text{Zab}}\right)$$

Competitive ratio of berseem (Crb)

$$= \left(\frac{\text{LERb}}{\text{LERa}}\right)\left(\frac{\text{Zab}}{\text{Zba}}\right) \text{Relative crowding coefficient of oats (Kab)}$$

$$= \frac{(\text{Yab} \times \text{Zba})}{(\text{Yaa} - \text{Yab}) \times \text{Zab}} \text{Relative crowding coefficient of berseem (Kba)}$$

$$= \frac{(\text{Yba} \times \text{Zab})}{(\text{Ybb} - \text{Yba}) \times \text{Zba}} \text{Monetary advantage index (MAI)}$$

$$= \text{Net returns from combined produce (₹/ha)} \times \frac{\text{LER} - 1}{\text{LER}}$$

where, La and Lb were land equivalent ratio of oats and berseem, respectively. Yaa and Ybb were yielded as a sole crop of a (oats) and b (berseem) and Yab and Yba were yielded as intercrops of oats and berseem, respectively. Zab, the proportion of intercrop area allocated to oats and Zba, proportion of intercrop area allocated to berseem.

Nutrient analysis: Analysis of nutrients was carried out using the digested samples by following standard 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).

Economics and statistical analysis: Further, to find out the most profitable treatments, 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 appropriate method of analysis of variance as described by Gomez and Gomez (1984).

Results and Discussions

Green forage and equivalent yield: Intercropping of oats and berseem with varying row ratios had a significant effect on green fodder and their equivalent yield in these fodder crops (Table 1). The maximum green fodder yield (oats + berseem) was recorded with 2:1 row ratios of oats + berseem intercropping (66.70 t ha^{-1})

Table 1. Effect of sole and intercropping on green fodder and equivalent yield of oats and berseem

Treatments	Green fodder yield (t ha^{-1})							Equivalent yield (t ha^{-1})	
	Oats			Berseem			Total	Oats	Berseem
	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut			
Sole Oat	22.43	14.97	11.87	-	-	-	49.27	49.27	73.90
Sole Berseem	-	-	-	23.20	18.07	12.67	53.93	35.96	53.93
Oat + Berseem (1:1)	11.90	10.33	7.30	12.40	10.30	7.10	59.33	49.40	74.10
Oat + Berseem (2:1)	20.00	15.33	10.83	8.47	7.13	4.93	66.70	59.86	89.78
Oat + Berseem (1:2)	8.57	7.90	5.20	15.73	12.00	8.20	57.60	45.62	68.43
Oat + Berseem (2:2)	11.90	9.87	7.07	12.13	10.07	6.67	57.70	48.08	72.12
Oat + Berseem (3:1)	21.37	14.60	11.17	5.73	4.87	3.37	61.10	56.44	84.67
Oat + Berseem (1:3)	5.67	6.60	3.90	16.67	13.20	8.30	54.33	41.61	62.42
Oat + Berseem (3:3)	11.50	10.20	6.70	11.87	9.70	6.30	56.27	46.98	70.47
SEM	0.79	0.65	0.62	0.64	0.61	0.52	1.67	1.42	2.13
CD (P<0.05)	2.38	1.98	1.88	1.93	1.84	1.57	5.02	4.26	6.39

followed by 3:1 row ratios (61.10 t ha^{-1}). The increase in total green fodder yield in 2:1 row ratio was 35.38 and 23.68% over sole oats and sole berseem, respectively. Further, it was also observed that all the intercropping combinations of oats + berseem had yield advantage over sole oats and sole berseem. The difference in yield in different intercropping treatments might be due to the respective proportion of component crops in the respective treatment. The increase in green fodder yield in intercropping systems might be owing to better utilization of space and light interception coupled with the nutrient contribution of leguminous fodder to cereal. These results were also in agreement with the statement that inclusion of legume component in the cereal-legume association increased the green forage yield up to 35 to 45% over mono-crops due to reduced intercrop competition and better use of resources (Tripathi *et al*., 1997; Obuo *et al*., 1998; Pandita *et al*., 1998). These results were in close confirmation with Ganvit *et al.* (2018) who reported that the highest total green fodder yield of oats and lucerne was recorded with 2:1 row ratio of oat + lucerne intercropping, which was significantly superior over sole oat and sole lucrene. Similarly, maximum oats (38.6 t ha^{-1}) and berseem (36.2 t ha^{-1}) equivalent yield was also recorded with 2:1 row ratios of oats + berseem intercropping. However, intercropping row ratios 2:1 and 3:1 recorded at par values of green fodder equivalent yield both in oats and berseem. The difference in equivalent yields was mainly as a consequence of differences in yield of component crops and prices of individual component crops (Jan *et al.*, 2016). Higher oats and berseem equivalent yield in 2:1 row ratio might be attributed to the yield advantage achieved in this combination (Marer *et al.*, 2007). A similar finding was also reported by Ninama *et al*. (2022), who reported the highest oat equivalent yield with 2:1 row ratio of oat + lucerne intercropping.

Table 2. Effect of different intercropping combinations on intercropping indices of fodder oats and berseem (calculated on green fodder yield basis)

Treatments	LER			Aggressivity		CR		RCC			MAI
	Oats	Berseem	Total	Oats	Berseem	Oats	Berseem	Oats	Berseem	Total	
Oat + Berseem (1:1)	0.60	0.55	1.15	0.05	-0.05	1.09	0.93	1.53	1.26	1.93	4997
Oat + Berseem (2:1)	0.94	0.38	1.32	0.09	-0.09	1.24	0.81	7.60	1.24	9.42	12411
Oat + Berseem (1:2)	0.44	0.67	1.11	0.11	-0.11	1.32	0.76	1.60	1.02	1.63	3205
Oat + Berseem (2:2)	0.59	0.53	1.12	0.03	-0.03	1.09	0.91	1.42	1.15	1.63	3824
Oat + Berseem (3:1)	0.96	0.26	1.22	0.06	-0.06	1.24	0.81	12.23	1.05	12.84	8100
Oat + Berseem (1:3)	0.33	0.71	1.04	0.09	-0.09	1.40	0.72	1.47	0.83	1.22	910
Oat + Berseem (3:3)	0.58	0.52	1.10	0.02	-0.02	1.12	0.90	1.37	1.07	1.47	2859

LER: Land equivalent ratio; CR: Competitive ratio; RCC: Relative crowding coefficient; MAI: Monetary advantage index

Table 3. Effect of sole and intercropping on nutrient content of fodder oats

Treatments	Nitrogen content (%)			Phosphorus content (%)			Potassium content (%)		
	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut
Sole Oats	1.90	1.79	1.60	0.316	0.273	0.190	2.29	2.01	1.72
Oat + Berseem (1:1)	1.99	1.86	1.69	0.330	0.297	0.213	2.46	2.21	1.88
Oat + Berseem (2:1)	1.96	1.83	1.66	0.327	0.290	0.205	2.40	2.15	1.84
Oat + Berseem (1:2)	2.05	1.92	1.74	0.348	0.311	0.226	2.54	2.30	1.96
Oat + Berseem (2:2)	2.01	1.88	1.70	0.338	0.300	0.215	2.49	2.26	1.91
Oat + Berseem (3:1)	1.95	1.82	1.64	0.323	0.282	0.198	2.36	2.10	1.79
Oat + Berseem (1:3)	2.07	1.95	1.77	0.352	0.317	0.228	2.58	2.33	1.97
Oat + Berseem (3:3)	2.03	1.90	1.72	0.345	0.305	0.219	2.51	2.29	1.93
SEM	0.03	0.03	0.03	0.008	0.007	0.005	0.05	0.04	0.03
CD (P<0.05)	0.10	0.09	0.08	0.023	0.020	0.016	0.16	0.13	0.09

Competitive performance: Intercropping treatments of fodder oats and berseem showed variation in their competitive performance (Table 2). All the intercropping combinations of fodder oats + berseem recorded land equivalent ratio (LER) value of more than 1. This indicated yield advantage of mixing these crops in all these intercropping treatments. The highest value of LER (1.32) was recorded in 2:1 row ratio of oats + berseem intercropping combination followed by in 3:1 row ratio (1.22). The value of 1.32 indicated that almost 32% more land would be required to plant the sole crops to produce the same quantity of the fodder 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 fodder berseem indicated their poor competitiveness than the fodder oats, which had positive aggressivity in all the intercropping combinations. The higher values of aggressivity of fodder oats in 1:2, 2:1 and 3:1 row ratio of oats + berseem intercropping combination showed its greater dominance over other intercropping combinations. Higher values of the competitive ratio of fodder oats also indicated that it was more competitive to berseem. Fodder oats + berseem (1:3 row ratio) recorded a competitive ratio of 1.40, which means oats produced 1.40 times as much as the expected yield and was 1.40 times as competitive. Thus, in general, yields of legume components are significantly depressed by grasses components in intercropping (Hassan *et al.*, 2017). 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 (Javanmard *et al.*, 2014). 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 fodder oats was obtained from 3:1 row ratio (12.23) of oats + berseem intercropping combinations followed by 2:1 row ratio (7.60) indicating greater advantage from these intercropping combinations, which was further evident from their respective higher values of product crowding coefficient (Oats crowding coefficient x berseem crowding coefficient) of 12.84 and 9.42, respectively. Similarly, the highest monetary advantage index was obtained with 2:1 row ratio (12411) of oats + berseem intercropping combinations followed by 3:1 row ratio (8100). The results were in close confirmation with Javanmard *et al.* (2014), who reported that relative crowding coefficient and monetary advantage index were significantly influenced by mixing of different seeding ratios of barley + grass pea and barley + vetch.

Nutrient content and uptake: Nitrogen, phosphorus and potassium content of fodder oats and berseem were significantly influenced by different intercropping combinations and sole cropping. The highest value of nitrogen (I cut- 2.07%, II cut- 1.95% and III cut- 1.77%), phosphorus (I cut- 0.352%, II cut- 0.317% and III cut- 0.228%) and potassium (I cut- 2.58 %, II cut- 2.33% and III cut-1.97%) contents in fodder oats were recorded with 1:3 row ratio of oats + berseem intercropping. However, intercropping row ratios of 1:2, 1:1, 2:2 and 3:3 were recorded statistically at par value of nitrogen, phosphorus and potassium content in fodder oats (Table 3). Further, the highest value of nitrogen (I cut- 3.06%, II cut- 2.92% and III cut- 2.71%), phosphorus (I cut- 0.307%, II cut- 0.289% and III cut- 0.264%) and potassium (I cut- 3.76 %, II cut- 3.41% and III cut-2.91%) contents in fodder

Table 4. Effect of sole and intercropping on nutrient content of fodder berseem

Treatments	Nitrogen content (%)			Phosphorus content (%)			Potassium content (%)		
	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut
Sole Berseem	3.06	2.92	2.71	0.307	0.289	0.264	3.76	3.41	2.92
Oat + Berseem (1:1)	2.91	2.76	2.57	0.290	0.274	0.250	3.54	3.22	2.77
Oat + Berseem (2:1)	2.81	2.70	2.48	0.281	0.266	0.245	3.45	3.13	2.73
Oat + Berseem (1:2)	3.01	2.85	2.67	0.300	0.283	0.260	3.68	3.35	2.87
Oat + Berseem (2:2)	2.94	2.79	2.59	0.293	0.276	0.254	3.57	3.07	2.81
Oat + Berseem (3:1)	2.78	2.67	2.46	0.271	0.261	0.239	3.38	3.27	2.68
Oat + Berseem (1:3)	3.05	2.90	2.68	0.303	0.287	0.262	3.72	3.38	2.90
Oat + Berseem (3:3)	2.96	2.83	2.64	0.295	0.280	0.257	3.61	3.30	2.83
SEM	0.06	0.05	0.05	0.006	0.005	0.005	0.08	0.06	0.05
CD (P<0.05)	0.17	0.16	0.14	0.019	0.017	0.014	0.23	0.19	0.15

Table 5. Effect of sole and intercropping on nutrient uptakes in fodder oats and berseem

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	Oats	Berseem	Total	Oats	Berseem	Total	Oats	Berseem	Total
Sole Oats	115.01	-	115.01	17.17	-	17.17	131.49	-	131.49
Sole Berseem	-	178.33	178.33	-	17.70	17.70	-	208.84	208.84
Oat + Berseem (1:1)	70.82	84.68	155.50	10.77	8.38	19.15	83.63	98.53	182.16
Oat + Berseem (2:1)	105.77	59.29	165.06	16.18	5.86	22.04	124.56	69.64	194.20
Oat + Berseem (1:2)	50.91	110.77	161.68	7.93	10.98	18.91	60.88	129.83	190.71
Oat + Berseem (2:2)	68.82	83.14	151.96	10.58	8.24	18.82	82.29	94.89	177.18
Oat + Berseem (3:1)	107.15	39.13	146.28	16.13	3.82	19.95	124.47	46.48	170.95
Oat + Berseem (1:3)	38.41	121.17	159.58	5.99	12.00	17.99	45.68	141.72	187.40
Oat + Berseem (3:3)	69.01	81.05	150.06	10.71	8.00	18.71	82.42	94.37	176.79
SEM	3.86	4.46	6.86	0.54	0.52	0.83	4.51	5.38	8.01
CD (P<0.05)	11.72	13.53	20.55	1.65	1.58	2.49	13.67	16.31	24.02

berseem were recorded with sole cropping of berseem. However, intercropping row ratios of 1:3, 1:2, 1:1, 2:2 and 3:3 recorded statistically at par value of nitrogen, phosphorus and potassium content in fodder berseem (Table 4). Higher contents of N, P and K in intercropping as compared to sole cropping in fodder oats 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. Further, the lower content of N, P and K in intercropped berseem as compared to sole berseem might be due to decrease in light and water resources under the cereal canopy, which directly reduces nodule formation and N fixation in legume species (Silsbury, 1981). Significantly lesser nitrogen concentrations were found in Egyptian clover when intercropped with oats and intercropping of forage legumes with oats influenced the content of nutrients accumulated in oats grain (Gecaitė *et al.*, 2021). Tamta *et al.* (2019) also reported that row ratios of intercrops significantly influenced N content in fodder maize + cowpea intercropping system. The uptake of nitrogen, phosphorus and potassium in fodder oats and berseem were also significantly influenced by different intercropping combinations and sole cropping (Table 5). Significantly highest value of total nitrogen (178.33 kg ha^{-1}) and potassium (208.84 kg ha^{-1}) uptake was recorded by sole cropping of berseem. However, intercropping row ratios 2:1, 1:2 and 1:3 of oats + berseem were recorded at par values of nitrogen and potassium uptake with sole berseem. Further, highest total phosphorus uptake (22.04 kg ha^{-1}) was recorded by 2:1 row ratio of oats + berseem intercropping. However, intercropping row ratios of 2:1 and 3:1 were recorded at par value of total phosphorus uptake. The results of nitrogen and potassium uptake

Table 6. Effect of sole and intercropping on economics fodder oats and berseem

Treatments	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
Sole Oats	73900	32887	1.80
Sole Berseem	53933	16181	1.43
Oat + Berseem (1:1)	74100	36991	2.00
Oat + Berseem (2:1)	89783	51307	2.33
Oat + Berseem (1:2)	68433	31971	1.88
Oat + Berseem (2:2)	72117	35008	1.94
Oat + Berseem (3:1)	84667	45337	2.15
Oat + Berseem (1:3)	62417	26108	1.72
Oat + Berseem (3:3)	70467	33358	1.90
SEM	-	2130	0.06
CD (P<0.05)	-	6386	0.17

B:C ratio: Benefit cost ratio

were in close confirmation with Gao *et al.* (2019) who reported that sole maize and sole peanut had greater N 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.

Economics: The economics of fodder production were also significantly influenced by different intercropping combinations of fodder oats and berseem (Table 6). The highest gross return (Rs 89783/ha), net return (Rs 51307/ha) and benefit: cost ratio (2.33) was obtained with 2:1 row ratio of fodder oats + berseem intercropping combination followed by 3:1 row ratio. It was obvious because of higher total green fodder yield with relatively smaller extra investment in fodder oats + berseem intercropping system with 2:1 row ratio as compared to other intercropping combinations, which consequently resulted in higher net return and benefit: cost ratio. Similar results were also reported by Ganvit *et al.* (2018) and Ninama *et al.* (2022), who 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) also observed that intercropping row ratios significantly influenced monetary returns and benefit-cost ratio in forage crops.

Conclusion

Results of the study confirmed that different row ratios significantly influenced intercropping of fodder oats and berseem. The maximum values of green fodder yield, land equivalent ratio, monetary advantage index, phosphorus uptake, net return and benefit-cost ratio were recorded with oats + berseem intercropping of 2:1 row ratio. However, the maximum value of nitrogen and potassium uptake was recorded by sole cropping of berseem, which was at par with 2:1 row ratio of oats + berseem intercropping combination. Hence, it was concluded that two rows of oats + one-row berseem (2:1) intercropping combination needs to be practiced for obtaining maximum green fodder yield, profitability and land use efficiency.

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