Climate Resilient Intercropping Systems for Rainfed Black Soils of Andhra Pradesh and Maharashtra

G. Rajender Reddy[1], Y.G. Prasad[2], M. Osman[2], T. Himabindu[1], B.M.K. Raju[2], N. Sudhakar[1] and Ch. Srinivasa Rao[2]

[1]ICAR-Zonal Project Directorate, Zone-V, CRIDA complex, Hyderabad-500 059, Telangana
[2]ICAR-Central Research Institute for Dryland Agriculture, Hyderabad-500 059, Telangana

Email: grreddy99@gmail.com

ABSTRACT: The assessment studies on different intercropping systems along with their respective sole crops were implemented with active participation of farmers in Yagantipalle village of Kurnool district (Andhra Pradesh), Aurangabad and Nandurbar districts of Maharashtra during 2011 to 2014 as a part of National Initiative on Climate Resilient Agriculture (NICRA) project. The main objective of the study was to popularize climate resilient rainfed intercropping systems in black soils to mitigate climate variability. Intercropping of foxtail millet + pigeonpea (5:1) was identified as best climate resilient system in black soils (kurnool district) of Andhra Pradesh. This system on an average enhanced pigeonpea seed equivalent yields by 406 and 191 kg/ha compared to sole crops of foxtail millet and pigeonpea and recorded 41% of yield advantage over sole crops. In Aurangabad district of Maharashtra, soyabean + pigeonpea (4:2) and pigeonpea + green gram (1:2) were identified as climate resilient intercropping systems. Cotton + greengram (1:1) intercropping system was suitable during medium and good rainfall years in black soils of Aurangabad district. In Nandurbar district of Maharashtra, soybean + pigeonpea (3:1) was found stable over different rainfall patterns. On an average, the intercropping system of soybean + pigeonpea (3:1) recorded 73% higher net income than sole pigeonpea. Though the seed yields of intercrops were reduced by 15-20% than respective sole crops in intercropping system, the seed yields of intercropping system was always higher (30 to 60%) than sole crops. Hence, adoption of intercropping systems in rainfed black soils is climate resilient system and also helps in improving food security in rainfed areas.

Change in climate is likely to aggravate the problems of future food security by exerting pressure on agriculture. India is more vulnerable to climate change in view of the high population depending on agriculture, excessive pressure on natural resources and poor coping mechanisms. In India, significant negative impacts have been implied with medium-term (2010-2039), climate change, predicted to reduce yields by 4.5 to 9%, which is roughly up to 1.5% of GDP per year (Jasna *et al.,* 2014).

Rainfed agriculture which constitutes nearly 58% of net cultivated area will be the most impacted. Crop production in the rainfed lands in India is presently plagued with numerous problems like insufficient and erratic rainfall, land degradation and low soil fertility, poor supply of agri-inputs, weak technology dissemination system, low investment capacity of farmers etc. Further, it is strongly believed that climate change will further exacerbate the problems of rainfed agriculture. The vulnerability of rainfed lands to climate change and variability has been exposed by the devastating effects of recent floods and prolonged droughts in different parts of the country. Therefore, it is of utmost importance to enhance resilience of rainfed agriculture to climate change through planned adaptation of appropriate inter/sequence cropping systems and also with other management practices of natural resource management (Singh *et al.,* 2004).

Intercropping is an important aspect than sole cropping to address the issues of rainfed agriculture under changing climate scenario and it also helps in the maximization of productivity and profitability by efficient utilization of natural resources like land, light and water (Chandra *et al.,* 2010 b). Inclusion of legumes as intercrops in cereals and oilseeds under pulse based intercropping sequences would have a positive effect on the productivity, economics and fertility status of the soil. Keeping this in view, an attempt was made to evaluate different cereal/pulse and oilseed based intercropping systems to bring stability in productivity and profitability against climate risks in selected villages of Andhra Pradesh and Maharashtra.

Materials and Methods

Three demonstration sites covering 3 districts viz., Kurnool from Andhra Pradesh, Aurangabad and Nandurbar from Maharashtra were selected for the purpose of study. The steps followed in selection of sites in different districts include:analysis of climatic constraints of villages based on long term data, assessment of natural resources, identification of major farming situations, constraints of crop production, climatic vulnerabilities, yield gaps and opportunities for climate change adaptations. Based on the detailed analysis, action plans to demonstrate appropriate intercropping systems to meet climate vulnerability (drought) was prepared on participatory mode with the help of scientists and farmers in each district. The demonstrations were implemented during 2011-12, 2012-13 and 2013-14.

The farmers in each selected village of the district were stratified based on size of holding into: marginal (<1ha), small (1-2 ha), medium (2-4 ha) and big farmers (>4 ha). The farmers for this study were selected based on stratified random sampling representing 10% of population in each

category. The training programmes on production skills of different crops/intercropping systems were imparted to the participants before conducting demonstrations. The details of villages selected for the purpose of study along with soil types and normal rainfall and climate vulnerabilities faced by the farming communities are presented in Table 1.

The demonstrations on improved intercropping systems along with sole crops were conducted in 0.4 ha area on each farmer's site in all selected districts in participatory mode (Table 2). At the time of harvest, the yields of improved intercropping systems and sole crops were recorded. The economic analysis of input and output relationships and grain equivalent yields were worked out to quantify the benefits of intercropping systems for the last three years. Grain equivalent yield for each intercropping system was calculated based on the yield of individual crops in each intercropping systems and their market prices prevailing at the time of experimentation for comparison of intercropping systems with sole crop.

Table 1 : Site characteristics of different NICRA villages

District	NICRA village	Soil type	Normal rainfall (mm)		Climate variability
			Annual	cropping season	
Kurnool	Yagantipalle	Black soils	633	558	Drought
Aurangabad	Shekta	Black soils	644	641	Drought
Nandurbar	Umarani	Red & black soils	813	814	Drought & heat stress

Table 2 : Area and number of farmers under different intercropping systems

District	Cropping system and varieties	Year	Area (ha)	No. of farmers
Kurnool	Foxtail millet (Setaria) + pigeonpea (5:1)	2011	8.8	22
	(SIA-3085 + PRG-158)	2012	16.0	40
		2013	12.0	30
	Castor + pigeonpea (1:1)	2011	12.0	30
	(PCH-111 + PRG-158)	2012	16.0	40
		2013	8.0	20
Aurangabad	Soyabean + pigeonpea (4:2)	2011	2.4	60
	(MAUS-71 + BDN-708)	2012	1.2	03
		2013	5.6	14
	Pearlmillet + pigeonpea (3:3)	2011	2.8	07
	(Sharada + BDN-708)	2012	1.2	03
		2013	5.2	13
	Pigeonpea + greengram (1:2)	2011	1.2	03
	(BDN-708 + BM-2002-1)	2012	1.6	04
	Cotton + greengram (1:1)	2012	1.2	03
	(Bt hybrid + BM-2002-1)	2013	2.8	07
	Rabisorghum + safflower (3:3)	2012	1.6	04
	(Parbhani moti + PBNS-12)	2013	2.8	07
Nandurbar	Soybean + pigeonpea (3:1)	2012	2.4	06
	(JS-9305 + ICPL-87)	2013	2.0	05

Rainfall pattern at experimental sites

Kurnool

The NICRA village Yagantipalle in Kurnool district receives normal annual rainfall of 633 mm. The village normally receives a rainfall of 558 mm during the cropping season. The rainfall in the village was less by 76, 226 and 13 mm during 2011, 2012 and 2013 compared to the normal annual rainfall (633 mm). During the cropping season, there was a deficit rainfall by 90.4, 195 and 49 mm than the normal in 2011, 2012 and 2013, respectively. In 2011, the rainfall was deficient by 41, 8, 53, 42, 3 and 8 mm compared to the normal rainfall in June, July, September, October, November and December respectively. The rainfall was excess by 18.26% in August 2012. Kharif sowings were taken up with the rainfall received during last week of July in 2013. The rainfall was excess by 7.2 and 66 mm during June and September compared to the normal rainfall of corresponding months in 2013. The total rainfall was deficient by 11.7, 8, 72, 22 and 8 mm than normal rainfall received during July, August, October, November and December.

Aurangabad

The NICRA village Shekta in Aurangabad district on an average receives a normal rainfall of 644 mm annually. The rainfall was deficient by 18, 63 and 20% than normal annual rainfall in 2011, 2012 and 2013, respectively. The rainfall was higher by 61 and 91mm in July and August than corresponding normal rainfall in 2011. While the rainfall was deficient by 104, 42, 102 and 104 mm in June, July, August and September, respectively in 2012. The village received excess rainfall of 26 mm in July than normal rainfall in 2013. But the rainfall was deficient in all other months than corresponding normals. A rainfall of 125 mm received in the month of June facilitated land preparation for kharif crops. Complete dry spell was experienced from 13th October to 30th December, affected the productivity of long duration crops like pigeonpea, cotton and rabi sorghum.

Nandurbar

The NICRA village Umarani of Nandurbar receives a normal rainfall of 813 mm in a year with 57 rainy days. The rainfall was deficit by 23.6% as compared to the normal rainfall in 2012. But the rainfall was excess by 10.2 and 52.8% as against the normal annual rainfall in 2011 and 2013. The rainfall was deficient in the months June and September by 64 and 47 mm respectively in 2011. In 2012, the rainfall was less in the months of June, July and October to the tune of 111, 84 and 47 mm, respectively. A rainfall of 181 mm received in June was helpful for land preparation and sowing of kharif crops in 2013. The excess rainfall received in July (305 mm), August (249 mm) and September (661 mm) created water stagnation in the fields.

Results and Discussion

Sole and intercropping systems

Assessment of intercropping systems of foxtail millet + pigeonpea (5:1), castor + pigeon pea (1:1) were done with active participation of 182 farmers in 72.8 ha in black soils of Yagantipalle village of Kurnool district diring 2011-13. The results showed that intercropping of foxtail millet + pigeonpea (5:1) recorded higher pigeonpea seed equivalents by 196, 277 and 744 kg/ha compared to the sloe crop of foxtail millet and 127, 101 and 345 kg/ha than sole pigeonpea in 2011, 2012 and 2013, respectively. On an average, the intercropping system of foxtail millet + pigeonpea significantly enhanced pigeonpea seed equivalent yields by 406 and 191 kg/ha and B:C ratio by 0.38 and 0.31 as compared to sole crops of foxtail millet and pigeonpea. Similar results were reported by Sashidhara *et al.* (2000) which showed that small millets performed better even under drought and erratic rainfall, both as sole and intercropping systems probably due to their drought tolerant capacity. Similarly castor + pigeon pea intercropping system (1:1) on an average gave significant increase in pigeonpea grain equivalent yields by 561 and 583 kg/ha and B:C ratio by 0.59 and 0.57 as compared to the sole crops of castor and pigeon pea respectively (Table 3). Higher grain equivalent yields in castor and pigeonpea system might be due to efficient utilization of resources than respective sole crops (Sharma *et al.,* 2004).

In NICRA village of Shekta in Aurangabad district of Maharashtra, intercropping systems of soybean + pigeonpea (4:2), pearlmillet + pigeon pea (3:3) and pigeonpea + greengram (1:2) were demonstrated in farmers fields during 2011-2013. Soya bean + pigeonpea (4:2) registered higher pigeonpea seed equivalent yields by 545, 96 and 400 kg/ha over sole crop of pigeonpea in 2011, 2012 and 2013 respectively. On an average intercropping system of soybean + pigeonpea significantly increased seed equivalents by 24% and B:C ratio by 0.64 than sole crop of pigeonpea. Similar trends of results were noticed in soyabean + pigeonpea intercropping system by Ghosh *et al.* (2006).

Intercropping system of pearl millet + pigeonpea (3:3) recorded higher seed equivalents of pigeonpea by 800, 859 and 2155 kg/ha and B:C ratios by 0.38, 0.50 and 1.34 over sole crop of pigeonpea in 2011, 2012 and 2013 respectively. The additional yield advantages might be due to better complementary effects in utilizing the resources than respective sole cropping systems (Guggari and Kalaghatagi, 2005; Kumar and Rana., 2007). Similarly intercropping system of pigeonpea+green gram on an average gave higher seed equivalent yields by 42% and B:C ratio by 0.71 over sole pigeonpea. The reason for higher yield may be attributed to better utilization of other resources like light, nutrients and moisture by pigeonpea + greengram intercropping system (Sharma *et al.,* 2004) and differential growth and maturity of component crops (Subba Reddy *et al.,* 2004).

In cotton + green gram intercropping system, cotton equivalent yields were higher by 34 and 72% over sole cotton in 2012 and 2013, respectively. Rabi sorghum and safflower intercropping system in black soils of Aurangabad showed higher sorghum grain equivalent yields by 135% and B:C ratio by 1.12 over sole rabi sorghum (1150 kg/ha) over the period of two years (Table 4).

In NICRA village Umarani of Nandurbar district (Maharashtra), demonstrations of soybean + pigeopea (3:1) were conducted in 4.4 ha with 11 farmers in 2012 and 2013.

Intercropping of pulses gave significantly higher soybean grain equivalent yield by 61 and 14% and B:C ratios by 0.82 and 0.19 over sole soya bean in 2012 and 2013, respectively (Table 5). Similar results were reported by Lakhena *et al.* (2009) in soybean and pigeonpea intercropping system. Although intercrops in intercropping system reduced their yields from 20 to 30% over respective sole crops, the soyabean + pigeon pea system gave the benefit to the extent of 40 to 60% in different sites of Kurnool in Andhra Pradesh, Aurangabad and Nandurbar districts of Maharashtra.

Table 3 : Productivity and profitability of intercropping systems in black soils of Kurnool (Andhra Pradesh)

Year	Cropping systems	Yield (kg/ha)		Pigeonpea equivalent yield (kg/ha)	Gross income (₹/ha)	Net income (₹/ha)	BC Ratio
		Sole crop	Inter crop				
Foxtailmillet							
2011	Sole foxtail millet	1785	-	643	22312	10562	1.98
	Sole pigeon pea	712	-	712	24920	10240	1.70
	Foxtailmillet + pigeonpea	1650	245	839	29200	13400	1.90
2012	Sole foxtail millet	1562	-	609	23430	7457	1.47
	Sole pigeon pea	785	-	785	29830	9330	1.46
	Foxtail millet + pigeonpea	1385	245	886	33900	11044	1.74
2013	Sole foxtail millet	2390	-	696	27532	14577	2.13
	Sole pigeon pea	1095	-	1095	43600	27137	2.63
	Foxtail millet + pigeonpea	2084	815	1440	58650	39690	3.09
Mean	Sole foxtail millet	1912	-	649	24425	10865	1.86
	Sole pigeon pea	864	-	864	32783	15569	1.93
	Foxtail millet + pigeonpea	1706	435	1055	40583	21378	2.24
CD (P=0.05)		37.9					
Castor							
2011	Sole castor	796	-	907	31840	19068	2.49
	Sole pigeon pea	782	-	782	27615	13755	1.99
	Castor + pigeonpea	732	665	1499	49230	24615	2.70
2012	Sole castor	1336	-	1055	40080	19100	1.91
	Sole pigeon pea	875	-	875	33250	12515	1.60
	Castor + pigeonpea	1075	415	1264	49320	25835	2.10
2013	Sole castor	1086	-	858	32580	14121	1.76
	Sole pigeon pea	1095	-	1095	43800	16663	2.63
	Castor + pigeonpea	1063	900	1740	67890	46222	3.13
Mean	Sole castor	1073	-	940	34833	17430	2.05
	Sole pigeon pea	918	-	918	34888	14310	2.07
	Castor + pigeonpea	957	660	1501	55480	32224	2.64
CD (P=0.05)		32.0					

Table 4 : Productivity and profitability of intercropping systems in blacksoils of Aurangabad (Maharashtra)

Year	Cropping systems	Yield (kg/ha)		Grain equivalent yield (kg/ha)	Gross income (₹/ha)	Net income (₹/ha)	BC Ratio
		Sole crop	Inter crop				
Soybean							
2011	Sole foxtail millet	1785	-	643	22312	10562	1.98
	Sole pigeon pea	712	-	712	24920	10240	1.70
2012	Sole pigeonpea	1250	-	1250	47500	24880	2.09
	Soybean + pigeonpea	1100	400	1346#	50996	34096	3.01
2013	Sole pigeonpea	1200	-	1200	42000	18240	0.77
	Soybean + pigeonpea	1000	600	1600#	56000	31900	1.32
Mean	Sole pigeonpea	1417	-	1417	43633	21790	1.67
	Soybean + pigeonpea	1200	600	1764#	53621	33071	2.31
t-Stat for mean Grain Equivalent Yield				7.26**			
Pearlmillet							
2011	Sole pigeonpea	3000	-	3000	30000	14400	1.92
	Pearlmillet + pigeonpea	2800	1000	3800#	38000	21500	2.30
2012	Sole pigeonpea	2200	-	2200	26400	14400	2.20
	Pearlmillet + pigeonpea	2100	1000	3059#	37920	21220	2.70
2013	Sole pigeonpea	1600	-	1600	16000	12000	1.08
	Pearlmillet + pigeonpea	1300	700	3755#	37500	22050	2.42
Mean	Sole pigeonpea	2267	-	2267	24133	13600	1.64
	Pearlmillet + pigeonpea	2067	900	3538#	37807	21590	2.14
t-Stat for mean Grain Equivalent Yield				30.10**			
Pigeon pea							
2011	Sole pigeonpea	1110	-	1110	36474	19974	2.21
	Pigeon pea + green gram	800	600	1419#	45445	28145	2.62
2012	Sole pigeonpea	800	-	800	32000	17440	2.19
	Pigeon pea + green gram	600	500	1300#	52000	35750	3.20
Mean	Sole pigeonpea	955	-	955	34237	18707	2.20
	Pigeon pea + green gram	700	550	1360#	48723	32082	2.91
t-Stat for mean Grain Equivalent Yield				12.13**			

Cotton							
2012	Sole cotton	1080	-	1080	48600	28370	2.23
	Cotton + green gram	1150	400	1449##	65150	44700	2.90
2013	Sole cotton	800	-	800	32000	7500	0.31
	Cotton + green gram	750	500	1375##	55000	29700	1.17
Mean	Sole cotton	940	-	940	40300	17935	1.27
	Cotton + green gram	950	450	1412##	60075	37200	2.04
t-Stat for mean Grain Equivalent Yield				13.92**			
Rabi sorghum							
2012	Rabi sorghum	1400	-	1400	8500	4700	2.20
	Rabi sorghum + safflower	1650	600	3702###	22500	14610	2.85
2013	Rabi sorghum	900	-	900	9000	5000	1.25
	Rabi sorghum + safflower	1100	300	1700###	17000	12600	2.86
Mean	Rabi sorghum	1150	-	1150	8750	4850	1.73
	Rabi sorghum + safflower	1375	450	2701###	19750	13605	2.85
t-Stat for mean Grain Equivalent Yield				35.08**			

Where # indicates pigeonpea equivalent yield, ##indicates cotton equivalent yield and ### indicates Rabi sorghum equivalent yield. Level of Significance **p=0.01

Table 5 : Productivity and profitability of intercropping systems in blacksoils of Nandurbar (Maharashtra)

Year	Cropping systems	Yield (kg/ha)		Soyabead Grain equivalent yield (kg/ha)	Gross income (₹/ha)	Net income (₹/ha)	BC Ratio
		Sole crop	Inter crop				
Soyabean							
2012	Sole soyabean	1175	-	1175	30550	16850	2.22
	Soyabean + pigeonpea	1025	310	1335	34710	20360	2.41
2013	Sole soyabean	1180	-	1180	30680	16530	2.17
	Soyabean + pigeonpea	920	820	1904	56120	37320	2.99
Mean	Sole soyabean	1178	-	1178	30619	16690	2.61
	Soyabean + pigeonpea	973	820	1620	45415	28840	2.70
t-Stat for mean Grain Equivalent Yield				14.65**			

Conclusions

The assessment studies on intercropping system in balck soils of Kurnool (Andhra Pradesh), Aurangabad and Nandurbar (Maharashtra) districts clearly indicated that foxtail millet + pigeonpea (5:1) in Yagantipalle of Kurnool district and pigeonpea + green gram (1:2) and soyabean + pigeonpea (3:1) systems in Auragabad and soyabean + pigeonpea (4:2) in Nandurbar districts of Maharashtra were found more stable and climate resilient in rainfed environment. Thus, intercropping offers solution to obtain higher yields per unit area, diversified food and reduced risk of crop failure under rainfed conditions.

References

ASharma A, Pujari BT, Suhas Yelchetty and Dharmaraj PS. 2004. Studies on pigeonpea based intercropping systems with small millets, Bajra and greengram under shallow black soils. Karnataka Journal of Agricultural Sciences, 17(3): 544-547.

Chandra A, Kandari LS, Payal KC, Maikhuri RK, Rao KS, Saxena KG. 2010 b. Conservation and Sustainable Management of Traditional Ecosystems in Garhwal Himalaya, India. New York Science Journal, 3(2):71-77.

Ghosh PK, Mohanty M, Bandyopadhyay KK, Painuli AK and Misra. 2006. Growth, competition, yields advantage and economics in soybean/pigeonpea intercropping system in semi-arid tropics of India. Field crop Research, 96 (1): 90-97.

Guggari AK and Kalaghatagi SB. 2005. Effect of fertilizer and biofertilizer on pearl millet (Pennisetum glaucum) and pigeonpea (Cajanus cajan) intercropping system under rainfed conditions. Indian Journal of Agronomy, 50(1): 24-26.

Singh H P, Sharma KD, Reddy GS, Sharma KL. 2004. Challenges and strategies of Dryland Agriculture. CSSA Special Publications American Society of Agronomy, 32: 67-92.

Jasna VK, Sukanya Som R, Roy burman, Padaria RN and Sharma JP. 2014. Socio Economicimpact of climate resilient technologies. International Journal of Agriculture and Food Science Technology, 5(3):185-190.

Kumar A and Rana K S. 2007. Performance of pigeonpea (Cajanus cajan) + greengram (Phaseolus radiatus) intercropping system as influenced by moisture-conservation practice and fertility level under rainfed conditions. Indian Journal of Agronamy, 52(1): 31-35.

Lakhena KK and Maurya BM. 2009. Intercropping of soybean and pigeonpea under rainfed condition. Mysore Journal of Agricultural Sciences, 43(2):369-373.

Sashidhara GB, Basavaraja R and Nadagouda VB. 2000. Studies on pigeonpea intercropping system in small millets under shallow red soils. Karnataka Journal of Agricultural Sciences, 13(1):7-10.

Subba Reddy G, Maruthi V and Vanaja M. 2004. Effect of soil depth on productivity of mungbean and pigeonpea under rainfed environment. Legume Res, (1): 1-10.

Received: December 2014; Accepted: April 2015