Indian J. Dryland Agric. Res. & Dev. 2014 29(2) : 34-40 DOI 10.5958/2231-6701.2014.01212.3

A Study on Sorghum (*Sorghum bicolor L.*) + Chickpea (*Cicer arietinum*) Intercropping Systems with Varying Row Proportions on a Semiarid Vertisol

S.M. Dhadge[1], N.R. Satpute[1], D.K. Kathmale[1], S.V. Patil[1], G. Ravindra Chary[2], Ch. Srinivasa Rao[2], J.D. Jadhav[1] and J.R. Kadam[1]

[1] *All India Coordinated Research Project for Dryland Agriculture, Solapur-413 002, Maharashtra*

[2]*Central Research Institute for Dryland Agriculture, Hydrabad-500 059, Telangana*

Email: satputenitin1@gmail.com

ABSTRACT: A field experiment was carried out during *rabi* 2008 to 2012 at Mulegaon farm of All India Coordinated Research Project for Dryland Agriculture, Solapur Maharashtra to find out suitable geometry for sorghum + chickpea strip intercropping system on Vertisols under dryland condition. Among the various row proportions studied, sorghum + chickpea (3:3) at 45 cm row spacing system was found to be promising and registered significantly higher net returns (₹ 28676/ha), sustainable yield index (0.41), better land equivalent ratio (1.43) and rainwater use efficiency (31.93 kg/ha-mm) over the respective sole crops followed by sorghum + chickpea (2:6) at 30 cm row spacing (₹ 28537, 0.67, 1.43 and 32.81 kg/ha-mm, respectively) and sorghum + chickpea (2:1) at 30 cm row spacing (₹ 27593, 0.60, 1.33 and 30.96 kg/ha-mm, respectively).

Key words: *Rabi* sorghum, intercropping, vertisols, rainwater use efficiency, sustainability yield index, dryland agriculture

Sorghum (*Sorghum bicolor L*) is the fourth staple cereal in India after rice, wheat and maize, well adapted to drought environments (Borrell *et al.,* 2006) and thus, a natural crop of choice for cultivation in semi-arid tropics. In India, it is cultivated under rainfed conditions in marginal farming situations by resource poor farmers in arid and semiarid rainfed agroecoregions i.e 500 to 1200 mm rainfall and on black and red soils (Entisols, Inceptisosl, Vertisols and Alfisols) for grain and fodder during *kharif* (south-west monsoon) and *rabi* (post-rainy season). The major area under rabi sorghum is concentrated in Maharashtra with 3.1 m ha purely cultivated on residual moisture on shallow to deep black soils (Vertisols and Vertic Inceptisols) and characterized by the lowest long term yield average (about 460 kg/ha) due to abiotic stresses, mainly intra-season drought during vegetative to reproductive stages of the crop and improper soil, water and crop management practices. In rainfed farming regions, the advantages of intercropping are well documented in respect of more efficient utilization of available resources, stability in yield and income leading to more risk resilience and resource use-efficiency (Ravindra Chary *et al.,* 2012), particularly with cereals and pulses (Rao *et al.,* 2003). Chickpea a biological N fixing pulse crop, is a widely cultivated *rabi* crop in the scarcity zone. In order to achieve higher resource use-efficiency, stability in yield and income, an attempt was made to identify better row spacings of *rabi* sorghum + chickpea intercropping systems on Vertisols of scarcity zone of Maharashtra.

Materials and Methods

Site information and treatments

The field experiment was conducted during *rabi* seasons for five years from 2008 to 2012, at Research Farm, All India Coordinated Research Project for Dryland Agriculture, Solapur (17^0 4' N latitude and 75^0 5' E longitude with elevation 483.63 m above mean sea level), Maharashtra state. The experimental site is medium deep black soil (Vertisol) characterized with clay loam, water holding capacity 85 mm, pH of 8.2, EC(1:2.5) of 0.41 ds/m, low in available N (111 kg/ha), medium in available P_2O_5 (14.5 kg/ha) and high in available K_2O (255 kg/ha). Sorghum cv M 35-1 and chickpea cv 'Digvijay' were the component crops. The treatment combinations comprised of T_1= Sole sorghum, T_2= Sole chickpea, T_3 = Sorghum + chickpea (2:4) at 45 cm row spacing, T_4= Sorghum + chickpea (2:6) at 30 cm row spacing, T_5= Sorghum + chickpea (3:3) at 45 cm row spacing, T_6= Sorghum + chickpea (4:4) at 30 cm row spacing, T_7= Sorghum + chickpea (6:6) at 45 cm row spacing, T_8= Sorghum + chickpea (2:1) at 45 cm row spacing and T_9= Sorghum + chickpea (2:1) at 30 cm row spacing. The experiment was conducted in a randomized block design with three replications. The gross and net plot size were 32.40 m^2 (6.0 m x 5.4 m) and 27 m^2 (5 m x 5.4 m), respectively. The details of dates of sowing, harvest of crops and crop duration are given in Table 1. The thinning and gap filling was done 10 days after germination to ensure the uniform plant population. Recommended package of practices were adopted for sorghum and chickpea.

The seasonal rainfall received during 2008 to 2012 ranged from 318.03 mm (2010) to 609.05 mm (2012). The sorghum equivalent yield (SEY) was calculated as the product of yield of chickpea and unit price of chickpea divided by unit price of sorghum. The rain water use-efficiency (kg/ha-mm) was calculated as sorghum equivalent yield (kg/ha)/ crop seasonal rainfall. The Land Equivalent Ratio (LER) was calculated as yield of main crop divided by yield of sole main crop plus yield of intercrop divided by yield of sole intercrop described by Willey (1979). Using the data of yield of different crops and cropping systems, analysis of variance (ANOVA) was carried out to test the treatment differences in each year and also for the data pooled over years. The treatments were assessed based on the Least Significant Difference (LSD) criteria at $p < 0.05$ level of significance. Sustainable yield index was calculated as per the reference of Reddy and Babu (2003). Based on this, sustainable yield index (SYI) was worked out by the formula:

Table 1 : Dates of sowing, harvest of crops, crop duration, cumulative rainfall (mm) and cumulative rainy days at experimental site

Crop/Year	Date of sowing (DOS)	Date of harvest (DOH)	Crop duration (days)	Cumulative rainfall (mm)	Cumulative rainy days
Sorghum					
2008	30/09/2008	31/01/2009	123	88.10	05
2009	27/09/2009	30/01/2010	126	265.0	10
2010	22/09/2010	25/01/2011	124	103.0	12
2011	06/10/2011	09/02/2012	126	141.5	05
2012	28/09/2012	27/01/2013	122	36.2	05
Chickpea					
2008	30/09/2008	31/12/2008	92	88.10	05
2009	27/09/2009	25/12/2009	90	265.0	10
2010	22/09/2010	19/12/2010	88	103.0	12
2011	06/10/2011	05/01/2012	91	141.5	05
2012	28/09/2012	25/12/2012	89	36.2	05

$$SYI = \frac{A - Y}{Ymax} \times 100$$

where,

A = mean of particular treatment,

Y = standard deviation of a particular treatment,

Ymax = potential yield in different years and treatments.

Results and Discussion

Yield of component crops

The pooled results of five years revealed that significantly maximum grain yield (894 kg/ha) of *rabi* sorghum as main crop was attained in sorghum + chickpea intercropping with row proportion at 2:1 at 45 row spacing (Table 3) This might be due to absence of competition between main crop and intercrop for resources because of shorter duration (Kumar and Rana, 2007) while the yield of chickpea as intercrop was significantly higher (812 kg/ha) in sorghum+ chickpea intercropping system with row proportion of 2:6 at 30 cm spacing (Table 4). This might be due to more plant population of chickpea/ha when compared to other strip cropping systems. The stalk yield of chickpea in different ratios and row spacing was significantly influenced. In sorghum + chickpea with 2:6 ratio at 30 cm row spacing, significantly higher stalk yield (1283 kg/ha) was attained and was at par with sorghum + chickpea with row ratio of 2:4 at 45 cm row spacing. Chickpea being a leguminous crop with deeper root system dominated by short and slender root hair produced directly on tap root, thus had more chance of extraction of

Table 2 : Monthly rainfall (mm) data at experimental site

Month	Rainfall (mm)											
	2008		2009		2010		2011		2012		Mean	
	N	A	N	A	N	A	N	A	N	A	N	A
Jan	4.2	0.0	4.2	0.0	4.2	32.0	4.2	0.0	4.2	0.0	4.2	6.40
Feb	3.9	0.0	3.9	0.0	3.9	4.1	3.9	0.0	3.9	0.0	3.9	0.82
March	4.7	43.3	4.7	4.4	4.7	0.0	4.7	0.0	4.7	0.0	4.7	9.54
April	15.3	27.0	15.3	6.0	15.3	8.6	15.3	62.5	15.3	12.3	15.3	23.28
May	32.6	2.5	32.6	52.1	32.6	3.2	32.6	26.7	32.6	20.4	32.6	20.98
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
Aug	139.6	167.5	139.6	161.5	139.6	194.4	139.6	182.9	139.6	96.4	139.6	160.54
Sep	172.7	227.0	172.7	223.5	172.7	86.8	172.7	60.9	172.7	105.0	172.7	140.64
Oct	97.9	54.7	97.9	157.6	97.9	38.1	97.9	141.5	97.9	150.9	97.9	108.56
Nov	21.6	6.8	21.6	23.5	21.6	29.5	21.6	0.0	21.6	14.8	21.6	14.92
Dec	6.0	3.7	6.0	0.7	6.0	5.7	6.0	0.0	6.0	0.0	6.0	2.02
Total	721.4	693.2	721.4	790.2	721.4	787.3	721.4	761.7	721.4	534.0	721.4	716.64

N- Normal rainfall; A - Actual rainfall

Table 3 : Main crop grain and stover yield as influenced by different strip cropping systems

Treatments	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
Sole Sorghum	997	1588	751	1152	1314	1161	5710	4568	3364	2686	3350	3936
Sole Chickpea	-	-	-	-	-	-	-	-	-	-	-	-
Sorghum + chickpea (2:4) at 45 cm row spacing	750	712	442	720	798	685	2309	2058	1183	1684	2034	1854
Sorghum + chickpea (2:6) at 30 cm row spacing	568	803	463	745	829	682	2109	1903	1780	1744	2113	1930
Sorghum + chickpea (3:3) at 45 cm row spacing	820	1159	441	715	791	785	2932	2325	1739	1666	2018	2136
Sorghum + chickpea (4:4) at 30 cm row spacing	708	1240	443	723	801	783	3393	2695	1759	1689	2049	2317
Sorghum + chickpea (6:6) at 45 cm row spacing	792	1312	442	718	795	812	2963	2387	1790	1674	2027	2048
Sorghum + chickpea (2:1) at 45 cm row spacing	934	1192	556	843	945	894	3395	2778	2047	1966	2413	2520
Sorghum + chickpea (2:1) at 30 cm row spacing	834	1203	476	761	845	824	3807	3035	2109	1774	2156	2576
General mean	800	1089	502	797	791	736	3315	2454	1971	1860	2018	2146
SEm±	22.2	101	42.9	28.94	32.50	56.75	224	174	150.8	63.98	82.12	176.51
CD (P=0.05)	66.05	306	130.2	87.79	97.44	163.50	678.3	528	457.4	194.0	246.2	508.52
C.V (%)	3.02	16.1	14.8	13.26	7.11	17.24	11.68	11.1	13.9	10.96	7.04	18.39

Table 4 : Intercrop seed and stalk yield as influenced by different strip cropping systems

Treatments	Intercrop grain yield (kg/ha)						Intercrop stalk 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
Sole Sorghum	-	-	-	-	-	-	-	-	-	-	-	-
Sole Chickpea	798	1353	967	853	969	988	818	2675	1163	1313	1688	1532
Sorghum + chickpea (2:4) at 45 cm row spacing	537	933	844	730	821	773	664	2253	813	1116	1477	1265
Sorghum + chickpea (2:6) at 30 cm row spacing	613	889	895	781	885	812	715	2212	700	1200	1588	1283
Sorghum + chickpea (3:3) at 45 cm row spacing	485	734	864	740	827	730	568	1389	957	1136	1482	1107
Sorghum + chickpea (4:4) at 30 cm row spacing	444	669	761	720	808	681	629	1389	895	1101	1455	1094
Sorghum + chickpea (6:6) at 45 cm row spacing	415	682	730	637	722	637	658	1430	833	978	131	1042
Sorghum + chickpea (2:1) at 45 cm row spacing	383	416	679	504	555	508	515	926	751	767	1000	792
Sorghum + chickpea (2:1) at 30 cm row spacing	247	434	741	699	802	585	407	988	792	1073	1444	941
General mean	446	680	798	708	709	634	684	1512	863	1085	1272	1006
SEm±	28.6	51.0	47.6	22.41	25.23	47.39	48.1	85	59	4079	57.3	123.08
CD (P=0.05)	88.01	154	144.5	67.98	75.65	136.52	146	258	180	123.7	171.8	354.59
C.V (%)	11.01	11.2	10.1	11.48	6.15	16.69	12.18	8.9	11.9	11.51	7.80	27.35

moisture from the deeper layers while sorghum had large rooting volume situated at greater distance in 2:6 proportion at 30 cm spacing, further the sorghum roots might not had extended its extension zone towards chickpea rhizosphere. These results are in agreement with the finding of Patil (1998) and Surkod *et al.* (2003).

Sorghum equivalent yield

The pooled sorghum equivalent yields (Table 5) among the sorghum + chickpea intercropping systems ranged between 2640 to 2950 kg/ha and were significantly superior over sole crops of sorghum (2210 kg/ha) and chickpea (2074 kg/ha). Sorghum with chickpea, might have increased light interception in chickpea, reduced evaporation and improved soil moisture conservation compared with sole crops, particularly sorghum. Similar observations were made by Ghanbari *et al.,* (2010). The SEY attained in sorghum + chickpea with 2: 6 ratio at 30 cm row spacing was higher (2950 kg/ha) and was at par with SEY attained in sorghum+ chickpea with 3:3 ratio at 45 cm row spacing (2892 kg/ha), sorghum + chickpea with 2:4 ratio at 45 cm row spacing (2837 kg/ha), sorghum + chickpea with 4:4 ratio at 30 cm row spacing (2819 kg/ha), sorghum + chickpea with 6:6 ratio at 45 cm row spacing (2748 kg/ha). In areas with low rainfall and post rainy season cropping under residual moisture, the initial establishment and good growth of the component crops is important which would be influenced by the quantum of rainfall and soil moisture status in the initial stages. During 2008 and 2010, the rainfall during October was less than the normal (Table 2) coinciding with the germination and initial growth stages of sorghum and chickpea while during 2009, 2010 and 2011, the rainfall during October was more than normal which influenced the performance and crops yield. The mean SEY was higher during 2009 and 2010 in the strip cropping systems compared to 2008 and 2012. In medium deep black soils, the appropriate land configuration besides the advantages of agronomic measures like component crops in appropriate row proportions play a vital role both for moisture conservation and removal of excess water during high rainfall events from the cropped fields.

Resource use efficiency

Land equivalent ratio

Land equivalent ratio (LER) in different sorghum + chickpea intercropping systems ranged from 1.31 to 1.44 which indicated the yield advantage of intercropping systems by efficient utilization of the environmental resources compared to sorghum and chickpea as sole crops (Willey and Rao, 1980). The intercropping systems are more productive when component crops differ in growth duration as in the case of long duration sorghum and relatively short duration chickpea crops (Keating and Carry, 1993). The maximum land equivalent ratio (1.44) attained with sorghum + chickpea in 2:4 row proportion at 45 cm row spacing which was significantly superior over T_8 (1.31) and T_9 (1.33) and statistically on a par with T_4 (1.43) and T_5 (1.43) (Table 5). The higher LER with sorghum + chickpea

Table 5 : Sorghum equivalent yield and land equivalent ratio (LER) as influenced by different strip cropping systems

Treatments	Sorghum 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
Sole Sorghum	1915	2350	1974	2604	2206	2210	-	-	-	-	-	-
Sole Chickpea	1496	3454	2216	1834	1371	2074	-	-	-	-	-	-
Sorghum + chickpea (2:4) at 45 cm row spacing	2114	3586	2787	3196	2500	2837	1.43	1.36	1.46	1.48	1.45	1.44
Sorghum + chickpea (2:6) at 30 cm row spacing	2070	3539	3127	3366	2645	2950	1.34	1.17	1.55	1.56	1.54	1.43
Sorghum + chickpea (3:3) at 45 cm row spacing	2211	3494	3046	3206	2502	2892	1.44	1.29	1.49	1.49	1.46	1.43
Sorghum + chickpea (4:4) at 30 cm row spacing	2113	3478	2826	3182	2496	2819	1.27	1.29	1.39	1.47	1.45	1.37
Sorghum + chickpea (6:6) at 45 cm row spacing	2083	3536	2763	2993	2362	2748	1.32	1.37	1.35	1.37	1.35	1.35
Sorghum + chickpea (2:1) at 45 cm row spacing	2217	2775	2850	2989	2377	2640	1.42	1.08	1.45	1.32	1.30	1.31
Sorghum + chickpea (2:1) at 30 cm row spacing	1933	2879	2931	3223	2562	2766	1.18	1.10	1.41	1.48	1.47	1.33
General mean	1979	3327	2742	2955	2336	2652	1.34	1.24	1.45	1.45	1.43	1.38
SEm±	37.6	71	51.9	75.27	15.31	121.97	0.04	0.03	0.08	0.04	0.03	0.4
CD (P=0.05)	112.6	212	155.7	225.5	195.8	351.40	0.13	0.10	NS	0.11	0.10	0.10
C.V (%)	5.2	8.65	8.3	10.41	4.84	10.28	5.53	5.10	9.18	5.10	5.32	7.63

in 2:4 row proportion at 45 cm row spacing might be due to low or no intra row competition between sorghum and chickpea for the same ecological niches, less interspecific competition for a given resource and complementary use of resources by sorghum and chickpea for growth resources such as light, soil moisture and nutrients resulting in higher crop biomass by chickpea over time and space, thus exploiting the variation of sorghum and chickpea in rates of canopy development, photosynthetic adaptation of canopies to irradiance conditions, and rooting depth (Midmore, 1993; Tsubo *et al.,* 2001).

Rainwater use efficiency

The actual seasonal rainfall varied in the months of October, November and December compared to normal rainfall during 2008 to 2011 indicating the temporal rainfall variability and risk of component crops to either deficit (2009, 2010) or excess soil moisture (2009, 2011) stress during initial and later growth stages. The pooled rainwater use efficiency (RWUE) over five years (Table 6) attained with sorghum + chickpea intercropping systems ranged from 30.02 kg/ha-mm to 32.81 kg/ha-mm and was higher than RWUE attained with sole sorghum (25.82 kg/ha-mm) and significantly higher than sole chickpea (20.47 kg/ha-mm). Cereal and legume as main and intercrop might have symbiotic beneficial effect with each other and reduced the competition for moisture and nutrients between the crops. These factors might have helped in increasing the yield of main and intercrop significantly and resulted in higher net returns. Waghmare *et al.* (1982) found that sorghum was benefited from greengram, groundnut, soybean and fodder and grain cowpea crops when grown as intercrop and gave good net returns and B:C ratio (Patil, 1998; Hebbi, 2000; Kiran, 2004). This indicated better utilization of available soil moisture in the initial stages by sorghum and chickpea, particularly during deficit years. Further, it might also be due to asynchrony in moisture demand by sorghum and chickpea as the late maturing sorghum might have recovered from possible damage caused , if any, by the early maturing chickpea during early stages (Keating and Carry, 1993). Among the different row proportions of sorghum and chickpea intercropping systems, maximum RWUE of 32.81 kg/ha-mm was attained with 2 rows of sorghum and 6 rows of chickpea spaced at 30 cm, however was at par with other row proportions of sorghum and chickpea at 30 and 45 cm inter-row spacing's. The higher RWUE attained with sorghum + chickpea with 2:6 row proportion might be due to better resource use-efficiency by both sorghum and chickpea.

Economics

The gross returns accrued ₹ 43001/ha (Table 7) were significantly higher in sorghum + chickpea with 2:6 row proportion at 30 cm row spacing over the respective sole crops and was statistically on a par with T_5 (₹ 41899/ha), T_3 (₹ 41203/ha), T_6 (₹ 41006/ha), T_9 (₹ 40158/ha) and T_7 (₹ 39631/ha). As regards to net return, sorghum + chickpea (2:6) at 30 cm row spacing and sorghum + chickpea (3:3)

Table 6 : Pooled rainwater use efficiency (RWUE kg/ha-mm) of sorghum + chickpea strip cropping systems

Treatments	Rainwater use efficiency (RWUE kg/ha-mm)					
	2008-09	2009-10	2010-11	2011-12	2012-13	Pooled mean
Sole sorghum	21.74	8.87	19.17	18.40	60.94	25.82
Sole chickpea	16.98	13.03	21.51	12.96	37.87	20.47
Sorghum + chickpea (2:4) at 45 cm row spacing	24.00	13.53	27.06	22.59	69.06	31.25
Sorghum + chickpea (2:6) at 30 cm row spacing	23.50	13.35	30.36	23.79	73.06	32.81
Sorghum + chickpea (3:3) at 45 cm row spacing	25.10	13.18	29.57	22.66	69.12	31.93
Sorghum + chickpea (4:4) at 30 cm row spacing	23.98	13.12	27.44	22.49	68.95	31.20
Sorghum + chickpea (6:6) at 45 cm row spacing	23.64	13.34	26.83	21.15	65.25	30.04
Sorghum + chickpea (2:1) at 45 cm row spacing	25.16	10.47	27.67	21.12	65.66	30.02
Sorghum + chickpea (2:1) at 30 cm row spacing	21.94	10.86	28.46	22.78	70.77	30.96
General mean	22.89	12.20	26.45	20.88	64.52	29.39
SEm±	-	-	-	-	-	1.88
CD (P=0.05)	-	-	-	-	-	5.43
C.V (%)	-	-	-	-	-	14.34

Table 7 : Pooled gross monetary returns, total cost of cultivation (₹/ha), net returns (₹/ha) B-C ratio and sustainable yield index as influenced by different strip cropping systems

Treatments	Gross returns (₹/ha)	Total cost of cultivation (₹/ha)	Net returns (₹/ha)	B-C ratio	Sustainable yield index
	Pooled mean	Pooled mean	Pooled mean	Pooled mean	
Sole sorghum	33436	13141	20295	2.54	0.54
Sole chickpea	27917	15136	12781	1.84	-
Sorghum + chickpea (2:4) at 45 cm row spacing	41203	14163	27040	2.91	0.68
Sorghum + chickpea (2:6) at 30 cm row spacing	43001	14464	28537	2.97	0.67
Sorghum + chickpea (3:3) at 45 cm row spacing	41899	13223	28676	3.17	0.41
Sorghum + chickpea (4:4) at 30 cm row spacing	41006	13777	27229	2.98	0.38
Sorghum + chickpea (6:6) at 45 cm row spacing	39631	13222	26409	3.00	0.35
Sorghum + chickpea (2:1) at 45 cm row spacing	38916	12020	26896	3.24	0.52
Sorghum + chickpea (2:1) at 30 cm row spacing	40158	12565	27593	3.20	0.60
General mean	38574	-	25050	2.81	-
SEm±	2134.08	-	2201.60	-	-
CD (P=0.05)	6148.24	-	6342.74	-	-
C.V (%)	12.37	-	19.44	-	-

at 45 cm row spacing and sorghum + chickpea (2:1) at 30 cm row spacing were significantly superior over receptive sole crops. Similar results were reported by Dhope *et al.* (1992). Gode and Bobde (1993) also reported more profitability with intercropping of sorghum + soybean than sole crop of sorghum. The higher B-C ratio (3.24) registered in sorghum + chickpea with 2:1 row proportion at 45 cm and this was due to low cost of cultivation i.e. ₹ 12,020/ha compared to other intercropping systems irrespective of row proportions and spacings (Table 7). This indicated that the variation in cost of inputs and labour influence the profitability of intercropping systems, however, the market price of the produce in particular would result in fluctuations in B-C ratios. Pal *et al*. (1991) observed the similar trend.

Sustainability yield index

Over five years, among the sorghum + chickpea intercropping systems with varying row proportions and spacings, the sustainability yield index recorded was higher in both row proportions of 2: 4 at 45 cm spacing (0.68), 2: 6 at 30 cm spacing (0.67) and 2:1 at 30 cm spacing (0.60) as compared to other row proportions at 45 and 30 cm spacings and sole crops of sorghum and chickpea (Table 7). This indicated the sustainability of the three systems in respect of yield obtained with seasonal rainfall variability and other resource factors.

Conclusion

Considering sustainable yield index and benefit-cost ratio, it is inferred that three sorghum + chickpea intercropping systems in row proportions of 2:4 at 45 cm spacing, 2:6 and 2:1 each at 30 cm spacing were found better and are recommended on Vertisols under dryland condition in Scarcity zone of Maharashtra.

Acknowledgements

The authors acknowledge ICAR for providing the financial assistance under All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad.

References

Borrell AK, Jordan DJ, Mullet J, Henzell RG and Hammer G. 2006. Drought adaptation in sorghum. In: Ribaut, J.M. (Ed.), Drought adaptation in cereals. Haworth press Inc., New York, pp. 335-339.

Dhope AM, Mahakulkar BV, Wanjari SS, Shekhar VB and Potdhuke NR. 1992.

Intercropping of leguminous crops in newly evolved Sorghum genotype (SPV 669). Crop Research., 5 : 207-211.

Ghanbari A, Dahmardeh M, Siahsar BA and Ramroudi M. 2010. Effect of maize (*Zea mays* L.) – cowpea (*Vigna unguiculata* L.) intercropping in light distribution, soil temperature soil moisture and environment. Journal of food and agricultural environment, 8:102-108.

Gode DB and Bobde GN. 1993. Intercropping of Soybean in Sorghum. PKV Research Journal, 17 : 128-29.

Hebbi BS. 2000. Influence of *in- situ* moisture conservation practices in sunhemp green manuring and levels of nitrogen on *rabi* sorghum *M. Sc. (Agri.) Thesis,* University Agricultural Science, Dharwad.

Keating BA and Carry PS. 1993. Resource capture and use in intercropping solar radiation. Field Crops Research, 34:273-301.

Kiran JA. 2004. Effect of *in-situ* moisture conservation practices and nitrogen levels on growth and yield of *rabi* sorghum in vertisols under rainfed condition *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad.

Kumar A and Rana KS. 2007. Performance of pigeonpea (*Cajanus caja L.*) + greengram (*Phaseolus radiutus*) intercropping system as influenced by moisture conservation practices and fertility level under rainfed conditions. Indian Journal of Agronmy, 52(1):31-35.

Midmore DJ. 1993. Agronomic modifications of resource use and intercrop productivity. Field Crop Research, 34: 357-380.

Pal MS, Gupta PC, and Singh OP.1991. Effect of sorghum based Intercropping

Systems on productivity, LER and economics in mollisols of Nainital Tarai. Indian Journal of Agronomy, 36:12-16

Patil SL. 1998. Response of *rabi* sorghum (*Sorghum bicolor* L.Moench) to tillage, moisture conservation practices organics and nitrogen in vertisols of semi-arid tropics. *Ph.D. Thesis,* University of Agricultural Sciences*,* Dharwad.

Rao JV, Khan IA, and Sujatha (Eds.) 2003 Critical Review of Research on Intercropping Systems in Rainfed Regions of India. National Agriculture Research Project, Central Research Institute for Dryland Agriculture (CRIDA), Hydrabad, India.pp.1-100

Ravindra Chary G, Venketeswarlu B, Sharma SK, Mishra JS, Rana DS and Ganesh Kute. 2012. Agronomic Research in dryland farming in India: An Overview. Indian Journal of Agronomy. 57 (3rd IAC special issue): 157-167

Reddy BN and Sudhakara Babu SN. 2003. Sustainabilty of Sunflower-based crop Sequences in Rainfed Alfisols. Helia, 26, Nr. 39, p.p. 117-124, (2003) UDC 633.854.78:631.81.031

Surakod VS, Guled MB, Hiremath KA and Kabadagi CB. 2003. Indigenous Techniques of soil and moisture conservation and runoff management. Technical Bulletin 29: Univ. Agric. Sci., Dharwad.

Tsubo M, Wsalker S and Mukhala E. 2001. Comparison of radiation use efficiency of mono-inter-cropping systems with different row orientations. Field Crop Research, 17: 17-29.

Waghmare AB, Krishan TK and Singh SP. 1982. Crop compatibility and spatial arrangement in sorghum-based intercropping system. Journal of agricultural sciences, *(Camb),* 99:621-629.

Willey RW. 1979. Intercropping its importance and research needs I. competition and yield advantages. Field Crop Abstract, 32: 1-10.

Willey RW and Rao MR. 1980. A Competitive ratio for quantifying competition between crops, Experimental Agriculture, 16: 117-125.

Received: March 2014; Accepted: September 2014