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Evaluation of Pigeonpea (*Cajanus cajan L.*) based Intercropping Systems under Semi-arid Vertisol in Scarcity Zone of Maharashtra

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ABSTRACT: A field experiment was conducted during *kharif* for five years (2008 to 2012) at All India Coordinated Research Project for Dryland Agriculture centre, Solapur to evaluate pigeonpea based intercropping systems under Vertisols in scarcity zone of Maharashtra. Among pigeonpea based intercropping systems, pigeonpea + groundnut (1:3) was found superior with mean maximum pigeonpea equivalent yield 1425 kg/ha and mean maximum rainwater use efficiency of 3.19 kg/ha-mm compared to other intercropping systems across five years and also gave mean maximum net returns of ₹ 30,307/ha. Further, this intercropping system also recorded relatively higher land equivalent ratio of 1.29 indicating yield advantage of 29% compared to sole crops.

Key words: Pigeonpea based intercropping system, semiarid, vertisols, rainwater use efficiency, pigeonpea equivalent yield

Pigeonpea (*Cajanus cajan L.*) is an important *kharif* pulse crop of India with 75.7% area and 64.9% of production of the world (FAOSTAT, 2013). It is cultivated under diverse agroclimatic conditions either as sole or in mixtures with cereals, pulses or oilseeds under rainfed conditions. Intercropping is always preferred over sole cropping as intercropping systems minimize weather risks, ensure yield and income from the component crops in an abnormal year and enhance resource use efficiency. Pigeonpea has been found to be unique and highly preferred component crop across rainfed production systems (Itnal *et al.,* 1994; AICRPDA, 2003). Pigeonpea as a long duration crop, slow in growth and with deeper rhizosphere has the ability to overcome short intermittent dry spells and has the scope and compatibility with short duration component crops due to positive below and above ground spatial annidation. Pigeonpea based intercropping systems have proved sustainable in respect of yield and income with short duration intercrops of cereals, pulses and oilseed crops across diverse rainfed agroecologies in India (Rao *et al.,* 2003; Vittal *et al.,* 2005; Kantwa *et al.,* 2005; Ravindra Chary *et al.,* 2012). In scarcity zone of Maharashtra, pigeonpea is cultivated during *kharif* under diverse biophysical (soil and rainfall types) and socioeconomic settings, thus always risk prone due to in - season drought, particularly in the shallow to medium deep black soils often resulting in unsustainable yields and income. Thus, it becomes necessary to develop an efficient and profitable pigeonpea based intercropping system for scarcity zone of Maharashtra. In view of this, an attempt was made to evaluate pigeonpea based intercropping systems with predominant rainfed *kharif* crops in the scarcity zone as intercrops *viz.,* soybean, groundnut, cowpea, kidney bean (rajmabean), sunflower and pearl millet.

Materials and Methods

A field experiment was conducted during *kharif* season for five years (2008 to 2012) at Research Farm of All India Coordinated Research Project for Dryland Agriculture, Solapur, (17^0 4' N latitude and 75^0 5' E longitude with an elevation of 483.6 m above mean sea level), Maharashtra. The experimental site was Vertisol characterized with clay loam, 100 mm/water holding capacity, pH 8.1, EC (1:2.5), 0.30 dS/m, low in available N (211 kg/ha), medium in available P_2O_5 (22 kg/ha) and high in available K_2O (348 kg/ha). The treatments were T_1 = pigeonpea + soybean (1:3), T_2= pigeonpea + groundnut (1:3), T_3 = pigeonpea + cowpea (1:3), T_4 = pigeonpea + kidney bean (1:3), T_5= pigeonpea + sunflower (1:2), T_6= pigeonpea+pearl millet (1:3), T_7= pigeonpea + pearl millet (1:2), T_8 = sole pigeonpea, T_9 = sole soybean, T_{10} = sole groundnut, T_{11} = sole cowpea, T_{12} = sole kidney bean, T_{13} = sole sunflower and T_{14} = sole pearl millet. The experiment was laid out in randomized block design with three replications. The gross and net plot sizes were 32.40 m^2 (6.0 m x 5.4 m) and 27 m^2 (5 m x 5.4 m), respectively. After every one row of pigeonpea three rows of soybean, groundnut, cowpea, rajmabean, pearl millet, while two rows of sunflower and three rows of pearl millet after every row of pigeonpea evaluated. The optimum plant population was maintained by thinning and gap filling at 10 days after germination. For sole crop, recommended dose of fertilizers was applied and for intercrop, which crop recommended fertilizer dose was maximum that fertilizer dose was applied. Weeds were controlled by adoption of two hand weedings.

The sowing of intercrop and sole crop during the 2008-09, 2009-10, 2010-11, 2011-12 and 2012-13 *viz.,* pigeonpea, groundnut, soybean, kidney bean, sunflower and pearl millet was sown 30.07.2008, 22.06.2009, 30.06.2010, 09.07.2011 and 02.07.2012, respectively and harvested after attaining physical maturity. The monthly actual and normal rainfall during the experimentation period is given in Table 1.

During 2008 (June 08 to January 09), total rainfall received was 601.2 mm in 34 rainy days which was deficit by 9.58% against normal rainfall (664.9 mm), while during *kharif* season i.e. 23 to 37 standard meteorological weeks (SMW) from 4 June to 16 September, the seasonal rainfall received was 499.2 mm in 25

Table 1 : Monthly rainfall (mm) data from 2008 to 2012 at experimental site

Month	2008		2009		2010		2011		2012		Mean	
	N	A	N	A	N	A	N	A	N	A	N	A
June	107.1	18.1	107.1	173.3	107.1	178.2	107.1	22.1	107.1	48.7	107.1	88.08
July	115.8	123.4	115.8	23.6	115.8	206.7	115.8	265.1	115.8	85.5	115.8	140.86
August	139.6	167.5	139.6	161.5	139.6	194.4	139.6	182.9	139.6	96.4	139.6	160.54
September	172.7	227.0	172.7	223.5	172.7	86.8	172.7	60.9	172.7	105.0	172.7	140.64
October	97.9	54.7	97.9	157.6	97.9	38.1	97.9	141.5	97.9	150.9	97.9	108.56
November	21.6	6.8	21.6	23.5	21.6	29.5	21.6	0.0	21.6	14.8	21.6	14.92
December	6.0	3.7	6.0	0.7	6.0	5.7	6.0	0.0	6.0	0.0	6.0	2.02
January	4.2	0.0	4.2	32.0	4.2	0.0	4.2	0.0	4.2	0.0	4.2	0.0
Total	664.9	601.2	664.9	795.7	664.9	739.4	664.9	672.5	664.9	469.3	664.9	655.62

N- Normal; A - Actual

rainy days which was surplus by 19% against normal rainfall. During the 2009 (June 08 to January 09), total rainfall received was 795.7 mm in 31 rainy days which was surplus by 19.67% against normal rainfall (664.9 mm) while during *kharif* season, the rainfall received was 475.3 mm in 20 rainy days which was also surplus by 12.9% against normal rainfall.

During 2010 (June 08 to January 09), total rainfall received was 739.4 mm in 52 rainy days which was surplus by 10.07% against normal rainfall (664.9 mm) while during *kharif* season, the rainfall received was 609.5 mm in 38 rainy days which was surplus by 44.8% against normal rainfall. Total rainfall received during the year 2011 was 672.5 mm in 36 rainy days which was surplus by 1.14% against normal rainfall (664.9 mm) while during the *kharif,* total rainfall received was 514.4 mm in 29 rainy days which was surplus by 22.3% against normal rainfall. In 2012, the total rainfall received was 469.3 mm in 34 rainy days which was deficit by 29.41 % against normal rainfall while during the *kharif,* total rainfall received was 318.3 mm in 24 rainy days which was deficit by 24.3% against normal rainfall.

The pigeonpea equivalent yield (PEY) was determined by comparing different cropping systems and was calculated by taking into account the actual yields (kg/ha) attained by crops along with the prices or value (per kg) of the crops. The rainwater use efficiency (kg/ha-mm) of a crop or cropping system was determined by considering the pigeonpea equivalent yield (kg/ha) attained by the system and crop seasonal rainfall (mm) received from sowing to harvest of a given crop or the long duration crop in the cropping system. It is given as a ratio of the pigeonpea equivalent yield and the crop seasonal rainfall of a crop. The cost of cultivation (₹/ha) incurred under sole and intercropping systems was derived by taking into account all the costs involved for different agricultural inputs and operations. The value of different crops in sole and intercropping systems was considered to derive the gross returns (₹/ha). The land equivalent ratio (LER) was calculated as described by Willey (1979).

Results and Discussion

Yield of component crops and pigeonpea equivalent yield of intercropping systems

Among the pigeonpea based intercropping systems, higher grain (1285 kg/ha) and stalk yield (3751 kg/ha) of pearl millet as a intercrop was recorded in pigeonpea + pearl millet (1:3) system (Tables 3). The erect and taller cereal components (pearl millet) grew faster at the early stage and might have avoided the shading effect of the slow growing pigeonpea. The taller pearl millet or sunflower component of the intercropping might have exerted depressive effects through shading of the shorter and slower growing pigeonpea component. Hence, the pigeonpea yield under pigeonpea + sunflower (1:2) intercropping system and pigeonpea + pearl millet (1:3) was low (412 and 548 kg/ha, respectively) compared to pigeonpea yields with other intercrops i.e. soybean, groundnut and kidneybean (Table 2). Egbe and Adeyemo, (2006); Dasbak and Asiegbu (2009) made similar observations in pigeonpea/maize intercropping and attributed to negative effects of the intercropped cereal crop on the pigeonpea component. Competition between component crops for growth limiting factors is regulated by morphological differences and agronomic factors such as the proportion of crops in the mixture etc. Chetty, 1983; Itnal *et al*., 1994; Shankar *et al*., 2001 and Rao *et al.,* 2003).

There was a significant difference between mean pigeonpea equivalent yields (Table 4) with various pigeonpea based intercropping systems. Significantly higher mean pigeonpea equivalent yield (1425 kg/ha) was attained with pigeonpea + groundnut intercropping system (1:3) followed by 1310 kg/ha with pigeonpea + soybean (1:3) and 1268 kg/ha with pigeonpea + kidney bean (1:3). The increase in pigeonpea equivalent yield in pigeonpea + groundnut intercropping system might be due to no or low competition between main crop and intercrop for growth, development and for above ground and below ground resources as groundnut crop was of shorter duration and non-

Table 2 : Main crop grain and stover yield as influenced by different intercropping systems

Treatment	Main crop grain yield (kg/ha)						Main crop Stover yield (kg/ha)					
	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean
Pigeonpea + soybean (1:3)	764	826	833	760	512	739	2551	2870	1908	2555	2722	2521
Pigeonpea + groundnut (1:3)	608	715	586	746	510	633	2418	2665	1350	1716	1752	1980
Pigeonpea + cowpea (1:3)	560	763	524	710	296	571	2366	2243	1222	1703	1333	1773
Pigeonpea + kidney bean (1:3)	745	776	740	894	617	754	2263	2654	1699	2037	1552	2041
Pigeonpea + sunflower (1:2)	215	687	329	599	231	412	664	2263	752	1145	1139	1193
Pigeonpea + pearl millet (1:3)	515	784	424	701	315	548	1646	2356	950	1370	1568	1578
Pigeonpea + pearl millet (1:2)	646	846	658	778	451	676	1759	2407	1521	1938	1441	1813
Sole Pigeonpea	991	974	1059	1451	877	1070	3601	2973	2429	3728	2867	3120
Sole Soybean	996	0*	956	1167	457	715	1759	890	1340	1111	515	1123
Sole Groundnut	1285	0*	792	969	1324	874	4774	1070	1811	2444	5370	3094
Sole Cowpea	1363	0*	761	743	540	681	2675	1281	1257	1259	1327	1560
Sole Kidney bean	972	0*	586	778	293	526	2757	597	910	1074	586	1185
Sole Sunflower	1493	0*	1085	1290	889	951	4475	1152	2483	3518	3259	2977
Sole Pearl millet	3728	507	1337	1315	1204	1618	4280	2006	3463	4049	4731	3706

Table 3 : Intercrop grain and stover yield as influenced by different intercropping systems

Treatment	Intercrop grain yield (kg/ha)						Intercrop stover yield (kg/ha)					
	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean
Pigeonpea + soybean (1:3)	887	0*	735	866	432	584	1512	409	1205	950	992	1014
Pigeonpea + groundnut (1:3)	705	0*	483	1104	673	593	3477	323	1109	1706	6585	2640
Pigeonpea + cowpea (1:3)	744	0*	586	732	410	494	1934	602	945	1045	2739	1453
Pigeonpea + kidney bean (1:3)	483	0*	360	709	235	358	1785	288	715	1071	1199	1012
Pigeonpea + sunflower (1:2)	1284	0*	751	820	500	671	3683	597	1719	2283	4364	2529
Pigeonpea + pearl millet (1:3)	2695	381	977	1228	1142	1285	3457	1029	2238	3835	8198	3751
Pigeonpea + pearl millet (1:2)	2597	288	905	1037	999	1165	3189	939	2027	3043	5739	2987

* There was delayed onset of monsoon by 13 days and sowing of the *kharif* crops was done in second week of June 2009. After sowing, there was prolonged dryspell resulting in crops failed to produce grain yield and only biomass yield was obtained.

spreading nature and further, might be due complementary in resource utilization by groundnut crop (Ramesh and Devasenapathy, 2007). Further, legume and legume as main crop and intercrop might have symbiotic beneficial effect with each other and reduced the competition for moisture and nutrients between the component crops and significantly increased yield of both component crops (Waghmare *et al.,*1982).The lowest mean pigeonpea equivalent yield of 975 kg/ha was recorded in pigeonpea + sunflower intercropping system (1:2) and might be due to intense inter-specific competition between pigeonpea and sunflower roots indicating that pigeonpea was more competitive for nutrients in the soil. Ito *et al.,* (1993) had similar observations with sorghum intercropped with pigeonpea.

Land equivalent ratio

The land equivalent ratio (LER) obtained in all the intercropping systems was more than one ranging from 1.29 to 1.51 indicating yield advantage with pigeonpea based intercropping systems. The maximum LER of 1.51 was obtained with pigeonpea + soybean (1:3) intercropping system which indicated that 51% more area would be required by a sole crop to equal the yield attained under this intercropping system, followed by pigeonpea + kidney bean (1.45). The LER recorded with pigeonpea + groundnut (1:3) was at par with pigeonpea + cowpea with 1:3 ratio (1.31) and pigeonpea + pearl millet either with 1:3 ratio (1.37) or at 1:2 ratio (1.34) but was significantly higher than the LER (1.08) attained with pigeonpea + sunflower (1:3) system (Table 4). Anders *et al.,* (1996) had stated that successful intercropping combinations had both spatial and temporal complementarity, thus resulting in an overall increase of yield.

Rainwater use efficiency

The rainwater use efficiency (RWUE) attained with pigeonpea based intercropping systems, in general was higher as compared to RWUE attained with sole crops. This indicated higher resource use efficiency of both rainfall and soil moisture by both the component crops during the crop season. The mean maximum RWUE of 3.19 kg/ha-mm was obtained with pigeonpea + groundnut (1:3) intercropping system followed by pigeonpea + soybean (1:3) intercropping system (2.83 kg/ha-mm) and pigeonpea + kidney bean (2.72 kg/ha-mm) (Table 5). The RWUE was higher in intercropping system with legume crops (groundnut, soybean, cowpea and kidney bean) compared to erect crops like sunflower and pearl millet. The legumes as intercrops acted as cover crops in widely row spaced pigeonpea resulting in higher *in-situ* moisture conservation and efficient utilization by both the component crops, further helped in increased pigeonpea equivalent yields and higher RWUE.

Economics

The net returns accrued (₹ 30703/ha) were higher with pigeonpea + groundnut (1:3) intercropping system followed by pigeonpea + soybean (₹ 30430/ha) and pigeonpea + kidney bean (₹ 28569/ha) systems. However, pigeonpea + soybean (1:3) intercropping system registered higher BC ratio (2.96) followed by pigeonpea + kidney bean (2.73) and pigeonpea + groundnut (2.46) intercropping system (Table 6).

Table 4 : Pigeonpea equivalent yield (PEY) and land equivalent ratio (LER) as influenced by different intercropping systems

Treatment	Pigeonpea equivalent yield (kg/ha)						Land equivalent ratio (LER)					
	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean
Pigeonpea + soybean (1:3)	1360	849	1315	1688	1338	1310	1.74	1.42	1.56	1.24	1.61	1.51
Pigeonpea + groundnut (1:3)	1321	745	980	2252	1827	1425	1.39	1.16	1.17	1.64	1.09	1.29
Pigeonpea + cowpea (1:3)	1122	783	907	1780	862	1091	1.3	1.37	1.28	1.48	1.11	1.31
Pigeonpea + kidney bean (1:3)	1315	798	1104	1948	1176	1268	1.49	1.38	1.31	1.54	1.51	1.45
Pigeonpea + sunflower (1:2)	1126	708	794	1378	868	975	1.14	1.33	1.01	1.07	0.83	1.08
Pigeonpea + pearl millet (1:3)	1333	927	829	1272	1092	1091	1.41	1.66	1.13	1.32	1.31	1.37
Pigeonpea + pearl millet (1:2)	1441	961	1028	1275	1103	1162	1.35	1.46	1.3	1.26	1.31	1.34
Sole Pigeonpea	991	998	1091	1844	1275	1240	-	-	-	-	-	-
Sole Soybean	685	23	589	774	473	509	-	-	-	-	-	-
Sole Groundnut	1004	3	673	1332	2063	1015	-	-	-	-	-	-
Sole Cowpea	980	3	718	1030	487	644	-	-	-	-	-	-
Sole Kidney bean	1094	2	796	940	424	651	-	-	-	-	-	-
Sole Sunflower	1026	6	658	1173	831	739	-	-	-	-	-	-
Sole Pearl millet	1049	173	407	611	600	568	-	-	-	-	-	-
General mean	1132	499	849	1378	1029	977	1.40	1.40	1.25	1.36	1.25	1.33
SEm±	49	35	74.98	76.6	57	119	0.07	0.07	0.08	0.05	0.08	0.05
CD (P=0.05)	142	103	217.84	222.68	167	340	0.21	0.23	0.25	0.17	0.25	0.15

Table 5 : Rainwater use efficiency (kg/ha-mm) as influenced by different intercropping systems

Treatment	Rainwater use efficiency (kg/ha-mm)					
	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean
Pigeonpea + soybean (1:3)	2.72	1.79	2.16	3.28	4.20	2.83
Pigeonpea + groundnut (1:3)	2.65	1.57	1.61	4.38	5.74	3.19
Pigeonpea + cowpea (1:3)	2.25	1.65	1.49	3.46	2.71	2.31
Pigeonpea + kidney bean (1:3)	2.63	1.68	1.81	3.79	3.69	2.72
Pigeonpea + sunflower (1:2)	2.26	1.49	1.30	2.68	2.73	2.09
Pigeonpea + pearl millet (1:3)	2.67	1.95	1.36	2.47	3.43	2.38
Pigeonpea + pearl millet (1:2)	2.89	2.02	1.69	2.48	3.47	2.51
Sole Pigeonpea	1.99	2.10	1.79	3.58	4.01	2.69
Sole Soybean	1.37	0.05	0.97	1.50	1.49	1.08
Sole Groundnut	2.01	0.01	1.10	2.59	6.48	2.44
Sole Cowpea	1.96	0.01	1.18	2.00	1.53	1.34
Sole Kidney bean	2.19	0.00	1.31	1.83	1.33	1.33
Sole Sunflower	2.06	0.01	1.08	2.28	2.61	1.61
Sole Pearl millet	2.10	0.36	0.67	1.19	1.89	1.24
General mean	2.26	1.04	1.39	2.67	3.23	2.13
SEm±	-	-	-	-	-	0.31
CD (P=0.05)	-	-	-	-	-	0.90

Table 6 : Economics of different intercropping systems

Treatment	Gross returns (₹/ha)	Total cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
Pigeonpea + soybean (1:3)	46956	16522	30430	2.96
Pigeonpea + groundnut (1:3)	51137	20229	30703	2.46
Pigeonpea + cowpea (1:3)	39050	16311	22740	2.46
Pigeonpea + kidney bean (1:3)	45388	17025	28569	2.73
Pigeonpea + sunflower (1:2)	34793	16782	18012	2.10
Pigeonpea + pearl millet (1:3)	38895	15833	23062	2.48
Pigeonpea + pearl millet (1:2)	41453	18092	23387	2.43
Sole Pigeonpea	44682	16603	28079	2.71
Sole Soybean	16021	16056	1965	1.14
Sole Groundnut	36011	23304	12708	1.47
Sole Cowpea	22686	13041	9584	1.82
Sole Kidney bean	22870	15205	7665	1.53
Sole Sunflower	26045	15314	10871	1.68
Sole Pearl millet	19849	12896	6953	1.62
General mean	34703	16658	18195	2.11
SEm±	4455	-	4414	0.28
CD (P=0.05)	12643	-	12527	0.80

Table 7 : Market price (₹/kg) of pigeonpea based intercropping system experiment

Crops	2008-09		2009-10		2010-11		2011-12		2012-13	
	Grain (₹/kg)	Stover (₹/kg)	Grain (₹/kg)	Stover (₹/kg)	Grain (₹/kg)	Stover (₹/kg)	Grain (₹/kg)	Stover (₹/kg)	Grain (₹/kg)	Stover (₹/kg)
Pigeonpea	33	1.0	38	1.0	38	1.0	36	5.0	36	5.0
Soybean	24	1.0	22	1.0	22	1.0	22	2.0	35	2.0
Groundnut	26	1.0	26	1.0	30	1.0	47	1.5	50	1.5
Cowpea	23	1.0	36	1.0	35	1.0	45	1.0	30	1.0
Kidney bean	36	0.1	36	0.1	50	1.0	47	1.0	50	1.0
Sunflower	23	0.3	24	0.5	22	0.5	30	1.0	30	1.0
Pearl millet	10	0.5	16	0.5	9	1.0	12.5	1.0	14	1.0

Conclusion

Among pigeonpea based intercropping systems evaluated on semiarid Vertisols at Solapur in scarcity zone of Maharashtra, either pigeonpea + groundnut (1:3) or pigeonpea + soybean (1:3) or pigeonpea + cowpea (1:3) or pigeonpea + kidney bean (1:3) or pigeonpea + pearl millet (1:3) is recommended under dryland condition.

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