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Performance of pigeon pea (*Cajanus cajan* L.) based intercropping system with millets under northern dry zone of Karnataka

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Abstract
A two-year field trial was conducted in farmers field at Vijayapur (Karnataka), in shallow medium black soils to evaluate the pigeon pea based intercropping system with millets 1:2 row proportion under dry land condition. Sole pigeon pea recorded significantly higher seed yield (1115 kg $ha^{-1}$and 1090 kg ha^{-1}) for 2017 and 2018, respectively as compared to pigeon pea + foxtail millet (1:2) intercropping system (1079 kg $ha^{-1}$and 1045 kg ha^{-1}) for 2017 and 2018, respectively. Significantly higher (1152 kg $ha^{-1}$and 1146 kg ha^{-1}) SEY was recorded in pigeon pea + foxtail millet (1:2) intercropping system for 2017 and 2018 and which was on par with sole pigeon pea cropping system (1115 kg $ha^{-1}$and 1090 kg ha^{-1}) for 2017 and 2018, respectively. Significantly higher gross returns (Rs. 70819 ha^{-1} and Rs. 68400 ha^{-1}), net returns (Rs. 44419 ha^{-1} and Rs. 43600 ha^{-1}), and BC ratio (2.93 and 2.84) was recorded in pigeon pea + foxtail millet (1:2) based intercropping system for 2017 and 2018, respectively and this intercropping system is more remunerative over sole crops.

Keywords: Pigeon pea, Pigeon pea equivalent yield, millets, intercropping, northern dry zone

Introduction
Pigeon pea [(*Cajanus cajan* L. Mill sp.)] is a second most important grain legume crop next to chickpea, occupies a prominent place in Indian dry land agriculture by covering an area of around 3.9 m ha with productivity of about 729 kg ha^{-1} (MOA, 2016). It is an integral component of various agro ecological systems of the country mainly inter cropped with cereals, pulses, commercial crops, oilseeds and millets. In Karnataka, pigeon pea is a major pulse crop grown in an area of 0.73 m ha with production of 0.47 m tones (MOA, 2016). However, the productivity (651 kg ha^{-1}) is much lower than national average 729 kg ha^{-1} due to several abiotic and biotic constraints.

Pigeon pea is a crop for rainfed environments endowed with several features to thrive harsh climate. It adapts well in sole crop and inter cropped conditions (with cereals, millets, oils seeds and pulses) by enhancing the system productivity and net income to the small and marginal farmers across the globe. The range of maturity duration in the crop allows it to grow in diversified cropping systems and patterns in varied ecoregions of the world.

Millets are a group of highly variable small seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. Generally, these are rainfed crops grown in areas with low rainfall and thus resume greater importance for sustained agriculture and food security. Foxtail millet (*Setaria italica* L.) is one of the oldest cultivated millets and the most economically important species of the *Setaria* genus. Foxtail millet commonly known as navane in Karnataka. It can be grown on dry lands even under aberrant weather condition when the major crops cannot be grown. It is also called as famine reserve and it is extensively grown under low rainfall area. Foxtail millet is the second most widely grown species of millet and the most important food crop in East Asia. In India, foxtail millet is important crop in arid and semi-arid regions. In South India, it has been a staple diet among people for a long time and it is a warm season crop, typically grown in late spring season and harvest for grain in 75–90 days (800–900 kg ha^{-1}).

Millet cultivation is declining due to several reasons few of which are processing hardships, low economic gains and lack of awareness about the nutritional significance. The area under millets is declining at an alarming rate in spite of the favourable cultivation conditions available. According to a recent research study the millet cultivation area of about 44% is occupied by other crops since 1966 to 2006 (Halakatti *et al.* 2010) [5]. This has adversely affected the nutritional security and agricultural cropping systems.

Materials and Methods

A field demonstration was carried out during the subsequent rainy *(kharif)* season of 2017-18 and 2018-19 under northern dryzone of Karnataka at Baloothi village of Vijayapur district (situated at 16° 31' N latitude, 75° 39' E longitude and at an altitude of about 697 m above mean sea level). The rainfall received was 763.9 mm and 321.6 mm for the year 2017-18 and 2018-19 respectively. The demonstration was carried out with 3 treatments (T_1= pigeon pea + millet (1:2), T_2= sole pigeon pea and T_3= sole millet) and 10 replications in the farmer's field. The land was brought to optimum tilth by ploughing twice with tractor drawn mould board plough. The soils of demonstration field for evaluating pigeon pea and millet crops under intercropping system was deep clay soil with pH 8.2, available organic carbon 0.40 per cent, available N, P and K were 249.1, 36.7 and 471.2 *kg ha*$^{-1}$, respectively.

Sowing of pigeon pea and foxtail millet was done on 18th June 2017 and 21st June 2018. Seeds of pigeon pea variety (TS 3R) and foxtail millet (DHFT-109-3) were sown in line using *pora* method (dropping the seeds in furrow behind the plough) of sowing and seed rate of pigeon pea was 6 kg ha^{-1} foxtail millet was 3 kg ha^{-1} in all two intercropping systems. Weeds were controlled through one hoeing at 30 days after sowing and one manual weeding. The recommended rate of N (25 kg ha^{-1}) and P_2O_5 (50 *kg ha*$^{-1}$) was applied for pigeon pea at sowing. Simalarly for foxtail millet recommended rate of N (30 *kg ha*$^{-1}$) and P_2O_5 (15 kg ha^{-1}) was also applied sowing.

Pigeon pea was harvested on 15th and 13th December 2017 and 2018, respectively and foxtail millet was harvested on 24th and 28th September 2017 and 2018, respectively at physiological maturity. Five randomly selected plants from ten sites in each treatment were harvested. Standard procedures were used to measure the yield attributes and yield parameters of pigeon pea and foxtail millet. Variables were analyzed and least significance difference (LSD) test was carried out for analyzed mean square errors using Web Based Agricultural Statistics software Package (WASP 2.0). Significance and non-significance difference between treatments was derived through procedure provides for a single LSD value (Gomez and Gomez, 1984). Correlation studies among the yield components of pigeon pea was done using XLSTAT package. The yield was further computed for pigeon pea equivalent yield (PEY), land equivalent ratio (LER), gross and net returns as well BC ratio to assess the system productivity.

Calculated by using following formula

$$\text{SEY} = \frac{\text{Yield of millets (kg ha}^{-1}) \times \text{Price of millets (Rs q}^{-1})}{\text{Price of pigeon pea (Rs q}^{-1})} + \text{Yield of pigeon pea}$$

$$\text{LER} = \frac{\text{Yield of pigeon pea in intercropping system}}{\text{Yield of sole pigeon pea}} + \frac{\text{Yield of millets in intercropping systems}}{\text{Yield of sole millets}}$$

Results and Discussion

Effect of intercropping on yield and intercropping indices

The data presented in Table 1 reveals that, among the various cropping systems tried with pigeon pea, sole pigeon pea recorded the higher seed yield (1115 kg ha^{-1} and 1190 kg ha^{-1}) for 2017 and 2018 respectively followed by intercropping with pigeon pea + foxtail millet (1079 kg ha^{-1} and 1045 kg ha^{-1}) for 2017 and 2018 respectively. The higher grain yield of millets was recorded with sole foxtail millet cropping system 1225 kg ha^{-1} and 1180 kg ha^{-1}for 2017 and 2018 respectively. In intercropping systems with 1:2 row proportion seed yield of pigeon pea were significantly reduced due to increased population on intercrops. This is in conformity with the findings of Mahto *et al.,* (2007) [6] who reported that intercropping with decreased plant density of finger millet in association with pigeon pea resulted in higher seed yield of pigeon pea. The increase in seed yield of pigeon pea in intercropping system with decreased plant density of nutri-cereal crops under 1:1 row ratio may be due to wider spacing of intercrop compared to 1:2 row ratio, facilitating effective sharing of the growth resources with nutri-cereal crops to get higher seed yield.

The highest pigeon pea equivalent yield (PEY) was recorded with Pigeon pea + foxtail millet (1:2) intercropping system (1152 kg ha^{-1} and 1146 kg ha^{-1}) for both 2017 and 2018, respectively, followed by sole pigeon pea cropping system (1115 kg ha^{-1} and 1090 kg ha^{-1}) for 2017 and 2018, respectively. The results are in conformity with the findings of Basavarajappa (2003) [2] who reported that highest foxtail millet equivalent yield was recorded when foxtail millet was grown with pigeon pea where 100 per cent pigeon pea populations were maintained. Similarly, Dinesh Kumar *et al.* (2017) [3] reported that among the all intercropping system sesame grown with green gram in 3:2 paired row system recorded the highest (944 kg ha^{-1}) sesame equivalent yield which was statistically at par with sesame with green gram in 2:1 paired row systems.

The land equivalent ratio (LER) indicate the clear picture of merits and demerit of intercropping system. In present study, intercropping of pigeon pea + foxtail millet in 1:2 ratio recorded significantly higher LER (1.16 and 1.06) for 2017 and 2018 respectively compared to sole crops. This might be due to the fact that component crops are differ in utilizing growth and other resources and converting them into sink more effectively resulting in higher yield per unit area compared to sole crop. These results are in conformity with Abdel and Rea, (2014) [1] who reported that increase in millets population did not exert heavy competition between the component crops in groundnut + sesame intercropping system. Similarly, in castor based millet intercropping by Prajwal and Kalaghatagi (2018) [8] who reported that higher land equivalent ratio (LER) was found in castor + little millet (1.58).

Table 1: Growth parameters and yield of pigeon pea and foxtail millet (1:2) as influenced by intercropping system

Treatments	Seed yield (kg ha^{-1})						LER	
	Pigeon pea		Intercrop		PEY			
	2017	2018	2017	2018	2017	2018	2017	2018
T_1- Pigeon pea + foxtail millet (1:2)	1079	1045	235	215	1152	1146	1.16	1.06
T_2- Sole pigeon pea	1115	1090	--	--	1115	1090	1.00	1.00
T_3- Sole foxtail millet	--	--	1225	1180	1225	1180	1.00	1.00
S.E.m. ±	13.10	51.6	326.7	322.8	15.31	15.27	0.07	0.025
C.D. (5%)	39.0	153.0	997.0	973.0	45.8	46.1	0.15	0.07

Effect of intercropping on economics

The data presented in Table 2 reveals that among the different cropping systems, significantly higher gross return was recorded in 1:2 row ratio of pigeon pea + foxtail millet (Rs. 70819 $ha^{-1}$and Rs. 68400 ha^{-1}) for 2017 and 2018, respectively followed by sole pigeon pea cropping system (Rs. 68015 $ha^{-1}$and Rs. 66150 ha^{-1}). Similarly higher net return was observed in 1:2 pigeon pea + foxtail millet (Rs. 44419 $ha^{-1}$and Rs. 43600 ha^{-1}) for 2017 and 2018, respectively followed by sole pigeon pea cropping system (Rs. 43915 $ha^{-1}$and Rs. 42400 ha^{-1}). The higher gross and net returns in intercropping systems were mainly due to higher pigeon pea and millet yields and higher market price of pigeon pea. The Benefit Cost ratio also followed similar trend which was significantly higher in 1:2 row ratio of pigeon pea + foxtail millet (2.93 and 2.84) for 2017 and 2018 respectively and it was on par with sole pigeon pea cropping system (2.56 and 2.47) for 2017 and 2018 respectively. The results are in line with the findings of Sunilkumar *et al.* (2013) [9] reported that, significantly higher gross return (Rs. 34160 ha^{-1}), net return (Rs. 27336 ha^{-1}) and BC ratio (4.02) was obtained in pearl millet (multicut) + cowpea intercropping systems.

Table 2: Cost of cultivation, gross returns, net returns and BC ratio of pigeon pea and foxtail millet (1:2) intercropping system as influenced by intercropping system

Treatments	Cost of cultivation (Rs ha^{-1})		Gross returns (Rs ha^{-1})		Net returns (Rs ha^{-1})		BC ratio	
	2017	2018	2017	2018	2017	2018	2017	2018
T_1- Pigeon pea + foxtail millet (1:2)	24100	24030	70819	68400	44419	43600	2.93	2.84
T_2- Sole pigeon pea	26500	26750	68015	66150	43915	42400	2.56	2.47
T_3- Sole foxtail millet	12450	13430	22500	23620	10050	10190	2.23	2.31
S.E.m. ±	--	--	938.3	757.1	167.7	402.4	0.142	0.145
C.D. (5%)	--	--	2811.4	2263.6	509.5	1206.0	0.41	0.39

Conclusion

Based on two year results, it may be summarized that significantly higher pigeon pea equivalent yield, land equivalent ratio and benefit cost ratio was recorded with intercropping system compared to their sole cropping. The results indicated that, growing of pigeon pea with foxtail millet at 1:2 row proportions recorded higher pigeon pea equivalent yield (1152 kg ha^{-1} and 1146 kg ha^{-1}) for 2017 and 2018 respectively as compared to other sole cropping systems and also recorded higher land equivalent ratio (1.16 and 1.06) for for 2017 and 2018 respectively. Pigeon pea + foxtail millet intercropping system is more remunerative over sole cropping. Therefore, it is concluded that pigeon pea + foxtail millet (1:2) intercropping system was found suitable for northern dry zone of Karnataka under rainfed condition.

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