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Assessment of Pearl millet (*Pennisetum glaucum* L.) Legume Intercropping System under Dryland Condition

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***Abstract*:** Field experiment was carried out at CCS Haryana Agricultural University, Hisar during *kharif* season of 2020 for suitable pearl millet-legume intercropping system for enhancement of yield and economics. There were eleven treatments *viz*., pearl millet, green gram and cluster bean sole at 45 cm, pearl millet in combination with green gram and cluster bean at variable ratio at 45 and 30 cm with four replications. The highest yield parameters of pearl millet were in pearl millet sole at 45 cm which was closely followed by pearl millet + green gram (8:4) at 30 cm. Yield attributes of intercrops were higher under sole cropping of intercrops followed by pearl millet + green gram/cluster bean (8:4) at 30 cm. Pearl millet + green gram (8:4) at 30 cm recorded highest pearl millet equivalent yield (3109 kg/ha) with higher net returns (₹ 41256/ha) and benefit: cost ratio (2.61). Higher yield indices under pearl millet + green gram (8:4) at 30 cm showed the superiority over other intercropping systems.

***Keywords*:** Cluster bean, Dryland, Green gram, Intercropping, Pearl millet, Yield

Pearl millet is major coarse grain grown as rainfed crop on marginal lands under low input management conditions. Being inherent drought-escaping mechanism and adaptation to drier and low fertile conditions, it occupies a prime place in dryland agriculture and contributing significantly to country's food security. It is normally cultivated in those areas where annual rainfall ranges from 150 to 600 mm. Its sole cultivation is often risky and to avoid risks in rainfed/dryland areas, generally farmers grow green gram, cowpea, moth bean, black gram and cluster bean in mixed stands. Instead of sole and mixed cropping, intercropping of pearl millet with legumes has been reported to be more stable and profitable. In intercropping system, selection of compatible crops with different growth parameters and their suitable planting geometry are very significant because it helps to minimize the inter and intra specific competition for resources, thereby maximizing the production potential of the system (Sharma and Singh 2008). The suitable intercropping system might increase the total production through efficient utilization of production factors like space, moisture, nutrients etc. Short duration crops have ample scope to grow with other crops for introducing some compatible intercrops to increase the productivity. The complementarity effect and productivity increases are highest when the component crops have diverse growing habitat to meet their significant resource demands at different times (Maitra et al 2021). The selection of crops which will show complementarity among them is a key consideration to ensure efficient utilization of available resources (Huss et al 2022). Green gram and cluster bean with deep fast penetrating root system in combination with drought avoidance capabilities can survive and thrive for a considerable period in open field, exhibiting fast depletion of soil moisture with very high atmospheric temperature. The multi adaptive and adjusting nature of these crops have enabled them to become an integral part of different types of cropping and farming system of the arid and semi-arid regions. The information regarding intercropping systems of pearl millet-legume with varying row ratios is meagre under dryland conditions, therefore, the present study was undertaken.

MATERIAL AND METHODS

Field experiment was conducted during rainy (*kharif*) season of 2020 at Dryland Agriculture Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India (29^{0}10' N, 75^{0}46' E and 215.2 m above mean sea-level). The average annual precipitation of the experimental site estimated to 425.5 mm and most of which is received from South-Western monsoon during July to September. The soil of the experimental field was sandy loam, low in organic carbon (0.29%) and in available nitrogen (112 kg/ha), medium in available phosphorus (15.5 kg/ha) and potassium (235 kg/ha). The experiment was laid out in randomized block design with four replications comprising of eleven intercropping treatments (Table 1). Hybrid 'HHB 67 Improved' pearl millet, 'MH 421' green gram and 'HG 2-20' cluster bean

were sown on 14 July 2020. The fertilizer dose of 40 kg N + 20 kg P_2O_5/ha to pearl millet and 20 kg N + 40 kg P_2O_5/ha to legumes was applied at sowing. The other agronomic practices were followed as per package of practices during the crop growth period. The number of dry spells of more than 10 days experienced by the crop was 2 during the crop season. Pearl millet, green gram and cluster bean were harvested at 73, 57 and 87 days after sowing.

Observations on plant height and dry-matter accumulation/plant were recorded manually on 5 random plants from each plot of each replication separately as well as yield and yield-attributing characters were recorded as per the standard method. The grain yield of all the crops in sole as well as in intercropping systems were subjected to statistical analysis only after conversion into the pearl millet equivalent yield taking into consideration the average market prices of the grain (pearl millet ₹ 2150/100 kg, green gram ₹ 7196/100 kg and cluster bean ₹ 4000/100 kg). To find out the most profitable treatment, economics of different treatments were worked out in terms of net returns of the crop. Treatment-wise benefit: cost (B: C) ratio was calculated to ascertain economic viability. All the results were analyzed statistically for drawing conclusion using online statistical analysis tools (OPSTAT).

Land equivalent ratios (LER) = La + Lb, La = Yab/Yaa, Lb = Yba/Ybb where, La and Lb are land equivalent ratio of main and intercrops, respectively. Yaa and Yab are yields of main crop while Ybb and Yba are the yields of intercrops in sole stands and in intercropping, respectively. Area time equivalent ratio (ATER) = (LaTa + LbTb)/T where La and Lb, are partial LERs of main and intercrops, Ta and Tb are duration of main and intercrops and T is the total duration of the whole intercropping system. Income equivalent ratio (IER) = income from both main and intercrops in intercropping system/income from sole main crop. Monetary advantage index (MAI) = Net returns from combined produce (₹/ha) × (LER-1)/LER. Aggressivity of main crop (Aab) = {(Yab/Yaa × Zab) - (Yba/Ybb × Zba)} and of intercrop (Aba) = {(Yba/Ybb × Zba) - (Yab/Yaa × Zab)}. Relative crowding coefficient of main crop (Kab) = (Yab × Zba)/(Yaa-Yab) Zab and of intercrop (Kba) = (Yba× Zab)/(Ybb – Yba) Zba, and product of both (K) = Kab × Kba. Competitive ratio of main crop (Cra) = (LERa/LERb) (Zba/Zab) and of intercrop (Crb) = (LERb/LERa) (Zab/Zba) where Zab, proportion of intercrop area allocated to main crop and Zba, proportion of intercrops area allocated to intercrop.

RESULTS AND DISCUSSION

Weather and climate: The data on rainfall were recorded at the meteorological observatory of CCS Haryana Agricultural University, Hisar (Fig. 1). The total rainfall received was 151.9, 94.2 and 34.7 mm during July, August and September, respectively. However, total amount of rainfall received during the crop growth period was 239.4 mm. The mean weekly maximum and minimum temperatures ranged from 32.6 to 38.7°C and 16.3 to 27.9°C respectively during crop growing period. The weekly mean relative humidity ranged from 79 to 94% in morning and 28 to 77% in evening hours. The weekly mean wind speed fluctuated between 2.9 to 8.7 km/hour. The bright sun-shine hours ranged from 5.1 on a cloudy day to 8.7 on a clear day. Evaporation from open pan evaporimeter ranged between 3.5 to 7.6 mm/day in 36th to 27th standard weeks, respectively.

Pearl millet: Sole pearl millet recorded significantly higher plant height (182.22 cm) than that intercropping with green gram/cluster bean which is due to competition for sunlight among the plants (Table 1) and was at par with pearl millet + green gram (8:4) at 30 cm and pearl millet + cluster bean (8:4)

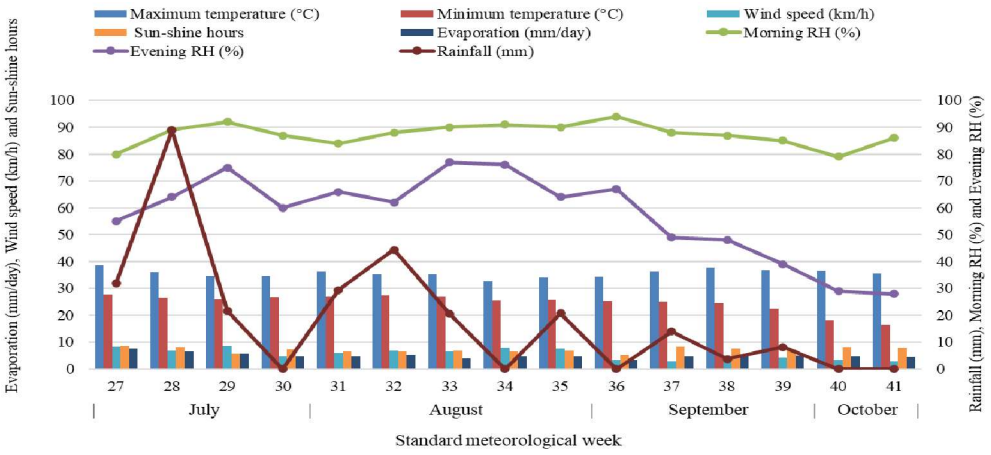

Fig. 1. Weather parameters during crop season

at 30 cm. The shorter plants of pearl millet were observed when intercropped at different row ratios with legumes. This was due to interspecies and cooperative interaction of intercrops with pearl millet for non-renewable resources like water, nutrients and light. The increase in plant height is a function of cell division and cell enlargement which depends on availability of nutrients in a balanced form especially N, P and K. Since soil of the experimental field was low in N, medium in P and K, therefore, sole stands of pearl millet might have faced less competition for growth and yield attributing characters as compared to intra-species competition in between pearl millet and intercrops (green gram and cluster bean). That may lead to establishment of better nutritional environment in root zone for growth and development. The number of total tillers/plant at harvest was significantly influenced by intercropping treatments. Sole pearl millet produced the maximum number of total tillers/plant (5.05) and was at par with pearl millet + green gram (8:4) at 30 cm, pearl millet + green gram (6:6) at 45 cm, pearl millet + cluster bean (8:4) at 30 cm, pearl millet + cluster bean (6:6) and pearl millet + green gram (4:4) both at 45 cm. These results corroborated with the finding of Suman et al (2021).

The significant increase in number of effective tillers/plant at harvest was observed in pearl millet sole at 45 cm over intercropping treatments. However, it was at par with pearl millet + green gram (8:4) at 30 cm, pearl millet + green gram (6:6) at 45 cm, pearl millet + cluster bean (8:4) at 30 cm and pearl millet + cluster bean (6:6) at 45 cm. This was due to less competition for resources by the intercrops during growth and development of the crop. Similar results were obtained by Renu et al (2018). Sowing of sole pearl millet at 45 cm produced significantly higher ear head length and ear head girth superior to all other intercropping treatments. However, it was at par with pearl millet + green gram (8:4) at 30 cm, pearl millet + green gram (6:6) at 45 cm and pearl millet + cluster bean (6:6) at 45 cm. The higher length and girth of earhead may be due to lower number of pearl millet density and wider space available for more growth and development of pearl millet. Suman et al (2021) had similar observations regarding yield-attributing characters of pearl millet. Seed index of pearl millet was not affected significantly with different intercropping treatments.

Intercrops: Sole green gram at 45 cm recorded significantly higher plant height (49.80 cm) than its intercropping with pearl millet except pearl millet + green gram (8:4) at 30 cm (Table 2). Yield- attributing characters of green gram, viz. number of branches/plant and pods/plant were higher under sole green gram at 45 cm which remained at par with pearl millet + green gram (6:6) at 45 cm and pearl millet + green gram (8:4) at 30 cm. Number of seeds/pod and seed index were not influenced significantly by intercropping treatments. Sole cluster bean at 45 cm being at par with pearl millet + cluster bean (8:4) at 30 cm recorded significantly higher plant height than other intercropping treatments. Cluster bean sole at 45 cm produced significantly higher number of pods/plant and seeds/pod compared to other intercropping treatments except pearl millet + cluster bean (8:4) at 30 cm. Yield attributes of cluster bean viz., number of branches/ plant and seed index were found to be non-significant with respect to different intercropping treatments. Similar results have also been reported by Kumar et al (2017).

Pearl millet-equivalent yield: The significant reduction in grain and stover yield was observed under intercropping treatments (Table 3). The maximum grain yield of pearl millet was found in sole pearl millet at 45 cm. The reduction in yield of pearl millet in the intercropping system was mainly due to reduction in plant stands and replacement and additive type

Table 1. Effect of intercropping on yield attributes of pearl millet

Treatments	Plant height (cm)	Total tillers/ plant	Effective tillers/ plant	Ear head length (cm)	Ear head girth (cm)	Seed index (g)
Pearl millet sole at 45 cm	182.22	5.05	4.15	23.15	9.02	8.97
Pearl millet + green gram (2:2) at 45 cm	172.52	4.45	3.44	22.12	8.08	8.72
Pearl millet + cluster bean (2:2) at 45 cm	169.56	4.00	3.05	22.16	7.94	8.74
Pearl millet + green gram (4:4) at 45 cm	173.08	4.50	3.47	22.37	8.52	8.79
Pearl millet + cluster bean (4:4) at 45 cm	171.09	4.30	3.35	22.81	8.48	8.72
Pearl millet + green gram (6:6) at 45 cm	176.36	4.80	3.75	22.94	8.84	8.91
Pearl millet + cluster bean (6:6) at 45 cm	173.95	4.60	3.70	23.03	8.82	8.89
Pearl millet + green gram (8:4) at 30 cm	179.03	4.90	4.03	23.09	9.11	8.85
Pearl millet + cluster bean (8:4) at 30 cm	178.40	4.63	3.71	22.71	8.72	8.85
CD (p=0.05)	4.17	0.56	0.46	0.40	0.44	NS

of intercropping system was followed under the present study. Sharma and Singh (2008) also recorded the maximum grain and stover yields of pearl millet in sole system over inter and strip cropping systems. The highest grain and stover yield of intercrops was found in the sole crops of green gram and cluster bean, respectively. The grain yield of intercrops was highest in their sole stands which decreased by 48.0, 46.3, 44.8 and 23.6% in case of green gram and 41.5, 39.3, 37.0 and 24.1% in cluster bean with 2:2, 4:4, 6:6 and 8:4 intercropping systems at 45 cm. Variation in the grain and straw yield of both intercrops (green gram & cluster bean) among different intercropping treatments were recorded. It might be due to less competition for resources by the other crops during growth and development of the crop. Similar trend was observed by Yadav et al (2015). Intercropping treatments significantly influenced the pearl millet equivalent yield (Table 3). The pearl millet equivalent yield was highest under pearl millet + green gram (8:4) at 30 cm which decreased by 32.3, 27.7 and 24.7% in case of green gram and 36.3, 33.5 and 24.7% in cluster bean with 2:2, 4:4 and 6:6 intercropping systems at 45 cm. These results corroborated with the finding of Sharma and Singh (2008). Among replacement series of intercropping treatments, highest pearl millet equivalent yield (2340 kg/ha) was obtained under pearl millet + green gram (6:6) at 45 cm. Lowest pearl millet equivalent yield (1654 kg/ha) was observed under pearl millet sole at 45 cm.

Economics: Among various intercropping treatments, pearl

Table 2. Effect of intercropping on yield attributes of intercrops

Treatments	Plant height (cm)	Branches/ plant	Pods/plant	Seeds/ pod	Seed index (g)
Green gram					
Green gram sole at 45 cm	49.80	5.60	25.79	8.93	4.58
Pearl millet + green gram (2:2) at 45 cm	41.75	5.01	23.65	8.83	4.12
Pearl millet + green gram (4:4) at 45 cm	42.70	5.20	24.44	8.85	4.14
Pearl millet + green gram (6:6) at 45 cm	43.21	5.35	24.84	8.88	4.28
Pearl millet + green gram (8:4) at 30 cm	47.80	5.28	24.72	8.90	4.31
CD (p=0.05)	2.93	0.35	1.25	NS	NS
Cluster bean					
Cluster bean sole at 45 cm	85.98	5.25	37.01	6.52	2.21
Pearl millet + cluster bean (2:2) at 45 cm	80.73	5.05	33.19	5.85	2.16
Pearl millet + cluster bean (4:4) at 45 cm	81.81	4.60	33.36	5.90	2.11
Pearl millet + cluster bean (6:6) at 45 cm	82.83	4.73	34.34	6.11	2.12
Pearl millet + cluster bean (8:4) at 30 cm	83.88	4.83	35.82	6.37	2.17
CD (p=0.05)	2.46	NS	2.35	0.19	NS

Table 3. Pearl millet-equivalent yield as affected by different intercropping treatments

Treatments	Grain yield (kg/ha)		Stover yield (kg/ha)		Pearl millet-equivalent yield (kg/ha)
	Pearl millet	Legume	Pearl millet	Legume	
Pearl millet sole at 45 cm	1409	-	2927	-	1654
Green gram sole at 45 cm	-	704	-	1141	2410
Cluster bean sole at 45 cm	-	942	-	942	1960
Pearl millet + green gram (2:2) at 45 cm	722	366	1563	597	2105
Pearl millet + cluster bean (2:2) at 45 cm	715	551	1541	551	1981
Pearl millet + green gram (4:4) at 45 cm	782	378	1671	631	2247
Pearl millet + cluster bean (4:4) at 45 cm	745	572	1595	572	2067
Pearl millet + green gram (6:6) at 45 cm	861	388	1807	639	2340
Pearl millet + cluster bean (6:6) at 45 cm	825	593	1777	593	2207
Pearl millet + green gram (8:4) at 30 cm	1079	538	2220	904	3109
Pearl millet + cluster bean (8:4) at 30 cm	1065	715	2139	715	2730
CD (p=0.05)	68	-	143	-	192

millet + green gram in 8:4 at 30 cm showed the maximum net returns of ₹ 41256/ha and B: C ratio of 2.61 (Table 4). The highest net returns and B: C ratio were associated with its higher grain and stover yields per unit of added cost. The minimum net returns were noticed in sole pearl millet at 45 cm and pearl millet + cluster bean (2:2) at 45 cm because cluster bean might be more competitive than green gram. These findings are in the vicinity with those reported by Kuri (2012) and Suman et al (2021).

Yield indices: Land equivalent ratio (LER) of all intercropping treatments varied from 1.05 to 1.55 (Table 5). The intercropping treatment of pearl millet + green gram (8:4) at 30 cm showed the highest LER (1.55), closely followed by pearl millet + cluster bean (8:4) at 30 cm whereas the lowest value of LER (1.05) was observed in pearl millet + green gram (2:2) at 45 cm. Higher values of LER in pearl millet + green gram (8:4) at 30 cm reflect development of complimentarily with least competition in this system. Higher land equivalent ratio in intercropping system under rainfed conditions was also reported by Sharma et al (2015). Highest value of MAI was recorded in pearl millet + cluster bean (8:4) at 30 cm followed by pearl millet + green gram (8:4) at 30 cm. Area time equivalent ratio (ATER) ranged from 0.78 to 1.40. The highest area time equivalent ratio (ATER) of 1.40 was obtained in pearl millet + cluster bean (8:4) at 30 cm followed by pearl millet + green gram (8:4) at 30 cm (1.15) while the minimum ATER was obtained in pearl millet + green gram (2:2) at 45 cm (0.78). The intercrops had negative values of aggressivity, representing the low competitiveness of crop when grown as intercrop with pearl millet. The aggressivity of intercrops ranged from -1.04 to -2.30. Pearl millet + green gram (2:2) at 45 cm had greater value of aggresivity (-1.04) which did offer less competition to pearl millet as compared to pearl millet + green gram (8:4) at 30 cm. The lowest competition ratio (0.50) of pearl millet was under pearl millet + green gram (8:4) at 30 cm while highest value was under pearl millet + green gram (6:6) at 45 cm. Green gram showed the highest competitive ratio when intercropped with pearl

Table 4. Effect of intercropping on economics of crops

Treatments	Gross returns (₹/ ha)	Cost of cultivation (₹/ ha)	Net returns (₹/ ha)	Benefit: cost ratio
Pearl millet sole at 45 cm	35561	23695	11866	1.50
Green gram sole at 45 cm	51815	23630	28185	2.19
Cluster bean sole at 45 cm	42140	20763	21378	2.03
Pearl millet + green gram (2:2) at 45 cm	45258	25033	20225	1.81
Pearl millet + cluster bean (2:2) at 45 cm	42592	23600	18992	1.80
Pearl millet + green gram (4:4) at 45 cm	48311	25033	23278	1.93
Pearl millet + cluster bean (4:4) at 45 cm	44441	23600	20841	1.88
Pearl millet + green gram (6:6) at 45 cm	50310	25033	25278	2.01
Pearl millet + cluster bean (6:6) at 45 cm	47451	23600	23851	2.01
Pearl millet + green gram (8:4) at 30 cm	66844	25588	41256	2.61
Pearl millet + cluster bean (8:4) at 30 cm	58695	24633	34063	2.38

Table 5. Yield indices under pearl millet-legume intercropping systems

Treatments	LER	MAI	ATER	A		CR		K		
				A_p	A_i	CR_p	CR_i	K_p	K_i	K_t
PM + GG (2:2) at 45 cm	1.05	0.53	0.78	1.06	-1.04	1.02	0.98	1.13	1.08	1.22
PM + CB (2:2) at 45 cm	1.10	1.11	1.02	1.02	-1.17	0.87	1.15	1.03	1.41	1.45
PM + GG (4:4) at 45 cm	1.10	1.11	0.82	1.11	-1.10	1.01	0.99	1.25	1.22	1.52
PM + CB (4:4) at 45 cm	1.14	1.60	1.05	1.06	-1.22	0.87	1.15	1.12	1.55	1.74
PM + GG (6:6) at 45 cm	1.16	1.74	0.87	1.22	-1.10	1.11	0.90	1.57	1.23	1.93
PM + CB (6:6) at 45 cm	1.21	2.50	1.12	1.17	-1.26	0.93	1.07	1.41	1.70	2.39
PM + GG (8:4) at 30 cm	1.55	5.63	1.15	1.15	-2.30	0.50	2.00	1.63	6.50	10.61
PM + CB (8:4) at 30 cm	1.52	6.09	1.40	1.14	-2.28	0.50	2.01	1.55	6.32	9.78

PM-Pearl millet, GG-Green gram, CB-Cluster bean, LER-Land equivalent ratio, MAI-Monetary advantage index, ATER-Area time equivalent ratio, A-Aggressivity, CR-Competitive ratio, K (K_t)
-Total relative crowding coefficient, K_p-Relative crowding coefficient of pearl millet, K_i-Relative crowding coefficient of intercrops

millet in 8:4 at 30 cm while green gram showed the lowest competitive ratio with pearl millet in 2:2 at 45 cm. In general, the competitive ability of pearl millet with green gram in 8:4 at 30 cm was better than other ratios. Relative crowding coefficient values of pearl millet were lower than that of all the intercrops, indicating the dominance of all the intercrops over pearl millet. The RCC values of intercrops were always >1. This indicates that all the intercrops yielded more than expected and had better competitive ability than pearl millet in the intercropping system. The total relative crowding coefficient (10.61) was observed highest in pearl millet + green gram (8:4) at 30 cm among all the intercropping treatments, indicating highest yield. Ram and Meena (2014) also observed the higher yield indices under pearl millet and green gram intercropping system in 1:7 rows in arid region of Rajasthan.

CONCLUSION

Pearl millet sown with green gram (8:4) at 30 cm proved beneficial for getting higher yield and profitability of pearl millet-legume intercropping system under dryland condition of sandy-loam soils in arid/semi-arid regions.

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