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PEARL MILLET AND CLUSTER BEAN INTERCROPPING FOR ENHANCING FODDER PRODUCTIVITY, PROFITABILITY AND LAND USE EFFICIENCY

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Abstract

An experiment was conducted to find out the suitable intercropping combination for pearl millet and cluster bean for higher fodder productivity, land use efficiency and profitability under Yamuna ravines of Uttar Pradesh, India. Nine treatments were evaluated which includes two treatment of sole crop (pearl millet and cluster bean) and seven intercropping combinations of pearl millet + cluster bean *viz.* 1 : 1, 2 : 1, 1 : 2, 2 : 2, 3 : 1, 1 : 3 and 3 : 3. Maximum value of total green fodder yield was obtained with intercropping of 3 : 1 row ratio; however, it was statistically at par with 2:1 row ratio. Further, maximum value of phosphorus and potassium uptake; LER, MAI, net return and benefit cost ratio was recorded with intercropping 2 : 1 row ratio. Thus, it was found that two row pearl millet + one row cluster bean (2 : 1) intercropping combination performed best in terms of yield, land use efficiency and profitability of fodder pearl millet and cluster bean.

Introduction

In India, livestock rearing is an important component of mixed farming system which influences agricultural economy leading to sustainable agriculture. With an estimated 187.7 million tons of annual milk production (MoFAH&D, 2020), India is the top-most milk producing country in the world. Although India recorded substantial increase in milk production but the productivity (production per animal) in the country is far less as compared to those in developed dairy nations. The success of livestock sector depends upon meeting the feed requirement of animals with green and nutritious forage. But, in India hardly 5% of the cropped area is used to grow fodder crops (Kumar *et al*. 2012), thus availability of quality feed and fodder is becoming a challenge. Therefore, the only way to overcome this problem of fodder deficit and to increase the forage productivity per unit area is to integrate the multiple fodder crops in the cropping system**.**

Intercropping system which provides crop intensification both in time and space dimension (Reddy, 2008) can be used as a tool for the production of good quality green fodder throughout the year. 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 the stability to the system (Tripathi 1989). It is also recorded that growing of cereal fodder crops in mixture with legumes enhanced fodder palatability as well as digestibility (Ginwal *et al*. 2019). Intercropping system have several advantages, mainly due to complementary use of environmental resources by the component crops which results in more stable yield, better nutrient recycling, better control of weeds, pest and diseases and improved biodiversity (Crews and Peoples 2004).

Pearl millet is good in producing lot of dry matter therefore it is very much liked by farmers as well as animals (Islam *et al.* 2018). The advantage of pearl millet fodder is that it is very delicious so most of animals like it and it can be safely fed to animals at all stages of growth due to absence of hydrocyanic acid (Khinchi *et al.* 2017). Cluster bean being a leguminous crop fulfills

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their nitrogen requirement through biological nitrogen fixation and it is also reported that it supplies some amount of fixed nitrogen to companion crops (Zerbini and Thomas 2003, Ayub *et al*. 2010, Ayub *et al.* 2011). Hence, intercropping of pearl millet (*Pennisetum americanum* L.) and Cluster bean (*Cyamopsis tetragonoloba* Taub) was used to identify the suitable intercropping combination for maximizing productivity, profitability and land use efficiency.

Materials and Methods

The experiment was conducted at Agriculture Farm, ICAR-Central Institute for Research on Goats, Makhdoom, Mathura (Uttar Pradesh), India during rainy season (July–October) of 2020. The mean weekly meteorological data recorded at the institute showed that the maximum and minimum temperatures during the crop growth period ranged between 34.0 and 39.9, 19.6 and 28.6ºC, respectively. The mean relative humidity ranged from 51.7 to 86.8% and the total rainfall received during the crop growing season was 269.3 mm (Fig. 1). The soil of the experimental field was nearly neutral in reaction (pH 7.3) with EC of 0.27 dS/m. The soil was low in organic carbon (0.22 %) and available nitrogen (241 kg ha^{-1}); and medium in available phosphorus (44 kg ha^{-1}) and potassium (168 kg ha^{-1}). The experiment consist of nine treatments *viz.* sole pearl millet, sole cluster bean, pearl millet + cluster bean (1:1 row ratio), pearl millet + cluster bean (2:1 row ratio), pearl millet + cluster bean (1:2 row ratio), pearl millet + cluster bean (2:2 row ratio), pearl millet + cluster bean (3:1 row ratio), pearl millet + cluster bean (1:3 row ratio), pearl millet + cluster bean (3:3 row ratio). The experiment was laid out in randomize block design with three replications. The field was allocated into 27 plots and each plot was 6 m x 3.6 m in size. All treatments were allocated in these unit plots without any biasness.

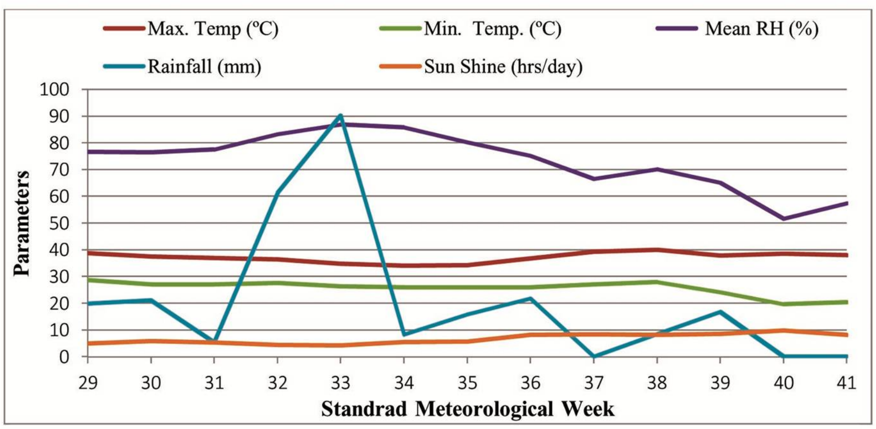

Fig. 1. Mean weekly meteorological data recorded during crop growing season.

Pearl millet variety AVKB-19 and cluster bean variety HG-365 were sown as per the treatment on 20th July, 2020, by using the seed rate of 10 and 35 kg/ha in sole pearl millet and sole cluster bean, respectively. Further, the crops were sown with row to row spacing of 30 cm in both sole as well as in intercropping combinations. All the intercultural operations like thinning (10 DAS) and weeding (20 DAS) were done manually. Total three irrigations were applied to the crops during the cropping period. Harvesting of pearl millet was done twice, first harvesting was done at 45 days after sowing and second harvesting was done at 40 days after first harvesting; in cluster bean only one cut was taken at 75 days after sowing.

Harvesting for green fodder was taken from 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 hot air oven for drying at a temperature of 65^0C till constant weight for obtaining dry matter percentage. The intercropping indices were calculated by using the following formulas: Land equivalent ratios (LER) = La+Lb, La =Yab/Yaa, Lb = Yba/Ybb (Willey and Osiru, 1972) where, La and Lb are land equivalent ratio of pearl millet and cluster bean, respectively. Yaa and Ybb are yields as sole crop of a (pearl millet) and b (cluster bean) and Yab and Yba are yields as intercrops of pearl millet and cluster bean, respectively. Aggressivity (Mc Gilchrist, 1965) of pearl millet (Aab) = {(Yab/Yaa × Zab) - (Yba/Ybb × Zba)} and of cluster bean (Aba) = {(Yba/Ybb × Zba) - (Yab/Yaa × Zab)}. Competitive ratio of pearl millet (Cra) = (LERa/LERb) (Zba/Zab) and of cluster bean (Crb) = (LERb/LERa) (Zab/Zba). Relative crowding coefficient (De Wit, 1960)of pearl millet (Kab) = (Yab × Zba)/(Yaa-Yab) Zab and of cluster bean (Kba) = (Yba× Zab)/(Ybb – Yba) Zba, where Zab, proportion of intercrop area allocated to pearl millet and Zba, proportion of intercrop area allocated to cluster bean. Monetary advantage index (MAI) = Net returns from combined produce (US$/ha) × (LER-1)/LER. Analysis of nutrients was carried out by using the digested samples by following methods: nitrogen by using micro Kjeldahl method (AOAC 2005), phosphorus by yellow colour method (Richards 1968) and potassium by flame photometer method (Richards 1968). Further, to find out the most profitable treatments, economics of different treatments was worked out as follow in terms of net return (US$ ha^{-1}) and B: C ratio. Net return= Gross return (US$/ha) - Cost of cultivation (US$ ha^{-1}) and B: C ratio = Gross return (US$/ha)/Cost of cultivation (US$/ha). The replicated means were subjected to ANOVA using MS excel (2010). The critical difference (CD) was found by using p = 0.05 that shows the results those were significantly different (Gomez and Gomez 1984).

Results and Discussion

Intercropping combinations had significant effect on fodder yield and production efficiencies of pearl millet and cluster bean (Table 1). The maximum value (44.00 t/ha) of total green fodder yield, green fodder production efficiency (969 kg/ha) and dry matter production efficiency (178 kg/ha) of pearl millet + cluster bean was obtained with 3:1 row ratios of pearl millet + cluster bean intercropping combination. However, 2:1 row ratios of pearl millet + cluster bean intercropping combination recorded statistically at par value of green fodder yield (43.80 t/ha), green fodder production efficiency (945 kg/ha) and dry matter production efficiency (172 kg/ha) with 3:1 row ratios. The increase in green fodder yield and production efficiencies in the intercropping systems might be owing to better utilization of space and light interception coupled with nutrient contribution of leguminous fodder to cereal. The reason behind difference in yield among intercropping combinations is may be due to respective proportion of component crops in the respective combination. These inferences were in line with Islam *et al.* (2018) who reported that total green forage yield is equal to the addition of yield produced by intercrops and it was greatly influenced due different mixtures of crops being grown with each other and two rows of millet alternating with one row of cowpea gave maximum forage yield. This result is in conformity with Ramanakumar and Bhanumurthy (2001) and Tamta *et al.* (2019) who reported that intercropping system of maize and cowpea in 2:1 ratio produced higher green fodder yield.

Nitrogen, phosphorus and potassium content of fodder pearl millet and cluster bean were significantly influenced by different intercropping combinations (Table 2). The maximum value of nitrogen content both in fodder pearl millet (I cut- 1.17 % and II cut- 1.12%) and cluster bean (2.92%) was recorded with 1 : 3 row ratio of fodder pearl millet + cluster bean intercropping combination. However, in case of fodder pearl millet all the intercropping combinations were

Table 1. Effect of different intercropping combinations on yield and production efficiency of fodder pearl millet and cluster bean at harvest.

Treatments	Green fodder yield (t/ha)				Dry matter (%)			Green fodder production efficiency (kg/ha)				Dry matter production efficiency (kg/ha)			
	PM		CB	Total	PM		CB	PM		CB	Total	PM		CB	Total
	I Cut	II Cut			I Cut	II Cut		I Cut	II Cut			I Cut	II Cut		
Sole PM	24.83	14.47	-	39.30	18.15	19.84	-	552	362	-	914	100	72	-	172
Sole CB	-	-	23.60	23.60	-	-	17.92	-	-	315	315	-	-	56	56
PM + CB (1:1)	15.30	9.90	11.20	36.40	17.92	19.54	16.61	340	248	149	737	61	48	25	134
PM + CB (2:1)	22.90	13.53	7.37	43.80	17.78	19.22	17.37	509	338	98	945	90	65	17	172
PM + CB (1:2)	9.97	6.40	15.33	31.70	17.31	18.82	17.59	221	160	204	586	38	30	36	104
PM + CB (2:2)	13.90	9.67	11.03	34.60	17.39	18.89	16.78	309	242	147	698	54	46	25	124
PM + CB (3:1)	24.10	14.37	5.53	44.00	17.93	19.16	17.04	536	359	74	969	96	69	13	178
PM + CB (1:3)	8.47	5.30	17.47	31.23	17.23	18.61	17.52	188	133	233	554	32	24	41	98
PM + CB (3:3)	14.20	9.30	10.77	34.27	17.89	19.39	16.89	316	233	144	692	56	45	24	126
SEm±	0.88	0.84	0.59	1.19	0.62	0.58	0.59	20	21	8	26	4	4	2	6
CD (p = 0.05)	2.66	2.55	1.78	3.58	NS	NS	NS	59	64	24	79	14	13	5	18

PM- Pearl millet; CB- Cluster bean.

recorded statistically at par value of nitrogen content whereas it was at par in 1 : 2, 2 : 2, 3 : 3 and 1 : 3 row ratio in fodder cluster bean. Similarly, maximum value of phosphorus (0.273, 0.235 and 0.414%) and potassium (2.27, 1.98 and 2.42%) content in pearl millet I cut, pearl millet II cut and cluster bean, respectively were found in 1:3 row ratio of fodder pearl millet + cluster bean intercropping combination. However, intercropping row ratios of 1 : 2, 2 : 2 and 3 : 3 recorded statistically at par value of phosphorus and potassium content in both fodder pearl millet and cluster bean. Higher contents of N, P and K in intercropping as compared to sole cropping might

Table 2. Effect of different intercropping combinations on N, P and K content of fodder pearl millet and cluster bean.

Treatments	N Content %			P Content %			K Content %		
	PM		CB	PM		CB	PM		CB
	I Cut	II Cut		I Cut	II Cut		I Cut	II Cut	
Sole PM	1.02	0.95	-	0.221	0.169	-	1.61	1.07	-
Sole CB	-	-	2.67	-	-	0.329	-	-	1.96
PM + CB (1:1)	1.11	1.06	2.75	0.254	0.210	0.354	1.93	1.58	2.19
PM + CB (2:1)	1.09	1.04	2.72	0.241	0.193	0.336	1.81	1.39	2.09
PM + CB (1:2)	1.15	1.11	2.84	0.267	0.226	0.401	2.13	1.81	2.31
PM + CB (2:2)	1.13	1.08	2.82	0.261	0.218	0.380	2.04	1.77	2.22
PM + CB (3:1)	1.08	1.02	2.70	0.233	0.182	0.321	1.72	1.27	2.03
PM + CB (1:3)	1.17	1.12	2.92	0.273	0.235	0.414	2.27	1.98	2.42
PM + CB (3:3)	1.14	1.08	2.90	0.269	0.229	0.386	2.19	1.86	2.35
SEm±	0.03	0.03	0.05	0.009	0.008	0.011	0.08	0.07	0.09
CD at 5%	0.09	0.09	0.16	0.029	0.025	0.034	0.23	0.21	0.26

PM- Pearl millet; CB- Cluster bean; N- Nitrogen; P- Phosphorus; K- potassium.

be attributed due to the fact that 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. Tamta *et al*. (2019) also reported that N content in fodder maize + cowpea intercropping system significantly influenced by row ratios of intercrops. Uptake of nitrogen, phosphorus and potassium in fodder pearl millet and cluster bean were also significantly influenced by different intercropping combination (Table 3). Significantly highest total nitrogen uptake was recorded by 1 : 3 row ratio of fodder pearl millet + cluster bean intercropping (117.4 kg/ha). However, sole cluster bean, 1 : 2 and 2 : 1 row ratios of intercropping recorded at par values of total nitrogen uptake with 1 : 3 row ratios. Further, highest total phosphorus (19.1 kg ha^{-1}) and potassium (136.3 kg/ha) uptake was recorded with 2 : 1 row ratio of fodder pearl millet and cluster bean intercropping combinations. However, all the intercropping combinations recorded at par value of total phosphorus and potassium uptake. The results are in agreement with the findings of Ramanakumar and Bhanumurthy (2001). Singh *et al.* (2008) also reported that total N, P and K uptake of the system was significantly superior in intercropping system to sole cropping. Ginwal *et al*. (2019) reported maximum nitrogen and phosphorus uptake in 1 : 1 row ratios of Maize + Cluster bean intercropping combinations.

Table 3. Effect of different intercropping combinations on N, P and K uptake of fodder pearl millet and cluster bean.

Treatments	N Uptake (kg/ha)				P Uptake (kg/ha)				K Uptake (kg/ha)			
	PM		CB	Total	PM		CB	Total	PM		CB	Total
	I Cut	II Cut			I Cut	II Cut			I Cut	II Cut		
Sole PM	45.8	27.2	-	73.0	9.9	4.9	-	14.8	73.1	30.7	-	103.8
Sole CB	-	-	112.8	112.8	-	-	13.9	13.9	-	-	82.6	82.6
PM + CB (1:1)	30.5	20.6	51.0	102.1	7.0	4.0	6.6	17.6	52.9	30.5	40.9	124.2
PM + CB (2:1)	44.3	26.9	34.5	105.7	9.8	5.0	4.3	19.1	73.7	36.0	26.6	136.3
PM + CB (1:2)	19.8	13.3	76.8	110.0	4.6	2.7	10.8	18.2	36.8	21.8	62.5	121.1
PM + CB (2:2)	27.2	19.8	52.1	99.1	6.3	4.0	7.0	17.3	49.2	32.5	41.1	122.7
PM + CB (3:1)	46.6	28.0	25.3	100.0	10.1	5.0	3.0	18.2	74.3	34.9	19.1	128.3
PM + CB (1:3)	16.9	11.0	89.5	117.4	3.9	2.3	12.7	18.9	32.7	19.4	74.4	126.5
PM + CB (3:3)	29.0	19.7	52.7	101.4	6.8	4.1	7.0	18.0	55.6	33.6	42.6	131.8
SEm±	2.4	2.0	3.2	4.2	0.6	0.4	0.5	0.9	4.8	2.9	3.5	6.5
CD (p=0.05)	7.3	6.0	9.6	12.5	1.7	1.2	1.7	2.8	14.4	8.9	10.6	19.6

PM- Pearl millet; CB- Cluster bean; N- Nitrogen; P- Phosphorus; K- potassium.

Table 4. Effect of different intercropping combinations on intercropping indices of fodder pearl millet and cluster bean (calculated on green fodder basis).

Treatments	LER	Aggressivity		CR		RCC		MAI
		PM	CB	PM	CB	PM	CB	
PM + CB (1:1)	1.12	0.17	-0.17	1.38	0.76	1.9	0.93	2324
PM + CB (2:1)	1.24	0.15	-0.15	1.55	0.68	8.4	0.94	5639
PM + CB (1:2)	1.07	0.09	-0.09	1.30	0.79	1.5	0.94	1131
PM + CB (2:2)	1.07	0.07	-0.07	1.29	0.78	1.5	0.88	1204
PM + CB (3:1)	1.21	0.09	-0.09	1.42	0.72	24.1	0.92	4679
PM + CB (1:3)	1.09	0.10	-0.10	1.42	0.71	1.6	1.09	1559
PM + CB (3:3)	1.06	0.05	-0.05	1.33	0.77	1.5	0.85	1002

PM- Pearl millet; CB- Cluster bean; LER- Land Equivalent Ratio; CR- Competition Ratio; RCC- Relative Crowding Coefficient; MAI- Monetary Advantage Index.

Intercropping treatments of fodder pearl millet and cluster bean show variation in their competitive performance (Table 4). All the intercropping combinations of fodder pearl millet and cluster bean recorded land equivalent ratio (LER) value more than 1. This indicated yield advantage of mixing these crops in all these intercropping treatments. The highest value of LER (1.24) was recorded in 2 : 1 row ratio of fodder pearl millet + cluster bean intercropping combination followed by in 3 : 1 row ratio (1.21). The value of 1.24 indicated that almost 24 % 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 complementarily nature of component crops. Results are in close agreement with the results reported by Dwivedi *et al.* (2015), Dhonde *et al.* (2016). The negative values of aggressivity for fodder cluster bean indicated their poor competitiveness than the fodder pearl millet, it might be due to dominance of pearl millet over cluster bean, which has positive aggressivity in all the intercropping combinations. The higher values of aggressivity of fodder pearl millet in 1 : 1 row ratio of fodder pearl millet + cluster bean intercropping combination showed its greater dominance over other intercropping combinations. Higher values of competitive ratio of fodder pearl millet also indicated that it was more competitive to cluster bean. In general yields of legume component are significantly depressed by grasses components in intercropping (Hassan *et al.* 2017). Similar trends of aggressivity and competitive ratio were recorded by Takim (2012) in maize + cowpea intercropping system. Further, all the intercropping combinations were advantageous than sole planting systems because the product of relative crowding coefficient of both the component crops was more than one due to their complimentary relationship. The higher values of relative crowding coefficient of fodder pearl millet was obtained from 3 : 1 row ratio (24.1) of fodder pearl millet + cluster bean intercropping combinations followed by 2 : 1 row ratio (8.24) indicating greater advantage from these intercropping combinations which was further evident from their respective higher values of product crowding coefficient (pearl millet crowding coefficient × cluster bean crowding coefficient) of 22.17 and 7.90, respectively. Similarly, highest monetary advantage index was obtained with 2 : 1 row ratio (5639) of fodder pearl millet + cluster bean intercropping combinations followed by 3 : 1 row ratio (4679). Results are more or less similar to the results reported by Khonde *et al.* (2016).

Table 5. Effect of different intercropping combinations on economics of fodder pearl millet and cluster bean.

Treatments	Gross return (US\$ ha^{-1})	Net return (US\$ ha^{-1})	B:C ratio
Sole PM	689.19	261.01	1.61
Sole CB	509.38	135.28	1.36
PM + CB (1:1)	683.66	282.83	1.71
PM + CB (2:1)	797.92	387.82	1.95
PM + CB (1:2)	617.97	225.92	1.58
PM + CB (2:2)	651.42	250.59	1.63
PM + CB (3:1)	794.01	360.16	1.83
PM + CB (1:3)	618.42	228.53	1.59
PM + CB (3:3)	644.50	243.67	1.61
SEm±	-	21.98	0.05
CD at 5%	-	65.90	0.16

PM- Pearl millet; CB- Cluster bean; B:C ratio – Benefit cost ratio.

The economics of fodder production were also significantly influenced by different intercropping combination of fodder pearl millet and cluster bean (Table 5). The highest gross return (US$ 797.92/ha), net return (US$ 387.82/ha) and benefit: cost ratio (1.95) was obtained with 2:1 row ratio of fodder pearl millet + cluster bean intercropping combination followed by 3:1 row ratio. It is obvious because of higher total green fodder yield with relatively smaller extra investment in fodder pearl millet + cluster bean 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 reported by Tamta *et al.* (2019) and Ginwal *et al.* (2019) who reported that 2:1 row ratio of maize + cowpea intercropping recorded highest net return and benefit cost ratio. Langat *et al.* (2006) and Sharma *et al.* (2008) also observed that monetary returns and benefit cost ratio significantly were influenced by intercropping row ratios in forage crops.

Results of this study confirmed that intercropping of pearl millet and cluster bean significantly influenced productivity, profitability and land use efficiency by different row ratios. Maximum value of green fodder yield was obtained with intercropping of three rows pearl millet + one row cluster bean (3 : 1) whereas maximum nitrogen uptake was recorded with one row pearl millet + three row cluster bean (1 : 3). However, intercropping of two row pearl millet + one row cluster bean (2:1) recorded at par value of both green fodder yield and nitrogen uptake. Further, maximum value of phosphorus and potassium uptake; LER, MAI, net return and benefit cost ratio was recorded with intercropping of two row pearl millet + one row cluster bean (2 : 1). Hence, this investigation recommended two row pearl millet + one row cluster bean (2 : 1) intercropping combination for obtaining maximum value of green fodder yield, profitability and land use efficiency.

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