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Promising Chickpea based Cropping Systems for Vertisols of Andhra Pradesh

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ABSTRACT

Background: The promising cropping system over the years in vertisols of Andhra Pradesh is fallow- chickpea and the yields and profits were declining gradually. Farmers were switched over to double cropping system with *kharif* cereals before chickpea cultivation. Most of the farmers burnt the preceding crop residues which lead to harmful effects on soil flora and air pollution. Preceding crop residues incorporation will improve the soil moisture content, soil carbon content and stabilize the yields of chickpea and system productivity. The present study was conducted to study the impact of crop residues on system productivity and to find suitable cropping system.

Methods: Field experiments were conducted during *Kharif* and *rabi* seasons of 2018-19 and 2019-20 with split- split plot design and replicated thrice.

Result: Foxtail millet-chickpea cropping system recorded higher chickpea equivalent yields, during both years of investigation followed by greengram-chickpea cropping system. Greengram-chickpea cropping system recorded high production use efficiency (48 and 69 kg ha^{-1} in 2018-19 and 2019-20 respectively) followed by foxtail millet-chickpea (43 and 61 kg ha^{-1} in 2018-19 and 2019-20 respectively). By the end of the year of experimentation, greengram-chickpea cropping system showed higher values of SYI, due to higher organic carbon and added biological nitrogen than foxtail millet-chickpea cropping system.

Key words: Chickpea equivalent yields, Cropping system, LUE, PE, SYI.

INTRODUCTION

Now in India farmers concentrate mainly on monocropping system which is subjected to high degree of income and can decrease system productivity, reduction in profitability and declining in soil health. Continuous use of chemical fertilizers in intensive cropping system leads to imbalance of nutrients in soil, which has adverse effect on soil health and also on crop yields (Hashim *et al.* 2015). Inclusion of legumes and cereals in cropping system have advantage beyond N addition, recycling from soil layers, minimizing soil compaction, protecting soil from erosion, increasing soil organic matter through root biomass and leaf fall and minimizing the harmful allopathic effects (Jain *et al.* 2015).

In vertisols of scarce rainfall zone of Andhra Pradesh with unimodel distribution of rainfall mainly during *kharif* season, chickpea is grown as a *rabi* crop based on residual soil moisture. The promising cropping system over the years in this area is fallow- chickpea or cereal-chickpea, particularly with maize/foxtail millet-chickpea cropping system. From point of view of biological value and protein efficiency, pulse-chickpea cropping system provides better nutritional standards, sustain yields and soil fertility

The chickpea area in Andhra Pradesh under double cropping system is increasing recently due to higher yields and profits within short crop growing period by exploiting residual moisture. Since very little scope exists for horizontal growth the alternative seems by achieving vertical growth through increasing its productivity level. Under double cropping system, preceiding crop residues can incorporate to sustain the soil moisture which is the key factor to improve soil moisture content and organic carbon content of the soil as chickpea is mostly grown in residual moisture condition which decides the yields and returns.

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MATERIALS AND METHODS

Field experiments were carried out for two consecutive *kharif* and *rabi* seasons for the year 2018-19 and 2019-20 at R.A.R.S. Farm, Nandyal, Andhra Pradesh. The treatments comprised of three crop residue incorporations *viz.,* foxtail millet, (C_1) greengram(C_2) and fallow(C_3) as main plot treatments and four times of sowing *viz.* October 2nd FN (D_1), November 1st FN (D_2), November 2nd FN (D_3) and December 1st FN (D_4) as sub plot treatments and three irrigation schedules as sub- sub plots with irrigation at pre-flowering stage (I_1), irrigation at pod development stage (I_2) and irrigation at pre-flowering and pod development stage (I_3)

During *kharif* season, foxtail millet and greengram crops were raised as bulk crops in respective main plots and crop residues were incorporated after harvest of economic parts *viz.*, panicles of foxtail millet and pods of greengram. Experimental design was split-split plot, with three replications.

The site was situated at an altitude of 216 m above mean sea level at 15°29′19″ N latitude and 78° 29′11″ E longitude, mostly under rainfed conditions, categorized in the scarce rainfall agro-climatic zone of Andhra Pradesh. The meteorological data of maximum and minimum temperature, rainfall, number of rainy days, morning and evening relative humidity and wind speed were recorded from meteorological observatory, Regional Agricultural Research Station, Nandyal near the experimental site, during the period of crop growth. Soil of the site was medium in fertility and slightly saline in reaction having pH 8.42, electrical conductivity 0.24 dSm^{-1}, organic carbon 0.32% with available nitrogen, phosphorus and potassium 143, 53 and 451 kg/ha, respectively. Sowing of seeds was done in rows, 30 cm apart with 10 cm between plants. An amount of 20 kg nitrogen and 50 kg P_2O_5 per hectare was applied through urea and SSP as basal. Sowing was done in four intervals as D_1 on October 2nd fortnight, D_2 on November 1st fortnight, D_3 on November 2nd fortnight, D_4 on December 1st fortnight, in respective treatment plots. Healthy and matured seeds of desi chickpea variety NBeG-3 having high germination percentage were used for sowing. Seed rate @ 50 kg ha^{-1} was adopted and sown in the open furrows made with the help of hand hoe. The seeds were dropped to a depth of 5 cm and covered thoroughly. System productivity indicators, land use efficiency, production efficiency, sustainable yield index equivalent yields and economics were calculated based on standard formulas:

Land use efficiency

Land use efficiency of cropping system was calculated by using the following formula and expressed in percentage.

Land use efficiency (%) =

$$\frac{\text{Duration of crops in a year}}{365} \times 100$$

Production efficiency

Production efficiency of cropping system was calculated by using the following formula and expressed in kg ha^{-1} day^{-1}) based on chickpea equivalence yields.

Production efficiency (kg ha^{-1} day^{-1}) =

$$\frac{\text{Total production of a system}}{\text{Total duration of the cropping system}}$$

Sustainable yield index

The sustainable yield index for foxtail millet / greengram – chickpea cropping system was worked out by the formula given by Tomar and Tiwari (1990) based on chickpea equivalence yields.

YI =

$$\frac{\text{Mean chickpea equivalence yields of cropping system - Standard daviation of chickpea equivalence yields}}{\text{Maximum chickpea equivalence yields of cropping system}}$$

Equivalent yields and economics

The seed yield of the *kharif* crops was converted in to chickpea equivalents on the basis of price of seed of *kharif* crops involved in the cropping system.

The total cost of cultivation of double cropping system (ha^{-1}) was calculated for each treatment on the basis of input cost of both the seasons. Gross returns (ha^{-1}) was computed by considering the prevailing market price of the outputs. Net return (ha^{-1}) were arrived by deducting the cost of cultivation from gross returns of corresponding cropping system. Cost benefit ratio was worked out for each system.

RESULTS AND DISCUSSION

Cropping system equivalent yields and economics

System productivity was estimated by converting foxtail millet and green gram yields into to chickpea equivalent yields and presented in Table 1 and outline indicates that foxtail millet - chickpea cropping system recorded higher chickpea equivalent yields, during both years of investigation followed by greengram - chickpea cropping system. Fallow - chickpea cropping system recorded lower values of chickpea equivalent yields in both years of study.

Cropping system cost of cultivation, gross and net returns and benefit cost ratio was calculated for all treatments for both years of study and presented in Fig. 1 and 2). Gross and net returns were highest with foxtail millet-chickpea cropping system followed by greengram - chickpea cropping system. Minimum returns were obtained when fallow-chickpea system adopted.

Under rainfed condition cultivation of foxtail millet / greengram in *kharif* season and incorporation of their residues before chickpea sowing effect on productivity and profitability of cropping system instead of fallow chickpea in vertisols. The same line of results was reported by Amgain *et al.* (2013).

Land use efficiency (LUE) (%)

Land use efficiency (%) of different chickpea based cropping systems under study was calculated and mean values were shown in Table 2. The data indicated that both foxtail millet -chickpea and greengram-chickpea cropping system increased the LUE by 20-25 per cent over fallow- chickpea cropping system in all four times of sowing. Hence, under rainfed vertisols foxtail millet-chickpea (46%) and greengram -chickpea (45.5%) was found suitable cropping system with high land use efficiency. similar line of results were reported by Dudhra *et al.* (2002).

Production efficiency

Production efficiency of three chickpea based cropping systems under different time of sowing were worked out and presented in Table 1. The data indicated that greengram - chickpea cropping system recorded high production use efficiency (48 and 69 kg ha^{-1} in 2018-19 and 2019-20 respectively) followed by foxtail millet-chickpea (43 and 61 kg ha^{-1} in 2018-19 and 2019-20 respectively) cropping system during both years of study. Fallow-chickpea cropping system recorded lower values in all four *rabi* chickpea sowing time.

These results indicated that greengram - chickpea and foxtail millet - chickpea were more productive systems under double cropping systems in vertisols of Andhra Pradesh. Pacharne *et al.* (2018) also reported that groundnut- onion cropping system recorded significantly maximum total productivity, production use efficiency, economic efficiency and maximum monetary returns when compared with groundnut- wheat/ groundnut- chickpea cropping system.

Sustainable yield index

The sustainable yield index values calculated for different treatments of foxtail millet / greengram-chickpea cropping system clearly showed the yield sustainability with crop residue incorporations and time of sowing of chickpea crop (Table 1).

The sustainable yield index values were higher during second year of study due to adequate rains, which helped in better decomposition of incorporated residues. By the end

Table 1: Chickpea equivalent yield of foxtail millet/greengram - chickpea double cropping system.

Treatments	2018-19				2019-20			
	Foxtail millet	Greengram	Chickpea	*CEY	Foxtail millet	Greengram	Chickpea	*CEY
$C_1D_1I_1$	1798	-	992	1639	1871	-	1576	2926
$C_1D_1I_2$	1789	-	1076	1720	1859	-	1738	2908
$C_1D_1I_3$	1795	-	1461	2107	1872	-	2170	2928
$C_1D_2I_1$	1792	-	1128	1773	1855	-	1942	2955
$C_1D_2I_2$	1785	-	1321	1964	1870	-	2138	2922
$C_1D_2I_3$	1789	-	1951	2595	1866	-	2514	2956
$C_1D_3I_1$	1779	-	914	1554	1889	-	1681	2901
$C_1D_3I_2$	1791	-	1192	1837	1868	-	1838	2925
$C_1D_3I_3$	1788	-	1797	2441	1890	-	2163	2919
$C_1D_4I_1$	1779	-	656	1296	1879	-	1115	2939
$C_1D_4I_2$	1789	-	870	1514	1855	-	1504	2901
$C_1D_4I_3$	1787	-	1391	2034	1874	-	2020	2931
$C_2D_1I_1$	-	534	836	1498	-	783	1602	2847
$C_2D_1I_2$	-	539	960	1628	-	785	1814	3062
$C_2D_1I_3$	-	536	1547	2212	-	791	2081	3338
$C_2D_2I_1$	-	549	987	1668	-	783	1960	3205
$C_2D_2I_2$	-	537	1126	1792	-	790	1951	3207
$C_2D_2I_3$	-	539	1798	2466	-	778	2374	3611
$C_2D_3I_1$	-	542	944	1616	-	785	1722	2970
$C_2D_3I_2$	-	536	1037	1702	-	793	2007	3268
$C_2D_3I_3$	-	541	1643	2314	-	779	2098	3336
$C_2D_4I_1$	-	540	614	1284	-	792	1043	2302
$C_2D_4I_2$	-	538	744	1411	-	776	1404	2638
$C_2D_4I_3$	-	546	1461	2138	-	779	1882	3120
$C_3D_1I_1$	-	-	541	541	-	-	1162	1162
$C_3D_1I_2$	-	-	628	628	-	-	1437	1437
$C_3D_1I_3$	-	-	1357	1357	-	-	1723	1723
$C_3D_2I_1$	-	-	792	792	-	-	1384	1384
$C_3D_2I_2$	-	-	1035	1035	-	-	1365	1365
$C_3D_2I_3$	-	-	1583	1583	-	-	1985	1985
$C_3D_3I_1$	-	-	680	680	-	-	1196	1196
$C_3D_3I_2$	-	-	934	934	-	-	1234	1234
$C_3D_3I_3$	-	-	1475	1475	-	-	1990	1990
$C_3D_4I_1$	-	-	566	566	-	-	953	953
$C_3D_4I_2$	-	-	889	889	-	-	1166	1166
$C_3D_4I_3$	-	-	1224	1224	-	-	1770	1770

*CEY: Chickpea equivalent yield.

of the year of experimentation, greengram-chickpea cropping system showed higher values of SYI, due to higher organic carbon and added biological nitrogen. The lower SYI values were with fallow-chickpea cropping system, due to single season yields.

Soil carbon sequestration

Data on soil carbon content at different crop growth stages were calculated and shown in Table 3. After crop residue incorporation, when the sowing of *rabi* chickpea delayed from October to December, the soil organic carbon pool increased, however, the chickpea seed yield was not proportional to soil organic pool due to crop weather relations.

The soil organic content during the crop period of chickpea indicated that crop residues incorporation treatments significantly influenced the soil carbon sequestration only during *rabi* 2019-20, but not by time of sowing and irrigation treatments. Maximum soil carbon

Table 2: Land use efficiency (LUE), production efficiency (PE) and sustainable yield index (SYI) of different chickpea based cropping systems under different times of sowing.

Treatments	LUE (%)		P E (kg ha^{-1} day^{-1})		SYI	
	Rabi, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019
Foxtail millet-chickpea cropping system						
FM- chickpea October 2nd FN sowing	48	47	40	57	0.49	0.58
FM- chickpea November 1st FN sowing	46	47	47	67	0.60	0.60
FM- chickpea November 2nd FN sowing	47	47	44	61	0.53	0.59
FM- chickpea December 1st FN sowing	45	45	40	58	0.41	0.58
Mean	46	46	43	61	0.51	0.59
Greengram-chickpea cropping system						
GG- chickpea October 2nd FN sowing	47	46	47	63	0.47	0.63
GG- chickpea November 1st FN sowing	45	46	52	75	0.55	0.71
GG- chickpea November 2nd FN sowing	45	46	50	73	0.51	0.66
GG- chickpea December 1st FN sowing	44	44	44	67	0.48	0.52
Mean	45	46	48	69	0.50	0.63
Fallow-chickpea cropping system						
Fallow- chickpea October 2nd FN sowing	29	28	15	26	0.12	0.18
Fallow- chickpea November 1st FN sowing	27	28	21	30	0.22	0.22
Fallow- chickpea November 2nd FN sowing	27	28	19	27	0.18	0.18
Fallow- chickpea December 1st FN sowing	25	25	18	25	0.18	0.14
Mean	27	27	18	27	0.18	0.18

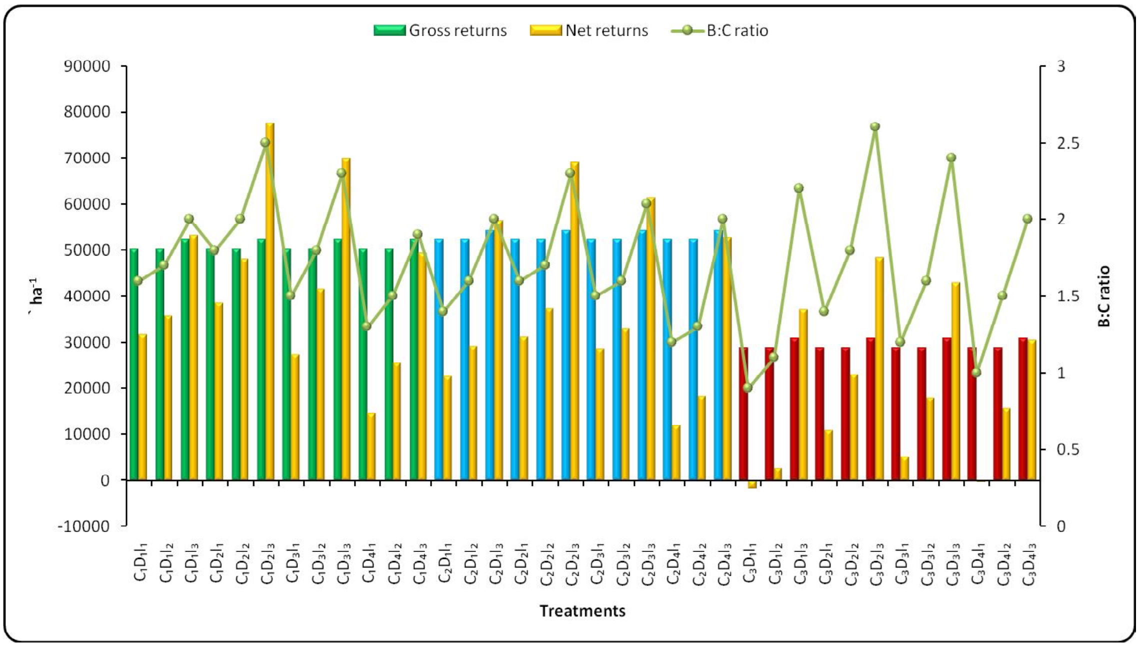

Fig 1: Economics of chickpea based cropping systems 2018-19.

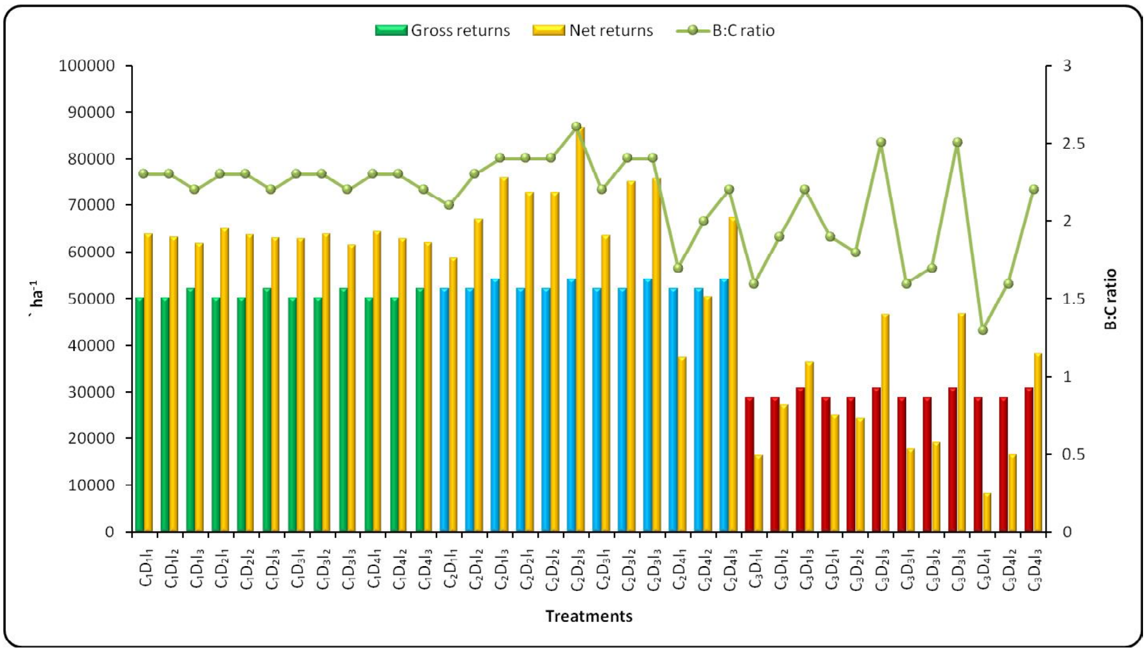

Fig 2: Economics of chickpea based cropping systems 2019-20.

Table 3: Soil carbon sequestration (t ha^{-1}) in chickpea field as influenced by crop residue incorporation, time of sowing and irrigation.

Treatments	30 DAS		60 DAS		At harvest	
	Rabi, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019
Crop residue incorporation						
C_1: Foxtail millet	6.16	6.37	6.37	7.12	6.37	9.93
C_2: Greengram	5.81	6.18	6.18	6.93	6.36	9.18
C_3: Fallow	6.18	6.06	6.15	5.62	6.18	6.18
SEm ±	0.263	0.319	0.353	0.223	0.278	0.292
CD (P = 0.05)	NS	NS	NS	0.64	NS	0.87
Time of sowing						
D_1: October 2nd FN	6.18	6.37	6.18	6.75	5.81	6.93
D_2: November 1st FN	6.06	6.18	6.75	6.93	7.12	8.25
D_3: November 2nd FN	6.18	6.56	6.37	6.75	6.56	7.31
D_4: December 1st FN	5.81	5.81	6.01	6.73	6.05	6.93
SEm ±	0.153	0.209	0.271	0.179	0.187	0.198
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Time of Irrigation						
I_1: Irrigation at pre-flowering stage	6.56	6.75	6.75	6.93	6.93	7.31
I_2: Irrigation at pod development stage	6.00	6.37	6.18	6.56	6.37	6.93
I_3: Irrigation at pre-flowering and poddevelopment stage	6.93	6.75	6.75	6.56	6.18	7.68
SEm ±	0.075	0.093	0.085	0.092	0.102	0.082
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
C × D						
SEm ±	0.272	0.325	0.177	0.823	0.723	0.257
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
C × I						
SEm ±	0.305	0.256	0.211	0.429	0.362	0.606
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
D × I						
SEm ±	0.421	0.309	0.615	0.633	0.301	0.326
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
C × D × I						
SEm ±	0.386	0.492	0.312	0.531	0.621	0.415
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

content was recorded with foxtail millet crop residue incorporation 7.19 (t ha^{-1}) and 9.93 t ha^{-1} at 60 DAS and at harvest stages, respectively and on par with greengram crop residue incorporation values of 6.93 t ha^{-1} and 9.18 t ha^{-1}. Significantly lower values were recorded with fallow-chickpea treatment.

Application of crop residues for two consecutive years improved the soil carbon content and showed positive response on chickpea crop growth and yield. This shows that crop residue incorporation technique is an important synergistic cultural practice to promote the way to mitigate the increased carbon content of the environment. Varalakshmi *et al.* (2005) also reported higher organic carbon content in groundnut- wheat cropping system.

CONCLUSION

In a nutshell, by the end of the experiment, greengram - chickpea cropping system had greater SYI values than foxtail millet-chickpea cropping system, owing to higher organic carbon and added biological nitrogen. Due to single-season yields, the fallow - chickpea cropping system had lower SYI values. Gross and net returns, as well as the B:C ratio, were higher with the foxtail millet-chickpea cropping system than with the greengram-chickpea cropping system on an equivalent yield basis. When using a fallow-chickpea system, the lowest returns were obtained. In the rainfed vertisols of Andhra Pradesh, double cropping systems combined with crop residue incorporation techniques have proven to be a crucial synergistic cultural practice and ideal productive cropping systems in light of changing climate.

Conflict of interest: None.

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