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Effect of soil depth on productivity of sorghum (*Sorghum bicolor*) and pigeonpea (*Cajanus cajan*) in sole and intercropping systems

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ABSTRACT

An experiment was conducted during 1992–95 at Hyderabad, Andhra Pradesh, to understand the interactive effect between soil depth, rainfall and crop growth in Alfisols under rainfed conditions. Sole crop of sorghum [*Sorghum bicolor* (L.) Moench], pigeonpea [*Cajanus cajan* (L.) Millsp.] and intercropping system of sorghum + pigeonpea were grown in 3 soil depths (< 10 cm, 10–20 cm and 20 cm) in rainfed to assess the influence of effective soil depth on productivity. Besides seed yields, dry matter and N uptake and other parameters like rainfall-use efficiency, moisture-adequacy index, land-equivalent ratio (LER), staple-land equivalent raio (SLER) and gross returns were also worked out. In all the systems, the seed yield (523 kg/ha) increased with the increase in the soil depth. However, over the years sorghum+pigeonpea intercropping systems gave stable yields (165 kg/ha) and gross return (Rs 2 514/ha).

Key words: Intercropping, Sorghum, Pigeonpea, Rainfall-use efficiency, *Sorghum bicolor*, *Cajanus cajan*, Moisture-adequacy index, Land-equivalent ratio, Staple land-equivalent ratio

Intercropping of sorghum [*Sorghum bicolor* (L.) Moench] and pigeonpea [*Cajanus cajan* (L.) Millsp.] is an age old and widely adopted practice in semi-arid tropics of India (Willey 1979). This system allows maximum utilization of available resources for production and minimize the risk of crop failures in drought years (Singh and Subba Reddy 1986). The productivity of this system can be enhanced by selecting suitable crops, genotypes, optimum row ratios and improved fertilizer and crop-protection measures (Singh and Subba Reddy 1986). Rainfed Alfisols where this system is mainly practised are generally degraded soils with poor native fertility and have serious limitations of soil depth leading low water-storage capacity (Vittal *et al.* 1990). Further, the yield advantage in the system depends on the total quantum and distribution of the rainfall and duration and intensity of the dry spells. The top soil depth and rainfall are therefore critical factors influencing the production potential of the stystem. Alfisols in Peninsular India vary considerably in depth and slope. The reduction in effective soil depth affects the phenological and morphological expression of crops due to soil-moisture limitation. Hence a study was conducted to investigate interactive effects between soil depth, rainfall, and crop growth in Alfisols under rainfed environment.

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MATERIALS AND METHODS

The experiment was conducted on an Alfisol watershed in Hayatnagar research farm of the Institute, Hyderabad (17^0–20'–02" N and 78^0–35'–08" E). The general physiography of watershed is characterized by gentle slopes (2–5%) with highest elevation of 520 m. The watershed covering an area of 5 ha has 3 pediments, consisting of upper, middle and lower portions. The interbunded area of each pediment is covered with 0.5 m^2 graded bund. The top soil is loose grained and subsoil structure compact, weakly sub-angular and blocky. The soil is classified as an Alfisol. Soil survey was made by making pits up to 60 cm depth, at 20 sites in each strip on watershed line in small grid fashion (10 m × 50 m). The average soil depth in upper, middle and lower basins of micro-catchment was 8.0 cm ± 4.3 cm (D_1), 15.0 ± 4.5 cm (D_2) and 30 cm ± 8 cm (D_3) respectively.

Sole crops of 'CSH 9' sorghum, 'LRG 30' pigeonpea and sorghum + pigeonpea (2 : 1) were raised in upper, middle and lower portions of the watersheds from 1992 to 1995. Sorghum and pigeonpea crops were grown in 45 and 90 cm rows with 0.2 and 0.075 million population/ha. Intercropping system of sorghum and pigeonpea was planted in 45 cm rows with 2 : 1 ratio in the second week of June in all the 4 years. The sorghum and pigeonpea crops in sole and intercropping systems received 65 kg diammonium phosphate/ha as basal placement. Urea @ 40 kg N/ha was applied 40 days after sowing in each season to sorghum crop in sole and intercropping. Intercultivation and plant-protection measures were undertaken as required. The experiment was conducted in randomized block design with 3 replications and each strip was considered as 1 replication. The rainfall and potential evapotranspiration were recorded daily and rainfall-use efficiency and moisture-adequacy index were calculated according to Singh and Joshi (1997). Dry matter, leaf-area index (LAI) and N uptake were recorded at different phenological stages of component crops. Grain and fodder yields of sorghum and pigeonpea were recorded in all the 4 years. The yield and economic advantages were estimated through values of land-equivalent ratio (LER) and staple land-equivalent ratio (SLER) and grain equivalents were estimated (Narayana Redddy and Ramanatha Chetty 1984).

RESULTS AND DISCUSSION

Rainfall pattern

The moisture availability in terms of moisture-adequacy index is depicted in Fig 1. Sorghum in sole and intercropping system faced severe moisture stress in early vegetative, ie second and third weeks after sowing, and at flowering stage 8 weeks after sowing in 1992 and 1994 at all soil depths. Moderate stress was experienced by sorghum during late vegetative stage 7 weeks after sowing in 1992, flowering stage in 1993 and grain-formation stage 13–17 weeks after sowing in 1994 in deeper soils. Similarly in 1993, the crop experienced moderate stress at late vegetative stage 7 weeks after sowing in shallow and medium soils and at flowering stage in medium soils. The stress was moderate at grain-formation stage in 1994 in shallow and medium soils.

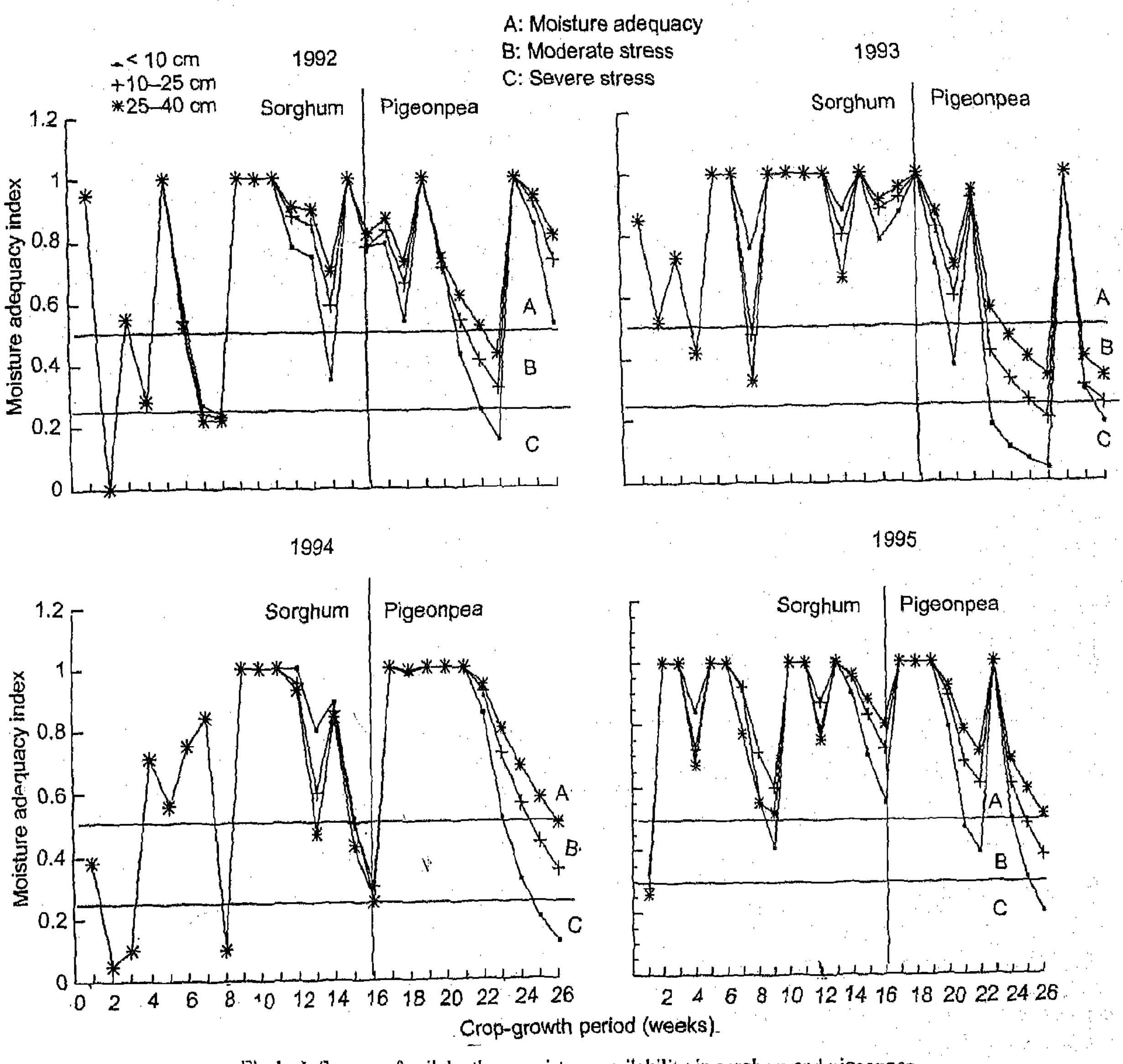

Fig 1 Influence of soil depth on moisture availability in sorghum and pigeonpea

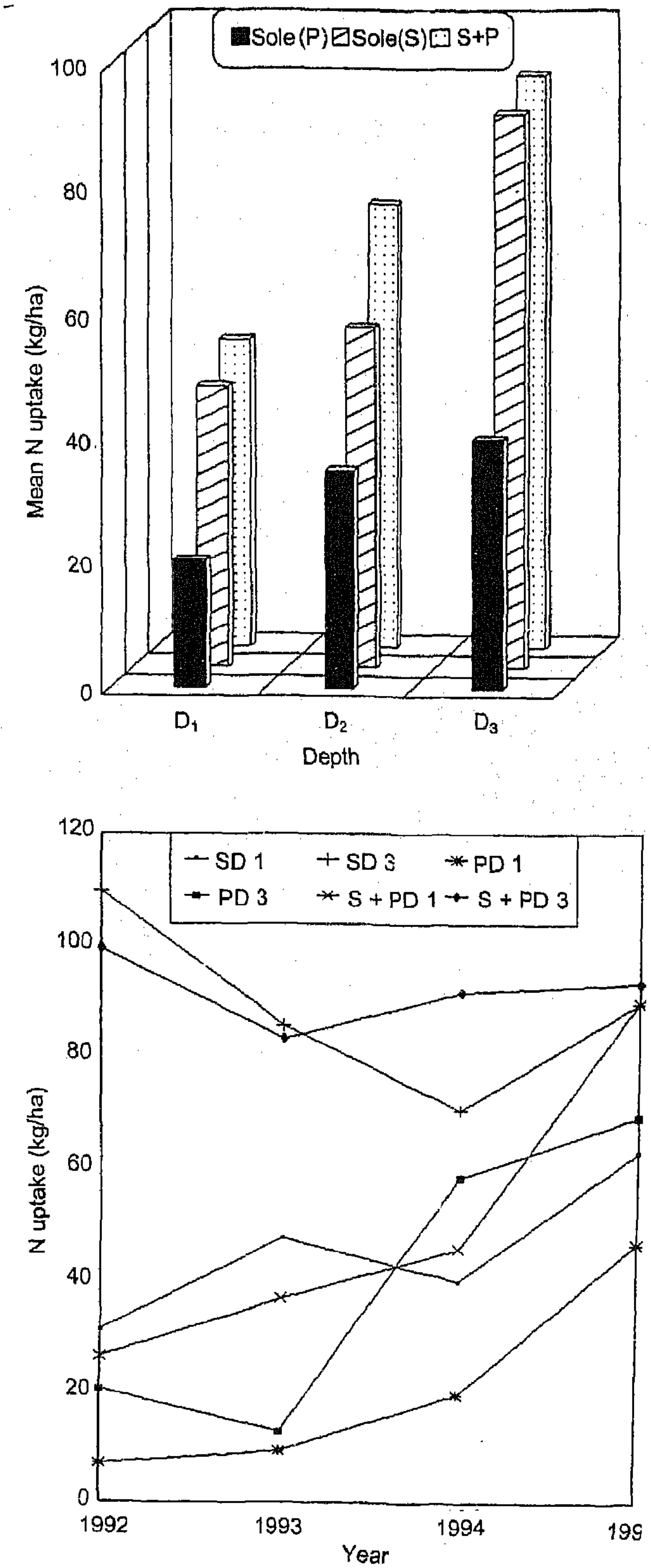

Fig 2 Mean nitrogen uptake in relation to soil depth of sorghum and pigeonpea (1992–95) (*top*); and nitrogen uptake in sorghum and pigeonpea in shallow and deeper soil depths (*bottom*) (D_1, 8.0 ± 4.3 cm; D_2, 15.4 ± 4.5 cm; D_3, 30 ± 8.0 cm)

Pigeo2npea experienced moderate stress at vegetative and reproductive stages in all the years under experimentation. Severe stress was experienced during vegetative stage in 1992 and 1994 in all soils and during flowering and pod-formation stages in medium soils in 1993 and in shallow soils in all the years.

Soil depth and crop yields

The leaf-area index (LAI) increased with an increase in soil depth in all the systems. In sorghum LAI increased up to 75 days after sowing and later decreased at all soil depths, whereas it increased up to 120 days after sowing in pigeonpea. Among the sysems, intercropping produced highest LAI compared with sole crops.

Total dry-matter production was the highest at deeper depths (20–40 cm) in all the cropping systems. Among the systems, intercropping produced higher total dry matter than sole crops. This may be due to more LAI and light interception by component crops leading to the production of photosynthates necessary for dry-matter production. The results confirm the findings of Barik *et al.* (1998) in sorghum–groundnut (*Arachis hypogaea* L.) intercropping system.

The seed yield of sorghum in sole and intercropping system significantly increased with the increase in soil depths (10 to 40 cm) in the watershed. The results confirm those of Vittal *et al.* (1990) in Alfisols with sorghum, pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] and castor (*Ricinus communis* L.) crops. On an average, the grain yield of sole sorghum was enhanced by 301 and 1 286 kg/ha in soils having depth ranges of 10–20 cm and 20–40 cm respectively compared with <10 cm depth. The influence of soil depth on grain yield of sole sorghum was highest in 1992, followed by 1993 owing to better distribution of rainfall for sorghum.

The productivity of piegonpea was more influenced by soil depth compared with sorghum. The seed yield of pigeonpea was higher by 66 and 46% in 10–20 cm and 20–40 cm soil depths, respectively, over the soil depth of <10 cm. The influence of soil depth on productivity of pigeonpea was the highest in 1994 and 1995 owing to better distribution of rainfall for pigeonpea. The seed yield of pigeonpea and sorghum in intercropping was reduced by 12–20 and 30–39% respectively compared with the respective sole crops at corresponding soil depths in all the years (Table1).

Sorghum-grain equivalent

Over the years, intercropping of sorghum and pigeonpea recorded higher sorghum-grain equivalents at all soils depths compared with the sole crops. At shallow depths (< 10 cm), the sorghum and pigeonpea intercropping system produced higher sorghum grain equivalents of 42 and 40% and 85 and 28% in medium soil depths (10–20 cm) and 71 and 24% in deeper soils (20–40 cm) than sole crops of sorghum and

Table 1 Influence of soil depths on seed yields of sorghum and pigeonpea in sole and intercropping systems

Treatment	Soil depth	Sorghum yield (kg/ha)					Pigeonpea yield (kg/ha)				
		1992	1993	1994	1995	Mean	1992	1993	1994	1995	Mean
Sole crop	D_1	1 409	2 355	1 556	2 597	1 979	130	145	318	830	355
	D_2	1 610	2 488	2 226	2 800	2 280	200	190	741	1 222	588
	D_3	4 405	4 334	2 365	3 150	3 566	350	206	890	1 986	858
Intercropping	D_1	1 017	2 066	1 400	2 025	1 627	105	120	202	440	217
	D_2	1 260	2 186	1 953	2 312	1 925	162	145	475	856	410
	D_3	3 524	3 936	1 970	2 425	2 963	220	162	523	1 283	547
CD(P=0.05)											
Crops (C)		70	99	NS	112		66	39	41	70	
Depths (D)		86	122	82	138		60	33	36	61	
C × D		121	173	143	195		104	66	71	122	

Details of soil depths are given under Materials and Methods

pigeonpea respectively. When the distribution of rainfall was favourable for sorghum and erratic for pigeonpea as in 1992 and 1993, intercropping system gave at par sorghum-grain equivalents with sole sorghum at all soil depths and in particular at deeper depth (20–40 cm). In 1995, where the rainfall distribution was favourable to both sorghum and pigeonpea, the sorghum-grain equivalents in sole pigeonpea and intercropping were higher than the sole sorghum at all soil depths. However, higher sorghum-grain equivalents were recorded in pigeonpea compared with sole sorghum. This is because of higher prices for pigeonpea than sorghum (Table 2).

Yield and monetary advantage

Land-equivalent ratio (LER): Intercopping of sorghum and pigeonpea recorded higher yield advantage with increasing soil depth up to 20 cm compared with the sole crops of pigeonpea and sorghum. Higher yield gain by 67–70 % was observed in 1993. The LER in the intercropping decreased beyond 20 cm soil depth in spite of obtaining higher absolute yields. While considering the yields of component crops at maximum soil depth, intercropping was not beneficial in yield advantage in soil with less than 10 cm soil depth in all the years. But sorghum and pigeonpea intercropping recorded additional yield advantage by 43, 70, 42 and 42% in 1992, 1993, 1994 and 1995 respectively over its sole crop yield, in soils with a depth of 20–40 cm. The additional yield advantages owing to intercropping of sorghum and pigeonpea ranged from 16 to 36% in medium soil depth (10–20 cm) over the sole crop yields at maximum soil depth (Table 3). The results are in accordance with the findings of Koppalkar and Sheelavantar (1990) for groundnut-sunflower (*Helianthus annuus* L.) intercropping system.

Staple land-equivalent ratio (SLER) : The SLER values of sorghum and pigeonpea system indicated that in medium deep soils (10–20 cm), an yield advantage of 41, 48, 54 and 36% was achieved at desired sole sorghum yield levels of 60, 70, 80 and 90% respectively. The SLER values increased with increase in soil depths from 10 to 20 cm and then decreased from 20 to 40 cm. Thus it is possible to achieve 80% of desired yield levels of sole sorghum with higher additional advantage at all depths. About 70% of sole crop yields of pigeonpea could be possible in the sorghum + pigeonpea system grown at all soil depths (Table 3).

Gross returns : Gross returns/ha increased with increase in soil depth in sole sorghum, sole pigeonpea and the intercropping system. Intercropping recorded higher gross returns compared to sole crops. The results confirm the findings of Singh and Joshi (1997). The sorghum and pigeonpea intercropping system recorded higher gross returns by 42, 86 and 74% for <10 cm 10–20 cm and 20–40 cm soil depths respectively compared with the sole crop of sorghum grown in corresponding soil depths based on average of 4 years. An additional gross returns of 40, 29 and 27% in sorghum and pigeonpea system was obtained as compared to sole pigeonpea at <10, 10–20 and 20–40 cm soil depths respectively. But sole pigeonpea recorded higher gross returns/ha compared to sole sorghum and the intercropping system in 1995 where the distribution of rainfall was more favourable for pigeonpea. The gross income from sole pigeonpea was consistently lower in shallow soil depth (<10 cm) compared with sole sorghum and intercropping during 1992 and 1993 (Table 2).

Rainfall-use efficiency

The rainfall-use efficiency of seed in soghum and pigeonpea in sole and intercropping systems increased with increase in soil depth in all the years. Among the systems, sole sorghum showed higher rainfall-use efficiency for grains compared with sole pigeonpea and intercropping at all soil depths in all the years (Table 2). Moderate stress had no significant effect on yield.

Table 2 Influence of soil depths on sorghum equivalents, gross returns and rainfall-use efficiency in sole and intercropping systems

Treatment	Soil depth	Sorghum grain equivalent (kg/ha)					Gross returns (Rs/ha)					Rainfall-use efficiency (kg/ha/mm)				
		1992	1993	1994	1995	Mean	1992	1993	1994	1995	Mean	1992	1993	1994	1995	Mean
Sole sorghum	D_1	1 409	2 355	1 556	2 597	1 979	2 818	4 710	3 112	5 194	3 959	3.69	4.31	4.74	4.67	4.35
	D_2	1 610	2 488	2 226	2 800	2 280	3 220	4 976	4 536	5 600	4 583	4.22	4.56	6.79	5.10	5.17
	D_3	4 405	4 344	2 365	3 150	3 566	8 810	8 668	4 730	6 300	7 127	11.55	7.94	7.21	5.70	8.10
Sole pigeonpea	D_1	520	880	1 590	5 395	2 021	1 040	1 160	3 180	10 790	4 042	0.28	0.25	0.48	1.12	0.53
	D_2	800	760	3 705	7 043	3 302	1 600	1 520	7 410	15 886	6 604	0.43	0.33	1.12	1.67	0.88
	D_3	1 400	824	4 450	12 900	4 896	2 800	1 648	8 900	25 818	9 792	0.75	0.35	1.33	2.7	1.28
Sorghum +	D_1	1 437	2 546	2 410	4 885	2 820	2 874	5 092	4 820	9 770	5 639	2.41	3.76	2.4	3.3	3.00
pigeonpea (2 : 1)	D_2	1 908	2 766	4 328	7 878	4 220	4 120	5 532	8 656	15 752	8 515	3.05	4.0	3.6	4.3	3.74
	D_3	4 404	4 884	4 585	10 765	6 085	9 848	9 168	9 170	21 529	12 429	8.03	7.04	3.74	5.0	6.00
CD(P=0.05)																
Crops		93.57	91.3	95.43	293	1 166	187	182	190	607	247					1.10
Depths		93.57	91.3	95.43	293	1 166	187	182	190	607	247					1.10
Crops×depths		162.0	158.1	165.0	507	NS	324	316	330	1 052	427					NS

Details of soil depths are given under Materials and Methods

Table 3 Land-equivalent ratio values of sorghum and pigeonpea intercropping as influenced by soil depth in rainfed Alfisol watershed and staple land-equivalent ratio (SLER) values for sorghum and pigeonpea in intecropping system

Year	Corresponding soil depth			Maximum soil depth			Sorghum (%) as sole crop (SLER)											
							D_1				D_2				D_3			
	D_1	D_2	D_3	D_1	D_2	D_3	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9
1992	1.53	1.59	1.43	0.53	0.76	1.43	1.44	1.52	1.38	1.19	1.45	1.53	1.54	1.21	1.32	1.38	1.43	1.22
1993	1.71	1.64	1.70	1.06	1.20	1.70	1.48	1.56	1.65	1.59	1.44	1.51	1.58	1.53	1.46	1.54	1.62	1.69
1994	1.54	1.52	1.42	0.82	1.36	1.42	1.36	1.42	1.48	1.54	1.35	1.41	1.47	1.43	1.30	1.35	1.41	1.25
1995	1.31	1.53	1.42	0.86	1.16	1.42	1.24	1.28	1.28	1.14	1.38	1.45	1.51	1.31	1.33	1.38	1.36	1.42
Mean	1.22	1.26	1.20	0.66	0.90	1.20	1.38	1.44	1.50	1.29	1.41	1.48	1.54	1.36	1.35	1.41	1.47	1.29

Details of soil depths are given under Materials and Methods

Nitrogen uptake

Nitrogen uptake in sorghum and pigeonpea in different cropping systems increased with an increase in soil depth. The intercropping system with sorghum and pigeonpea utilized higher amounts of nitrogen compared with the respective sole crops at corresponding soil depths. Similar trends was observed by Natarajan and Willey (1980). Among the crops, sorghum in sole and intercropping showed higher N uptake than pigeonpea over the years. At shallow depth (<10 cm), sorghum and pigeonpea intercropping recorded higher nitrogen uptake by 90 and 54% and 30 and 120% in medium soils (10–20 cm) than sole crops of pigeonpea and sorghum respectively.

During 1992 and 1993 the rainfall distribution was favourable for sorghum and erratic for pigeonpea, sole sorghum utilized higher amounts of nitrogen than pigeonpea and also sorghum and pigeonpea system. In years where distribution of rainfall was favourable for both components like 1994, intercropping system of sorghum and pigeonpea shared nitrogen efficiently than sole crops at all depths (Fig 2).

The yields of intercrops were higher than the sole crops of sorghum and pigeonpea at all depths. This may be owing to better exploitation of resources which reflected in favourable growth parameters like dry-matter production and LAI and in turn yield. Thus in fields with soil depth ranging from <10 to 20 cm, sorghum and pigeonpea intercropping system gave higher yield and income. The next suitable system was sole sorghum. On contrary, in deeper soils when rainfall was good and well distributed up to November sole pigeonpea fetched more than sole sorghum and the intercropping system. This may be owing to the more favourable soil moisture, deep root-system and higher prices for pigeonpea.

It was concluded that sorghum+pigeonpea intercropping system gives stable yield and income over the years with any of the soil depth compared to sole crops.

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