RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 58 Issue 2: 290-294 (April 2024)

Evaluation of Sorghum based Intercropping Systems for Rainfed Vertisols

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10.18805/IJARe.A-5934

ABSTRACT

Background: In Sri Potti Sriramulu Nellore district of Andhra Pradesh sorghum is a main *rabi* crop grown under rainfed conditions. Late or advancement of north east monsoon and prolonged breaks may have devastating effects on sorghum yield in rainfed areas of Sri Potti Sriramulu Nellore district, Andhra Pradesh even if the mean annual rainfall is normal. In this context, there is a need for intercropping systems with sorghum which are ideal even under changing climatic situations, so that farmers can meet out their basic needs of food and fodder.

Methods: A field experiment was conducted during *rabi*, 2018-19 and 2019-20 at Agricultural Research Station, Podalakur, Sri Potti Sriramulu Nellore, Andhra Pradesh, to find out the profitable sorghum based intercropping system for rainfed vertisols. The experiment was laid out in randomized block design with ten treatments each replicated thrice.

Result: Sorghum intercropped with blackgram in 2:2 ratio recorded highest sorghum equivalent yield (3539 kg ha^{-1}) and net return (Rs. 45645 ha^{-1}).

Key words: Aggressivity, Area time equivalent ratio, Intercropping, Land equivalent ratio, Sorghum equivalent yield, Sorghum.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important cereal in the world followed by wheat, rice, maize and barley and a major staple food crop of millions of people in the semi arid tropics. In India it ranks third after rice and wheat. It is mainly used for human consumption and also feed for cattle and poultry birds. In India, sorghum is cultivated over 11.0 mha producing 9.5 mt of grain with productivity of 850 kg ha^{-1}. In Andhra Pradesh, sorghum is grown in area of 1.41 L ha producing 2.27 Lt of grains with an average productivity of 1680 kg ha^{-1} during *rabi*.

Sri Potti Sriramulu Nellore district of Andhra Pradesh is mainly influenced by north-east monsoon and *rabi* is the main cropping season. A late or advancement of north east monsoon and prolonged breaks may have devastating effects on agriculture in rainfed areas of Sri Potti Sriramulu Nellore district, even if the mean annual rainfall is normal. However, this rational distribution of rainfall which affected crop growth and development, in turn reduced the sorghum productivity. In this context, there is a need for inter cropping systems with sorghum which are ideal even under changing climatic situations, so that farmers can meet out their basic needs of food and fodder.

Intercropping of cereal-legumes is widely practiced by small and marginal farmers under rainfed situation. Traditionally, this system of cropping aimed to improve efficiency of the available resources, improvement of soil fertility by legume components of the system, soil preservation through covering the bare land between the rows, reduction of biotic and abiotic risks by increasing diversity, suppression of weed infestation and to increase farm income from small holdings. Hence, this experiment was conducted to investigate profitable sorghum based intercropping system for rainfed vertisols of Sri Potti Sriramulu Nellore district.

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How to cite this article: Sujathamma, P. and Nedunchezhiyan, M. (2024). Evaluation of Sorghum based Intercropping Systems for Rainfed Vertisols. Indian Journal of Agricultural Research. 58(2): 290-294. doi: 10.18805/IJARe.A-5934.

Submitted: 16-10-2021 **Accepted:** 23-02-2022 **Online:** 30-03-2022

MATERIALS AND METHODS

The experiment was conducted during *rabi*, 2018-19 and 2019-20 at Agricultural Research Station, Podalakur (14°22′N latitude, 79°44′E longitude and 43 m above mean sea-level), Sri Potti Sriramulu Nellore district, Andhra Pradesh. The climatic condition of Sothern zone is sub-tropical influenced by north-east monsoon. The soils are clay loam in texture, porous and grayish black having pH of 8.48, EC of 0.229 dSm^{-1}, organic carbon 0.3%, available nitrogen 201 kg ha^{-1}, available phosphorus 46 kg $ha^{-1}$and available potassium 225 kg ha^{-1}. The field experiment was laid out in a randomized block design with 10 treatments each replicated thrice. The treatments were Sole crop of sorghum (T_1), Sole crop of blackgram (T_2), Sole crop of greengram (T_3), Sole crop of chickpea (T_4), 1:1 ratio of

sorghum and blackgram (T_5), 2:2 ratio of sorghum and blackgram (T_6), 1:1 ratio of sorghum and greengram (T_7), 2:2 ratio of sorghum and greengram (T_8), 1:1 ratio of sorghum and chickpea (T_9) and 2:2 ratio of sorghum and chickpea (T_{10}). Sorghum variety NJ 2647, blackgram variety TBG 104, greengram variety WGG 42 and chickpea variety NBeG-49 was used for the experiment. Sowings were done on 26-10-2018 and 09-10-2019 during 2018-19 and 2019-20, respectively. Sole sorghum was sown at 45 cm × 10 cm spacing (222222 plants ha^{-1}), whereas sole blackgram, greengram and chickpea were sown at 30 cm × 10 cm spacing (333333 plants ha^{-1}). Under intercropping of sorghum additive series was followed. In 1:1 ratio intercropping, sorghum was sown at 45 cm × 10 cm spacing, whereas intercrop (blackgram/ greengram/ chickpea) was sown in between two rows of sorghum at 10 cm plant to plant spacing. In 2:2 ratio intercropping, sorghum was sown in paired row at 30/45 cm × 10 cm spacing. Two rows of intercrop (blackgram/ greengram/ chickpea) was sown in between two paired rows of sorghum maintaining equival distance (20 cm) with plant to plant spacing of 10 cm. Thus, under 1:1 and 2:2 ratio intercropping, full population of sorghum and 222222 plants ha^{-1} of intercrop (blackgram/ greengram/ chickpea) were maintained. Gap filling and thinning were carried out at 15 DAS so as to maintain the required plant population.

The recommended dose of fertilizer @ 80:40:40 N, P_2O_5 and K_2O kg ha^{-1} were applied for sole sorghum and for inter cropping. The recommended dose of fertilizer @ 20:50 kg N and P_2O_5 kg ha^{-1} were applied for sole crops of blackgram, greengram and chickpea and 2/3rd of recommended dose under intercropping. Nitrogen, phosphorus and potassium were applied in the form of Urea, Single Super Phosphate and Muriate of Potash, respectively. Half of the nitrogen and entire quantity of P_2O_5 and K_2O was band placed at 5 cm deep and 5 cm away from the row as a basal dose and the remaining half of nitrogen was top dressed at 30 days after sowing for sorghum. Entire quantity of nitrogen and P_2O_5 were band placed at 5 cm deep and 5 cm away from the row as a basal to the pulse crops. The total rainfall of 290.3 mm was received in 10 rainy days during 2018-19 and 449.7 mm was received in 26 rainy days during 2019-20. Chickpea crop was severely affected in both the years due to high intensity rains.

Sorghum-equivalent yield (SEY) was calculated as:

$$SEY = \text{Sorghum grain yield (kg ha}^{-1}) + \frac{\text{Grain yeild of inter crop (kg ha}^{-1}) \times \text{Price kg}^{-1}}{\text{Price kg}^{-1} \text{ of sorghum grain}}$$

Land-equivalent ratio (LER) was calculated as suggested by Mead and Willey (1980).

$$\text{Land-equivalent ratio (LER)} = L_1 + L_2 = \frac{YI_1}{YS_1} + \frac{YI_2}{YS_2}$$

L_1 and L_2= LERs for the individual crops.
YI_1 and YI_2= Individual crop yields in inter cropping.
YS_1 and YS_2= Their yields as sole crops.

Aggressivity and area-time equivalent ratio (ATER) were calculated as per Mc Gilchrist (1965) and Hiebschand McCollum (1987), respectively.

RESULTS AND DISCUSSION

Grain yield

Grain yields of different component crops for both the years were presented in Table 1. Perusal of the data presented in Table 1, revealed that, grain yield of all the crops was higher during 2018-19 than 2019-20. This may be due to favourable weather during 2018-19 than 2019-20. Continuous rain after panicle emergence of sorghum and flowering of pulse crops during 2019-20 was severely affected crop yields. The grain yield of sorghum during the year 2018-19 was significantly higher in T_5. However, it was statistically on par with T_6, T_8 and T_7. During the year 2019-20, the grain yield of sorghum was significantly higher in T_6 and it was statistically on par with T_5. This indicated that sorghum intercropped with blackgram either in 2:2 or 1:1 ratio resulted in higher grain yield of sorghum than sole sorghum. This might be due to complemented effect of blackgram with sorghum because of growth requirement of both the crops differ in time, resulting in higher per day yield of the system due to temporal complemented effect and also owing to its increased addition of organic matter to the soil. In addition the organic matter might have increased the moisture and nutrient nutrition which favours the good growth of sorghum. Further, blackgram fixes atmospheric nitrogen in to the soil through root nodulation. This nitrogen is available to sorghum crop at later stages. The findings werein corroboration with the findings of Dai *et al*. (2019); Chen *et al.* (2018); Singh *et al.* (2020) and Choudhary and Choudhary (2016).

Among intercrops, blackgram recorded higher yield followed by green gram and chickpea (Table 1). This may be due to genetic potential of the crops. The chickpea yield under both sole and intercropping was very low (Table 1). The high intensity rain during crop growing period might be severely affected chickpea yield. In both the years, blackgram, greengram and chickpea yields were reduced to a considerable extent under intercropping compared to the respective sole crop yields (Table 1). This may be due to severe competition from sorghum for water and nutrients and also reduction of plant population of blackgram/ greengram/ chickpea under intercropping.

Sorghum-equivalent yield (SEY)

The (SEY) was higher in intercropping of sorghum with legumes as compared to sole crops of sorghum, blackgram, greengram and chickpea (Table 2). The treatment T_6 resulted in significantly higher SEY (3628 kg ha^{-1}). However, it was statistically on par with T_5 (3454 kg ha^{-1}). The treatments T_6 and T_5 registered 51.0 and 43.7% higher SEY respectively, than T_1 (sole sorghum) (Table 2). The higher SEY in these treatments was due to higher sorghum yield in addition to intercrop (blackgram) yield. Further, the

Table 1: Grain yield (kg ha^{-1}) of different component crops in sorghum based intercropping system.

Treatment	Sorghum		Blackgram		Greengram		Chickpea	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
T_1	2925	1881	-	-	-	-	-	-
T_2	-	-	1087	1066	-	-	-	-
T_3	-	-	-	-	957	123	-	-
T_4	-	-	-	-	-	-	224	52
T_5	3319	2168	208	307	-	-	-	-
T_6	3217	2205	281	359	-	-	-	-
T_7	3144	1405	-	-	124	23	-	-
T_8	3186	1786	-	-	124	41	-	-
T_9	2981	1859	-	-	-	-	85	20
T_{10}	3027	1808	-	-	-	-	91	32
SEm±	93	86	-	-	-	-	-	-
CD (P≤0.05)	272	254	-	-	-	-	-	-

Table 2: Sorghum equivalent grain yields (kg ha^{-1}) and net monetary returns (Rs ha^{-1}) as influenced by different treatments.

Treatment	Sorghum equivalent grain yield (kg ha^{-1})			Net monetary returns (Rsha^{-1})		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	2925	1881	2403	22020	16260	19140
T_2	3323	2730	3027	23337	29901	26619
T_3	3190	333	1762	20340	-28769	-4215
T_4	584	100	342	-30126	-38620	-34373
T_5	3954	2954	3454	41639	44645	43142
T_6	4130	3124	3628	44381	46909	45645
T_7	3557	2077	2817	34265	41402	37834
T_8	3600	1898	2749	34833	15410	25122
T_9	3204	1897	2551	25433	14512	19973
T_{10}	3263	1869	2566	26421	13227	19824
SEm±	114	101	118	-	-	-
CD (P≤0.05)	337	302	355	-	-	-

*During 2018-19, sale price of sorghum Rs 18 kg^{-1}, blackgram Rs 55 kg^{-1}, greengram Rs 60 kg^{-1} and chickpea Rs 47 kg^{-1}.

*During 2019-20, sale price of sorghum Rs 24.6 kg^{-1}, blackgram Rs 63 kg^{-1}, greengram Rs 68 kg^{-1} and chickpea Rs 47 kg^{-1}.

sale price of blackgram was higher than sorghum, which also led to higher SEY. Among intercrops, blackgram registered higher yield than other intercrops under intercropping (Table 2). Because of higher sale price and relatively higher yield, the treatment T_2 was found next best treatment. The treatment T_2 was recorded with 26.0% higher SEY than T_1. Intercropping greengram/ chickpea with sorghum recorded higher SEY than sole sorghum (T_1). The treatments T_7 and T_8 registered 17.2 and 14.4%higher SEY respectively, than T_1. Similarly, the treatments T_{10} and T_9 registered 6.8 and 6.2% higher SEY respectively, than T_1. Similar findings were reported by Biru *et al.* (2004), Kumar *et al.* (2011) and Ajit Panhale *et al.* (2016).

Net monetary returns

Net monetary returns (Rs ha^{-1}) were influenced by treatments during both the years of investigation (Table 2). All sorghum based intercropping systems proved their superiority than sole crops. The highest net monetary returns were recorded with T_6 (Rs 45645 ha^{-1}) and it was followed by T_5 (Rs 43142 ha^{-1}) and T_7 (Rs 37834 ha^{-1}) (Table 2). The treatments T_6, T_5 and T_7 resulted in 138.5, 125.4 and 97.7% higher net return respectively than T_1. This might be due to higher SEY in these treatments. Similar results were reported by Angadi *et al.* (2004). Net return from T_2 was the next best treatment (Table 2). This was because of higher yield and sale price of blackgram. Net return from T_8, T_9 and T_{10} was also higher than T_1 (Table 2). This indicated that intercropping in sorghum was more profitable than sole sorghum cultivation. Abdel-Wahab and Abdel-Wahab (2021) reported that higher economic returns realized when faba bean was included as intercrop in flax.

Land equivalent ratio (LER)

The LER values in different intercropping systems were greater than unity, indicating the yield advantage from intercropping systems. Among the intercropping systems, T_{10} recorded the highest LER and it was followed by T_9. Kumar *et al.* (2005) and Binoy Chhetri and Sinha (2020) also reported that LER was found more than 1 in all the

Table 3: Effect of sorghum based intercropping on different competition indices.

Treatment	LER			ATER			Aggressivity			
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19		2019-20	
							Sorghum	Intercrop	Sorghum	Intercrop
T_5	1.33	1.44	1.29	1.279	1.369	1.26	0.944	-0.944	0.865	-0.865
T_6	1.36	1.51	1.31	1.294	1.425	1.27	0.421	-0.421	0.471	-0.471
T_7	1.21	0.93	1.14	1.153	0.859	1.03	0.945	-0.945	0.560	-0.560
T_8	1.22	1.28	1.36	1.167	1.149	1.19	0.480	-0.480	0.308	-0.308
T_9	1.40	1.37	1.40	1.349	1.326	1.35	0.640	-0.640	0.603	-0.603
T_{10}	1.44	1.58	1.52	1.396	1.530	1.47	0.314	-0.314	0.173	-0.173

intercropping systems and the maximum LER in maize + cowpea (2:2) intercropping system compared to the 1:1 and 1:2 ratio. However, LER did not reflect absolute level of yield, but it was considered as an important variable for the yield target of an intercropping study (Sharma and Behera, 2009).

Area time equivalent ratio (ATER)

The ATER was also greater than unity in all the cases of intercropping systems. The 2:2 row ratio combination (T_6, T_8 and T_{10}) has recorded higher ATER values, which appeared to be advantageous and indicated higher productivity in comparison to 1:1 row ratio combination (T_5, T_7 and T_9). This was owing to greater resource use and resources complementarily when inter crops grown in 2:2 row ratio. The highest ATER values of the system established that growth requirement of both the crops differ in time, resulting in higher per day yield of the system due to temporal complemented effect. The highest ATER values recorded with T_{10}. Kheroar and Patra (2014) also reported that 2:2 maize blackgram intercropping system recorded the highest ATER value that was achieved owing to development of spacial complementarities. Anishetra and Kalaghatagi (2021) also reported that higher ATER was recorded in sesame+foxtail millet in 2:4 row proportions.

Aggressivity

The competitive ability of sorghum, blackgram, greengram and chickpea was also estimated through aggressivity. The results showed that the variation of aggressivity depended on the configuration of the intercropping systems (Table 3). The aggressivity values indicated that sorghum dominated the blackgram, greengram and chickpea in both the row ratios tested (Table 3). Aggressivity values were positive (+ve) in sorghum which obviously indicated the sorghum was the dominant crop, where the associated intercrops *viz*., blackgram, greengram and chickpea appeared to be the dominated ones having negative (-ve) values (Table 3). Between the two spatial arrangements, 1:1 intercropping (T_5, T_7 and T_9) resulted in higher values of aggressivity, which denoted higher interspecific competition. Among all the intercropping systems, T_{10} recorded the lowest values of aggressivity. Sharma *et al.* (2006) reported that maize intercropped with cowpea and rice bean (2:1) was found to be a compatible intercropping system with lower values of aggressivity.

CONCLUSION

The present investigation revealed that, the yield and monetary advantages were higher in intercropping of sorghum with legumes (blackgram, greengram and chickpea) as compared to sole crops of sorghum. For rainfed vertisols 2:2 or 1:1 ratio of sorghum and blackgram are the profitable sorghum based intercropping systems, than greengram and chickpea either in 1: 1 ratio or 2:2 ratio.

Conflict of interest

The authors declare no conflict of interest.

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