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RESEARCH PAPER

Effect of row proportion and nutrient management on growth, yield and economics of pigeonpea (*Cajanus cajan* (L.) Millsp.) and kodo millet [*Paspalum scrobiculatum*] intercropping system

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Abstract : An agronomic investigation entitled "Studies on row proportion and nutrient management in pigeonpea [*Cajanus cajan* (L.) Millsp.] and kodo millet [*Paspalum scrobiculatum*] intercropping system" was carried out at Agricultural College Farm, Raichur during *kharif* 2021. The experiment was laid out in randomized block design with three replications and ten treatments. Results revealed that, the sole crops of pigeonpea and kodo millet produced significantly higher seed and grain yield (1298 and 2015 kg ha^{-1}, respectively) when compared to their intercropping treatments. Among the different intercropping treatments, T_4 [pigeonpea+ kodo millet (1:1) with 125 per cent RDF to pigeonpea and no fertilizers to kodo millet] recorded significantly higher seed yield of pigeonpea (1101 kg ha^{-1}) and T_{10} [pigeonpea+ kodo millet (1:2) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet] recorded significantly higher grain yield of kodo millet (1878 kg ha^{-1}). The higher net returns was recorded under T_6 [pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet] (₹ 88,698 ha^{-1}). The treatment T_5 [pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and 50 per cent RDF to kodo millet] recorded significantly higher benefit cost ratio (4.54).

Key words: Intercrop, Nutrient management, Row proportion

Introduction

In spite of substantial gains in agricultural production over the past few decades, the task of meeting the food grains, feed, fodder and fuel needs of increasing human and livestock population remains a challenge before scientific community. It is estimated that India's population will touch nearly 1500 million by 2030 A. D. and the food requirement of the country by 2030 A. D. is expected to be 252 million tonnes. This additional production has to come from the existing land and water resources. In the present situation, increasing agriculture production through extensive agriculture has limited scope due to limited availability of cultivatable area and further expansion of cultivable area is extremely difficult. Under these situations, to meet the requirement of food grains for ever increasing population, the only option is through time and space utilization in agriculture.

The availability of land for agriculture is shrinking every day as it is increasingly utilized for non-agricultural purposes. Under this situation, one of the important strategies to increase agriculture output is the development of new high intensity cropping systems including intercropping systems. Intercropping system which involves raising more than one crop on the same piece of land simultaneously, which increases cropping intensity both in space and time dimensions.

The main concept of intercropping is to increase the total productivity per unit area and time, besides equitable and judicious utilization of land resources and farms inputs including labour. A careful selection of crops can reduce the mutual competition to considerable extent *i.e*., by including two crops having different morphological characters and growth habit. The demands of these two crops complement each other in time and space.

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is a long duration crop, grown under wider row spacing and initial growth of pigeonpea is very slow, hence the short duration crops like pearl millet, finger millet, foxtail millet, little millet, proso millet, barnyard millet, kodo millet, sunflower, groundnut can be grown as intercrop with pigeonpea without reducing the pigeonpea yield.

The information on row proportion and nutrient management in pigeonpea and kodo millet intercropping system is limited. Hence, there is need to study the influence of row proportion and nutrient management practices in pigeonpea and kodo millet intercropping system.

Material and methods

A field experiment was conducted during *kharif* season of 2021 at Agricultural Collage Farm, Raichur. The centre is situated between 16° 12' N latitude and 77° 20' E longitude with an altitude of 389 meters above the mean sea level and is located in North Eastern Dry Zone of Karnataka. The experiment was laid out in randomized complete block design with 10 treatments *viz*., Sole pigeonpea with 100 per cent RDF (T_1), sole kodo millet with 100 per cent RDF (T_2), pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and no fertilizer to kodo millet (T_3), pigeonpea + kodo millet (1:1) with 125 per cent RDF to pigeonpea and no fertilizers to kodo millet (T_4), pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and 50 per cent RDF to kodo milet (T_5), pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet (T_6), pigeonpea + kodo millet (1:2) with 100 per cent RDF to pigeonpea and no fertilizer to kodo millet (T_7), pigeonpea + kodo millet (1:2) with 125 per cent RDF to pigeonpea and no fertilizer to kodo millet (T_8), pigeonpea +

kodo millet (1:2) with 100 per cent RDF to pigeonpea and 50 per cent RDF to kodo millet (T_9), pigeonpea + kodo millet (1:2) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet (T_{10}) and replicated thrice.

In the experiment, the fertilizer application was followed on the basis of plant population occupied by each crop. The nutrients *viz.,* nitrogen, phosphorus and potassium were applied in the form of urea, di-ammonium phosphate (DAP) and muriate of potash (MOP). Recommended dose of fertilizers were applied for the sole crops of pigeonpea (25:50:0 kg N, P_2O_5 and K_2O ha^{-1}, respectively) and kodo millet (30:15:15 kg N, P_2O_5 and K_2O ha^{-1}, respectively). In the intercropping system, the fertilizers were applied to the component crops according to the treatment details. The entire quantities of fertilizers were applied to pigeonpea at the time of sowing as basal. For kodo millet, 50 per cent of nitrogen and full dose of phosphorus and potassium was applied at the time of sowing and remaining 50 per cent of nitrogen was applied after 30 days of sowing as top dressing. The fertilizers were placed in small furrows opened at 5 cm away from the seed line (crop row) and covered with soil.

Certified seeds of both pigeonpea (TS-3R) and kodo millet (HRK-1) were used for sowing. Both the crops were sown by providing recommended spacing as per treatment. Sole pigeonpea : 90 cm x 20 cm ; Sole kodo millet: 30 x 5 cm. For intercropped treatment : Common row spacing of 45 cm (1:1 row proportion) and 30 cm (for 1:2 row proportion) was maintained, while plant to plant spacing was same as that in sole crops.

The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance was used for analysis and interpretation of the data as outlined by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was P = 0.05. Critical differences were calculated wherever 'F' test was significant.

Results and discussion

Effect on growth and yield parameters of pigeonpea

In the present study, T_1 (Sole pigeonpea with 100 per cent RDF) recorded significantly higher plant height (171.34 cm), leaf area (19.35 dm^2 $plant^{-1}$), dry matter production (165.73 g $plant^{-1}$), number of pods per plant (101.12), test weight (10.84 g), seed yield (1298 kg ha^{-1}) and straw yield (3986 kg ha^{-1}) when compared to pigeonpea grown in intercropping. Among intercropping treatments, T_4 [pigeonpea + kodo millet (1:1) with 125 % RDF to pigeonpea and no fertilizers to kodo millet] recorded significantly higher plant height (162.52 cm), leaf area (12.58 dm^2 $plant^{-1}$), dry matter production (148.75 g $plant^{-1}$), number of pods per plant (92.12), test weight (9.87 g), seed yield (1101 kg ha^{-1}) and straw yield (3422 kg ha^{-1}) over other intercropped treatments and it was found on par with T_3, T_5 and T_6. However, significantly lower plant height, leaf area, dry matter production, number of pods per plant, test weight, seed yield and straw yield were obtained in the treatment, T_7 [pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and no fertilizer to kodo millet] (33.51 cm, 7.96 dm^2 $plant^{-1}$, 132.74 g $plant^{-1}$, 82.33, 7.72, 897 kg ha^{-1} and 2984 kg ha^{-1}, respectively) as compared to other intercropped treatments and it was found on par with T_8, T_9 and T_{10} (Table 1).

Table 1. Effect of growth and yield parameters of pigeonpea as influenced by row proportion and nutrient management practices in pigeonpea and kodo millet intercropping system

Treatment No.	Treatment details	Plant height (cm)	Leaf area (dm^2 $plant^{-1}$)	Dry matter production (g $plant^{-1}$)	Number of pods $plant^{-1}$	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	Sole pigeonpea with 100 % RDF	171.34	19.35	165.73	101.12	10.84	1298	3004
T_2	Sole kodo millet with 100 % RDF	-	-	-	-	-	-	-
T_3	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	157.39	11.73	145.78	90.58	9.31	1052	2538
T_4	Pigeonpea + kodo millet (1:1) with 125 % RDF to pigeonpea and no fertilizers to kodo millet	162.52	12.58	148.75	92.12	9.87	1101	2607
T_5	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 50 % RDF to kodomilet	158.45	12.14	147.30	91.24	9.57	1071	2573
T_6	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	158.98	12.26	147.60	91.32	9.61	1087	2584
T_7	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	147.01	7.96	132.74	82.33	7.72	897	2386
T_8	Pigeonpea + kodo millet (1:2) with 125 % RDF to pigeonpea and no fertilizer to kodo millet	150.91	9.15	134.95	84.01	8.21	954	2448
T_9	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 50 % RDF to kodo millet	148.25	8.83	133.47	83.37	7.98	913	2401
T_{10}	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	148.98	8.95	133.91	83.53	8.01	921	2412
	S.Em. ±	2.26	0.51	1.37	1.05	0.26	19	27
	C.D.(P=0.05)	6.76	1.55	4.12	3.16	0.78	59	80

The lower pigeonpea growth and yield parameters under intercropping system might be due to increased plant population pressure of both crops (pigeon pea and kodo millet) resulting in increased competition for resources like nutrients, water, space, and solar radiation compared to sole crop of pigeonpea. Similar results of decreased intercrop yield were obtained in pigeonpea and sunflower intercropping system (Vishwanatha, 2009), pigeonpea and soybean intercropping system (Billore *et al.,* 1993 and Paslawar *et al*., 1997).

The higher pigeonpea seed yield in T_4, T_3, T_5 and T_6 over T_7, T_8, T_9 and T_{10} might be attributed to superior yield attributing characters of pigeonpea due to reduced competition by kodo millet and also due to effective utilization of applied nutrients by the crop and subsequently higher translocation and accumulation of dry matter in reproductive parts. Similar findings were obtained with Jain *et al*. (2001), Padmavathi *et al*. (2003) and Rajput and Rawat (2019).

Effect on growth and yield parameters of kodo millet

Sole kodo millet with 100 per cent RDF (T_2) recorded significantly plant height (75.03 cm), number of tillers (8.23), dry matter production (18.52 g plant^{-1}), number of ears per plant (8.15) and test weight (5.31) when compared to intercropped treatments. Among the intercropped treatments, T_6 [pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet] produced significantly higher plant height (73.12 cm), number of tillers (7.96), dry matter production (17.51 g plant^{-1}), number of ears per plant (7.56) and test weight (5.15) when compared to other intercropped treatments. Further, T_7 [pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and no fertilizer to kodo millet] recorded significantly lower leaf area (0.29 dm^2 plant^{-1}) when compared to all other intercropped treatments, but it was found on par with T_8, T_3 and T_4 (Table 2).

The experimental results showed that significantly higher growth and yield parameters were observed in sole kodo millet compared to intercropped treatments. This might be due to increased competition for utilization of growth resources in intercropping system. Among the intercropping treatments, significantly higher growth and yield parameters were recorded with T_6 over other treatments. This was because of lesser competition with intercrop, improved nutrient supply, overall improvement in plant growth, vigour, production and translocation of photosynthates and nutrients to developing reproductive parts which reflected into greater number of ears per plant, grain yield per plant and test weight. Similar findings were observed in pigeonpea + foxtail intercropping system (Priyanka and Rajakumara, 2019). Nigade *et al*. (2012) and Ramamoorthy *et al*. (2004) also obtained similar results of higher yield attributing characters of finger millet in intercropping under higher doses of fertilizer. Superiority of 1:1 ratio over 1:2 ratio in yield attributing characters are in conformity with findings of Sunita Kujur (2009).

T_2 (Sole kodo millet with 100 per cent RDF) revealed significantly higher grain yield (2015 kg ha^{-1}) and straw yield (3917 kg ha^{-1}) compared to intercropped treatments. Significantly lower grain yield and straw yield was produced in T_3 [pigeonpea + kodo millet (1:1) with 100 per cent RDF to pigeonpea and no

Table 2. Effect of growth and yield parameters of kodo millet as influenced by row proportion and nutrient management practices in pigeonpea and kodo millet intercropping system

Treatment No.	Treatment details	Plant height (cm)	Number of tillers plant^{-1}	Dry matter production (g plant^{-1})	Number of ears per plant	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	Sole pigeonpea with 100 % RDF	-	-	-	-	-	-	-
T_2	Sole kodo millet with 100 % RDF	75.03	8.23	18.52	8.15	5.31	2015	3917
T_3	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	69.38	7.33	15.25	6.26	4.81	1418	2868
T_4	Pigeonpea + kodo millet (1:1) with 125 % RDF to pigeonpea and no fertilizers to kodo millet	69.50	7.40	15.50	6.48	4.87	1451	2934
T_5	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 50 % RDF to kodomilet	71.31	7.67	16.45	7.02	5.01	1546	3124
T_6	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	73.12	7.96	17.51	7.56	5.15	1638	3306
T_7	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	67.97	7.25	15.02	6.21	4.78	1667	3356
T_8	Pigeonpea + kodo millet (1:2) with 125 % RDF to pigeonpea and no fertilizer to kodo millet	68.09	7.34	15.34	6.34	4.86	1691	3426
T_9	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 50 % RDF to kodo millet	69.95	7.61	16.27	6.92	4.99	1777	3561
T10	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	71.71	7.90	17.33	7.48	5.13	1878	3743
	S.Em. ±	0.57	0.07	0.28	0.16	0.04	25	42
	C.D.(P=0.05)	1.71	0.22	0.83	0.50	0.12	77	126

Table 3. Total uptake of nutrients, pigeonpea equivalent yield (PEY), land equivalent ratio (LER) and economics as influenced by row proportion and nutrient management practices in pigeonpea and kodo millet intercropping system

Treatment No.	Treatment details	Total uptake ($kg\ ha^{-1}$) Nitrogen	Phosphorus	Potassium	PEY ($kg\ ha^{-1}$) (₹ ha^{-1})	LER	Cost of Cultivation	Net returns (₹ ha^{-1})	B:C
T_1	Sole pigeonpea with 100 % RDF	187.45	23.16	48.56	1298	1.00	22,941	44,555	2.94
T_2	Sole kodo millet with 100 % RDF	68.47	17.69	60.52	1356	1.00	21,352	49,173	3.30
T_3	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	185.25	26.06	91.15	2006	1.51	23,116	81,218	4.51
T_4	Pigeonpea + kodo millet (1:1) with 125 % RDF to pigeonpea and no fertilizers to kodo millet	198.89	27.95	101.62	2077	1.56	23,867	84,170	4.52
T_5	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 50 % RDF to kodomillet	205.18	29.29	108.89	2111	1.59	24,136	85,666	4.54
T_6	Pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	218.36	33.08	119.06	2189	1.65	25,156	88,698	4.53
T_7	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and no fertilizer to kodo millet	182.59	25.74	86.56	2019	1.51	23,291	81,698	4.50
T_8	Pigeonpea + kodo millet (1:2) with 125 % RDF to pigeonpea and no fertilizer to kodo millet	195.74	26.28	97.36	2092	1.57	24,042	84,751	4.52
T_9	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 50 % RDF to kodo millet	201.34	28.14	104.64	2109	1.58	24,311	85,360	4.51
T_{10}	Pigeonpea + kodo millet (1:2) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet	215.24	31.87	115.56	2185	1.64	25,331	88,291	4.48
	S.Em. ±	2.21	0.78	2.71	33	0.02	-	1725	0.06
	C.D.(P=0.05)	6.56	2.31	8.07	98	0.06	-	5128	0.20

fertilizer to kodo millet] (1418 $kg\ ha^{-1}$ and 2868 $kg\ ha^{-1}$, respectively) compared to other treatments and it was found on par with T_4. Among the intercropped treatments, T_{10} [pigeonpea + kodo millet (1:2) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet] recorded significantly higher grain yield (1878 $kg\ ha^{-1}$) and straw yield (3743 $kg\ ha^{-1}$) compared to the treatments, T_3, T_4 T_5, T_6, T_7, T_8 and T_9 (Table 2).

Sole kodo millet recorded significantly higher grain yield and straw yield when compared to intercropped treatments. This could be due to higher number of plants and better yield attributing characters. These results are in conformity with Kumar *et al.* (2012) and Sharma *et al.* (2010). Among the intercropped treatments, T_{10} recorded significantly higher grain and straw yield of kodo millet among the intercropped treatments. This might be due to balanced nutrient supply through recommended dose of fertilizer and legume's potential fixing ability of nitrogen. Similar results were obtained by El-Nagar *et al.* (2002), Ennin *et al.* (2002). Further, higher grain and straw yield of kodo millet were obtained in 1:2 row ratio treatments over 1:1 row ratio treatments. This might be due to increased plant density. These results are in conformity with Rao and Willey (1983) and Shelke and Krishnamurthy (1978).

Effect on total uptake of nutrients, pigeonpea equivalent yield (PEY), land equivalent ratio (LER) and economics

Significantly higher uptake of nitrogen, phosphorus and potassium, pigeonpea equivalent yield, land equivalent ratio and net returns were recorded in treatment T_6 [pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 100 % RDF to kodo millet] (218.36, 33.08 and 119.06 $kg\ ha^{-1}$, 2189 $kg\ ha^{-1}$, 1.65 and ₹ 88,698 ha^{-1}, respectively). However, higher cost of cultivation was recorded in treatment T_{10} [pigeonpea + kodo millet (1:2) with 100 per cent RDF to pigeonpea and 100 per cent RDF to kodo millet] (₹ 25,331 ha^{-1}). Further, T_5 [pigeonpea + kodo millet (1:1) with 100 % RDF to pigeonpea and 50 % RDF to kodo millet] recorded significantly higher B:C (4.54) and it was on par with all other intercropped treatments (Table 3).

The treatment T_6 recorded significantly higher total uptake of nutrients when compared to other treatments. Further, reducing the fertilizer application to intercrop from recommended dose decreased the total uptake of nutrients. Higher uptake of nutrients in intercropping system might be due to increased plant population, which led to higher uptake of nutrients. Similar results were reported by Raghavulu and Rama Rao (1994) and Gupta and Rai (1999). Subba Reddy (1985) reported that increase in fertilizer application leads to increase in the total uptake of nitrogen and phosphorus in pigeonpea and finger millet intercropping system. Further, results showed that higher total uptake of nitrogen, phosphorus and potassium in 1:1 ratio over 1:2 ratio

which is in conformity with Willey (1979), Rana *et al*. (1999) and Kujur *et al* . (2009).

Further, T_6 recorded significantly higher pigeonpea equivalent yield, land equivalent ratio and net returns, and T_5 recorded significantly higher B:C and was on par with other intercropped treatments. This was might be due to higher complementarity between these two component crops and finest performance of kodo millet in single stand compared to double stand which produced higher yield and there by higher net returns. Though, intercrop yields were lower than their respective sole crop yields, but they produced higher equivalent yields and income in combination. These results are in conformity with findings of Priyanka and Rajkumara (2019), Kujur *et al*. (2009) and Vishwanatha *et al*. (2012).

Conclusion

Sole crop of pigeonpea and kodo millet were recorded significantly higher yield as compared to their intercropping system in different row proportions and nutrient management practices. With respect to yield advantages and economics, significantly higher pigeonpea equivalent yield, land equivalent ratio and net returns were obtained in intercropped treatment pigeonpea and kodo millet (1:1 row proportion) applied with 100 per cent RDF to both the crops as compared to sole crop of pigeonpea.

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