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DIVERSIFICATION OF RICE (*ORYZA SATIVA* L.) BASED CROPPING SYSTEMS FOR HIGHER PRODUCTIVITY IN NORTH COASTAL ZONE OF ANDHRA PRADESH

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ABSTRACT
Field investigation was conducted at Agricultural College Farm, Naira on sandy clay loam soil during pre *kharif*, *kharif* and *rabi* 2012-2013. The experiment was laid out in randomized block design, with four replications and seven cropping systems. Sunnhemp, greengram, blackgram, sesame, clusterbean and bhendi during pre *kharif*, rice during *kharif* and rice fallow blackgram during *rabi* were tried. Sunnhemp as pre *kharif* crop has produced significantly highest crop residues on fresh weight basis (30.11 t ha^{-1}) and dry matter (13096 kg ha^{-1}) than other pre *kharif* crops while clusterbean was significantly inferior for both crop residues on fresh weight basis (1.16 t ha^{-1}) and dry matter (446 kg ha^{-1}). Incorporation of different crop residues significantly altered the growth and development of *kharif* rice. Crop residue incorporation of sunnhemp produced significantly highest dry matter production at harvest (14455 kg ha^{-1}), panicles m^{-2} (265), filled grains $panicle^{-1}$ (128), 1000 grain weight (24.33 g) and yield (6501 kg ha^{-1}) of *kharif* rice followed by greengram while lowest dry matter production at harvest (7754 kg ha^{-1}), panicles m^{-2} (204), filled grains $panicle^{-1}$ (100), 1000 grain weight (21.95 g) and yield (4125 kg ha^{-1}) was recorded with that of fallow. Post harvest soil OC (0.39%), available nitrogen (215.33 kg ha^{-1}), available phosphorus (20.83 kg ha^{-1}) and available potassium (256.99 kg ha^{-1}) improved with sunnhemp crop residue incorporation. Seed (382 kg ha^{-1}) and haulm (743 kg ha^{-1}) yield of rice fallow blackgram was found to be significantly superior with incorporation of sunnhemp crop residue while inferior seed and haulm was with fallow (225 and 462 kg ha^{-1} respectively). Productivity was the highest with bhendi-rice-rice fallow blackgram (9265 kg ha^{-1}), while sunnhemp improved both rice and rice fallow blackgram yields and hence sunnhemp -rice-rice fallow blackgram was suggested for North Coastal Zone of Andhra Pradesh.

INTRODUCTION

Green revolution has increased food grain production manifold with the use of fertilizer responsive high yielding varieties. Intensive agriculture involving exhaustive high-yielding varieties has led to heavy withdrawal of nutrients from the soil. Furthermore, imbalanced use of inorganic fertilizers deteriorated the soil health and can be met by greater and more efficient of fertilizers and organic sources (Sahu *et al.*, 2014). Hence, alternatives to chemical fertilizers such as crop residues/organic manures might be better option to meet fertilizer N requirement of successive crops in the cropping system. Cereal based cropping system is highly nutrient exhaustive resulting in negative N balances in the soil. Hence, crops which can improve the fertility status should be included in the cropping systems. Rice based cropping system (RBCS) is the most predominant in North Coastal Zone of Andhra Pradesh. However, the average productivity of rice in this zone is still hovering around 3 t ha^{-1} resulting in lower productivity of this system. Internalization of short duration pre *kharif* crops in RBCS supplements N need of the succeeding crop besides improving soil fertility. Induction of green manuring (dhiancha) and leguminous crops in the existing rice based cropping system can improve the soil fertility and crops productivity on sustainable basis (Ali *et al.*, 2012). So, diversification and intensification has been envisaged as a new strategy for enhancing and stabilizing productivity and economic security toward achieving the sustainable agricultural development (Bastia *et al.*, 2008 and Prasad *et al.*, 2013).

In North Coastal Districts, summer showers generally start from the beginning of May and fair amount of rainfall occurs during May to August. As rice transplanting extends till the end of August leaving around 80-90 days period, which is sufficient to take up a short duration crop preceding to rice. *Kharif* rice is followed by rice fallow blackgram during *rabi*. Research work done elsewhere in India has shown encouraging results of improved productivity by accommodating a short duration crop preceding to *kharif* rice (Kumari and Reddy, 2010). In the light of the prospective situation, the main objective of this study is to identify suitable pre *kharif* crop and its effect on succeeding *kharif* rice, *rabi* rice fallow blackgram and system productivity.

MATERIALS AND METHODS

Experimental site and Treatments

A field experiment was conducted during pre *kharif, kharif* and *rabi* 2012-13 at the Agricultural College Farm, Naira, Andhra Pradesh which is situated at 18.24°N latitude, 83.84°

E longitude and at an altitude of 27 m above the mean sea level. The experimental soil was sandy clay loam in texture with a pH of 7.55 and EC of 0.27 dSm^{-1}, low in organic carbon (0.24%), available nitrogen (175 kg ha^{-1}) and available phosphorus (17.5 kg ha^{-1}) and medium in available potassium (219 kg ha^{-1}). A total of 1030.8 mm rainfall was received during the cropping period. The experiment was laid out in randomized block design with four replications and seven cropping systems *viz*.,

T_1: Fallow-rice-rice fallow blackgram,

T_2: Sunnhemp-rice-rice fallow blackgram,

T_3: Greengram-rice-rice fallow blackgram,

T_4: Blackgram-rice-rice fallow blackgram,

T_5: Sesame-rice-rice fallow blackgram,

T_6: Clusterbean-rice-rice fallow blackgram and

T_7: Bhendi-rice-rice fallow blackgram.

Sunnhemp, greengram, blackgram, sesame, clusterbean and bhendi during pre *kharif*, rice during *kharif* and rice fallow blackgram during *rabi* were tried.

Pre *kharif* crops

Pre *kharif* crops were sown on May 26th 2012. The seeds of all pre *kharif* crops were sown by hand dibbling with spacing of 30 X 10 cm for all crops except for bhendi which was sown at 45 X 20 cm. The recommended dose of fertilizers was applied for sunnhemp (0-25-25), greengram (20-50-0), blackgram (20-50-0), sesame (40-20-20), clusterbean (30-60-60) and bhendi (120-60-60) $N-P_2O_5-K_2O$ kg ha^{-1} respectively. Nitrogen in the form of Urea, phosphorus in the form of SSP and potassium in the form of MOP was applied. Sunnhemp was grown as pre *kharif* crop for green matter purpose. Immediately after the last picking of economic yield of respective crops at 83 DAS, plants were cut to the base of stem and weight of six crop residues were recorded on fresh weight basis. All the pre *kharif* crop residues were incorporated *in situ* seven days prior to transplanting of rice.

***Kharif* rice**

Thirty day old seedlings were transplanted on August 24th 2012 at a spacing of 20 X 15 cm using two seedlings per hill. The recommended dose of fertilizers for rice (80 N, 60 P_2O_5 and 50 K_2O kg ha^{-1}) were applied uniformly to all the treatments. Nitrogen in the form of urea was applied in three equal split doses *i.e.* at planting, active tillering and panicle initiation stage. Phosphorus in the form of single super phosphate was applied as basal at the time of final puddling for fast decomposition of green biomass of pre *kharif* crops. Potash in the form of muriate of potash was applied in two equal splits once at planting and another at panicle initiation. The harvesting of rice was done on December 8th 2012.

***Rabi* rice fallow blackgram**

The sprouted seeds of blackgram were broadcasted in the standing rice crop on December 4th 2012 and were raised using the residual fertility. The harvesting of blackgram was done on February 27th 2013.

Growth parameters, yield attributes and yield

Five plants from destructive sampling area *i.e* second outermost row in border were cut randomly at harvest and the plants were shade dried and then oven dried at 60°C till a constant weight was obtained. The number of filled grains and 1000 grain weight from ten randomly tagged panicles were counted, averaged and expressed as number of filled grains $panicle^{-1}$. Grain yield of rice and pod yield of blackgram from the net plot was weighed and expressed in kg ha^{-1}. Straw and haulm yield obtained after threshing from net plot was thoroughly sun dried to a constant weight and expressed in kg ha^{-1}. The productivity of different cropping systems was compared by calculating their economic rice equivalent yield (REY) using formula given by Ahlawat and Sharma (1993), where:

$$\text{REY (kg ha}^{-1}) = \frac{\text{Grain yield of test crop (kg ha}^{-1}) \text{ X Grain price of test crop (Rs kg}^{-1})}{\text{Price of rice grain (Rs kg}^{-1})}$$

Post harvest soil fertility status

Soil samples were drawn from 0-30 cm depth in each treatment after harvest of *kharif* rice. Treatment wise soil organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.,* 1954) and available potassium (Jackson, 1973) was analysed.

Economics study

The cost of cultivation, calculated on existing input cost and economic value of different crop produce, based on market price (Table 1). Gross returns were computed by considering prevailing market price of the produce. Net return was calculated by subtracting cost of cultivation from gross value of the produce, including byproduct value. The benefit:cost ratio (BCR) was worked out dividing net return by the cost of cultivation.

Statistical analysis

The data on crop residues and dry matter production of pre *kharif* crops, growth parameters, yield attributes and yield of rice and yield and dry matter production of rice fallow blackgram, system productivity, total dry matter production of cropping system and economics were recorded and subjected to statistical analysis as per Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Crop residues and dry matter production at harvest of pre *kharif* crops

The highest quantity of crop residue and dry matter production at harvest (Table 2 and Table 7) was produced by sunnhemp (T_2) which was significantly superior to any of the pre *kharif* crops taken for the study. Crop residue and dry matter production at harvest with Clusterbean (T_6) was in lowest quantity and hence was inferior to all other crops in the treatments. With the advent of monsoon showers, sunnhemp has produced larger quantities of above ground biomass. Least above ground biomass of clusterbean could be attributed to the continuous rains received during the crop growth period leading to heavy leaf loss and thereby the lower shoot growth. The production of variable amounts of biomass by pre *kharif* crops could be attributed to the genetic characteristics of species and their fitness to particular agro-climatic conditions as reported by Zahir Shah *et al*. (2011).

Effect of pre *kharif* crops on succeeding rice

The highest dry matter (Table 3) of rice at harvest was recorded with crop residue incorporation of sunnhemp (T_2) which was significantly superior to rest of the pre *kharif* treatments. Number of panicles m^{-2} at harvest, number of filled grains $panicle^{-1}$ and thousand grain weight (Table 3) of rice increased with sunnhemp (T_2), which was significantly higher than that of remaining treatments. The lowest dry matter production at harvest, number of panicles m^{-2}, number of filled grains $panicle^{-1}$ and thousand grain weight of rice was observed with fallow (T_1) than all the preceding crops. Increase in dry matter production due to incorporation of crop residue of sunnhemp may be ascribed to its fast decomposition rate, huge quantity of its residue and synchronized availability of major plant nutrients, especially that of nitrogen to the crop for a longer period essential for the growth of rice. Panicles m^{-2} were highest with sunnhemp as the continuous supply of nutrients during the entire cropping period under this treatment facilitated in conversion of more number of total tillers to productive tillers. Sunnhemp has recorded highest filled grains $panicle^{-1}$ which might be due to more number of total grains $panicle^{-1}$ and lower sterility facilitated through favourable supply of nutrients and thereby better performance over other preceding crops. Studies by Bastia *et al*. (2008), Kumari and Reddy (2009) and Deshpande and Devasenapathy (2011) were in conformity with the present findings.

Table 1: Cost/Price (Rs kg^{-1}) of inputs and output of the experiment

Input	Seed cost (Rs kg^{-1})	Price (Rs kg^{-1})
Sunnhemp seed	30	-
Greengram seed	60	40
Blackgram seed	70	35.5
Sesamum seed	75	59
Clusterbean seed	400	23
Bhendi seed	80	21
Rice seed	21	12.5
Rice straw	-	1
Blackgram haulms	-	0.5

Table 2: Crop residues (t ha^{-1}) on fresh weight basis at harvest of pre *kharif* crops in rice based cropping system

Pre *kharif* crops	Crop residues on fresh weight basis (t ha^{-1})
T_1: Fallow	-
T_2: Sunnhemp	30.11
T_3: Greengram	10.48
T_4: Blackgram	5.94
T_5: Sesame	3.79
T_6: Clusterbean	1.16
T_7: Bhendi	4.73
S.Em +	0.85
CD (P=0.05)	2.55

Grain and straw yield (Table 3) of *kharif* rice was significantly influenced by different pre *kharif* crops. The highest grain yield of rice was realized with sunnhemp (T_2) which was significantly superior to all the other pre *kharif* crops tested. *Kharif* rice when preceded by greengram (T_3), blackgram (T_4), bhendi (T_7) and sesame (T_5) are next best to sunnhemp and produced statistically similar yields. The lowest grain yield of rice was obtained with fallow (T_1). The increase in grain and straw yield with sunnhemp could also be due to the enrichment of soil fertility through profused nodulation. Among the other pre *kharif* crops tested, greengram produced the next highest yields which can be attributed to higher crop residue of preceding crop, enhanced soil fertility which might have created favourable growing conditions to succeeding rice as evidenced in its higher number of panicles m^{-2}, filled grains $panicle^{-1}$ and thousand grain weight, which was next only to sunnhemp. Better performance of rice with the inclusion of preceding crops in the system was also well documented by Reddy and Surekha (2000), Porpavai *et al*. (2006), Bhargavi *et al*. (2008), Kumari and Reddy (2009) and Ali *et al*. (2012).

Post harvest soil nutrient status (Table 4) varied with all the pre *kharif* treatments. The highest organic carbon, available nitrogen, phosphorus and potassium were registered with incorporation of sunnhemp (T_2) which was comparable with that of greengram (T_3) and blackgram (T_4) and the lowest was registered with fallow (T_1) which in turn was comparable with that of incorporation of clusterbean (T_6), bhendi (T_7) and sesame (T_5) residues.

The increase in organic carbon with the above treatments could be attributed to the direct effect from incorporation of crop residue after crop harvest. Available N status was high with incorporation of sunnhemp crop residue, which might be due to considerable amount of N added through highest quantity of crop residue. The present study findings were in agreement with those of Sharma *et al*. (2004), Porpavai *et al*. (2011) and Sharma *et al*. (2013).

Economics (Table 5) of different pre *kharif* - *kharif* rice cropping systems differed significantly with different pre *kharif* crop treatments. The highest gross and net returns were realized with bhendi-rice (T_7) system, which was significantly superior

Table 3: Growth parameters, yield attributes and yield of *kharif* rice as influenced by pre *kharif* crops in rice based cropping system

Cropping system	Dry matter (kg ha^{-1}) production at harvest	Panicles m^{-2} at harvest	Number of filled grains $panicle^{-1}$	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Fallow-rice	7754	204	100	21.95	4125	5899
T_2: Sunnhemp-rice	14455	265	128	24.33	6501	8505
T_3: Greengram-rice	12199	247	119	23.48	5789	7592
T_4: Blackgram-rice	11838	243	118	23.33	5605	7522
T_5: Sesame-rice	10486	232	114	22.98	5310	7257
T_6: Clusterbean-rice	9692	223	109	22.78	4825	6627
T_7: Bhendi-rice	11645	242	119	23.05	5512	7485
S.Em +	642.39	5.59	2.56	0.27	177.24	217.81
CD (P=0.05)	1909	17	8	0.79	527	647

Table 4: Soil nutrient status after *kharif* rice as influenced by pre *kharif* crops in rice based cropping system

Cropping system	Soil OC (%)	Available nitrogen(kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium(kg ha^{-1})
T_1: Fallow-rice	0.27	159.90	14.38	186.96
T_2: Sunnhemp-rice	0.39	215.33	20.83	256.99
T_3: Greengram-rice	0.37	210.10	19.81	247.20
T_4: Blackgram-rice	0.36	206.98	19.35	241.23
T_5: Sesame-rice	0.28	163.05	15.09	195.41
T_6: Clusterbean-rice	0.31	194.43	17.84	220.83
T_7: Bhendi-rice	0.28	180.83	16.79	218.70
S.Em +	0.02	12.06	1.40	14.82
CD (P=0.05)	0.07	35.84	4.16	44.03

Table 5: Gross returns, net returns (Rs ha^{-1}) and benefit cost ratio of pre *kharif* - *kharif* rice as influenced by pre *kharif* crops in rice based cropping system

Cropping system	Cost of cultivation (Rs ha^{-1})	Gross returns(Rs ha^{-1})	Net returns(Rs ha^{-1})	B: C ratio
T_1: Fallow-rice	25390	57465	32075	2.26
T_2: Sunnhemp-rice	33210	89770	56560	2.70
T_3: Greengram- rice	39000	88624	49624	2.28
T_4: Blackgram- rice	38400	91239	52839	2.38
T_5: Sesame- rice	35630	81852	46222	2.30
T_6: Clusterbean- rice	50870	69083	18213	1.36
T_7: Bhendi- rice	42530	112978	70448	2.66
S.Em +	-	2951.09	2951.09	0.08
CD (P=0.05)	-	8768	8768	0.22

Table 6: Seed and haulm yield (kg ha^{-1}) of *rabi* rice fallow blackgram and productivity (kg ha^{-1}) of the cropping system as influenced by pre *kharif* crops in rice based cropping system

Cropping system	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	System productivity(kg REY ha^{-1})
T_1: Fallow-rice-rice fallow blackgram	225	462	4765
T_2: Sunnhemp-rice- rice fallow blackgram	382	743	7586
T_3: Greengram-rice rice fallow blackgram	342	667	7455
T_4: Blackgram-rice rice fallow blackgram	329	643	7633
T_5: Sesame-rice rice fallow blackgram	278	551	6757
T_6: Clusterbean-rice rice fallow blackgram	263	538	5742
T_7: Bhendi-rice rice fallow blackgram	291	569	9265
S.Em +	11.92	24.18	225.70
CD (P=0.05)	35	72	671

Table 7: Dry matter production (kg ha^{-1}) of whole cropping system

Cropping system	Pre *kharif*	*Kharif*	*Rabi*	Total
T_1: Fallow-rice-rice fallow blackgram	-	7754	661	8415
T_2: Sunnhemp-rice-rice fallow blackgram	13096	14455	1455	29006
T_3: Greengram-rice-rice fallow blackgram	4653	12199	1166	18017
T_4: Blackgram-rice-rice fallow blackgram	2669	11838	1086	15594
T_5: Sesame-rice-rice fallow blackgram	1993	10486	988	13467
T_6: Clusterbean-rice-rice fallow blackgram	446	9692	860	10998
T_7: Bhendi-rice-rice fallow blackgram	2097	11645	1066	14807
S.Em +	263.61	642.39	63.87	706.98
CD (P=0.05)	795	1909	190	2101

to all other cropping systems.

The lowest gross returns were recorded with fallow-rice (T_1) while net returns were with clusterbean-rice (T_6) which was significantly inferior to all other cropping systems. Highest BCR was recorded with sunnhemp-rice-rice fallow blackgram (T_2), which was however comparable with bhendi-rice-rice fallow blackgram (T_7) only. BCR was the lowest with clusterbean-rice-rice fallow blackgram (T_6). Differences in the gross returns, net returns and benefit cost ratio of different pre *kharif* - *kharif* rice cropping systems were due to differences in grain yield of component crops and cost of cultivation of the cropping system. These findings are in accordance with the results of Bastia *et al*. (2008) and Prasad *et al*. (2013).

Effect of pre *kharif* crops on succeeding rice fallow blackgram

The highest seed and haulm yield (Table 6) of rice fallow blackgram was recorded with sunnhemp (T_2) while the lowest was registered with fallow (T_1). Seed yield of rice fallow blackgram with incorporation of greengram (T_3) and blackgram (T_4) residues were comparable between them. This might be due to higher biomass production and prolonged availability of nutrients to rice as well as rice fallow blackgram with

Table 8: Gross returns, net returns (Rs ha^{-1}) and benefit cost ratio of *kharif* rice-*rabi* rice fallow blackgram as influenced by pre *kharif* crops in rice based cropping system

Cropping system	Cost of cultivation (Rs ha^{-1})	Gross returns(Rs ha^{-1})	Net returns(Rs ha^{-1})	B: C ratio
T_1: Fallow-rice-rice fallow blackgram	33490	65924	32434	1.97
T_2: Sunnhemp-rice-rice fallow blackgram	33490	104069	70578	3.11
T_3: Greengram-rice-rice fallow blackgram	33490	92776	59286	2.77
T_4: Blackgram-rice-rice fallow blackgram	33490	89918	56428	2.69
T_5: Sesame-rice-rice fallow blackgram	33490	84059	50569	2.51
T_6: Clusterbean-rice-rice fallow blackgram	33490	76797	43307	2.29
T_7: Bhendi-rice-rice fallow blackgram	33490	87276	53786	2.61
S.Em +	-	2480.87	2480.87	0.07
CD (P=0.05)	-	7371	7371	0.22

sunnhemp. Influence on the economic yield of second succeeding crop due to pre *kharif* cropping was also reported by Babou *et al*. (2005), Ashok Kumar *et al*. (2008) and Kumari and Reddy (2010).

The highest total dry matter production (Table 7) was produced by sunnhemp-rice-rice fallow blackgram (T_2) system which was significantly superior to any of the cropping system taken for the study. Total dry matter production with Clusterbean-rice-rice fallow blackgram (T_6) was in lowest quantity and hence was inferior to all other crops in the treatments.

Sunnhemp as pre *kharif* crop has produced larger quantities of above ground biomass and its incorporation has resulted in increased dry matter of succeeding rice and rice fallow blackgram hence, resulted in highest total dry matter of cropping system. Least above ground biomass of clusterbean during pre *kharif* season and its incorporation has not improved the dry matter of succeeding crops resulting in the lowest dry matter of the cropping system. The production of variable amounts of dry matter by different cropping systems could be attributed to the different amounts of crop residues produced during pre *kharif* season and less contribution of nutrients from their corresponding residues.

Economics of *kharif* rice - *rabi* rice fallow blackgram

Economics (Table 8) of different *kharif* rice - *rabi* rice fallow blackgram systems differed significantly with different pre *kharif* crop treatments. The highest gross returns, net returns and BCR were realized with sunnhemp-rice-rice fallow blackgram (T_2) system, which was significantly superior to all other cropping systems while the lowest was recorded with fallow-rice-rice fallow blackgram (T_1) system which was significantly inferior to all other cropping systems. Differences in the gross returns, net returns and benefit cost ratio of different *kharif* rice - *rabi* rice fallow blackgram systems were due to differences in grain yield of component crops and cost of cultivation of the cropping system. These findings are in accordance with the results of Jat *et al*. (2012) and Prasad *et al*. (2013).

Based on the above findings, it was concluded that sunnhemp was the most suitable pre *kharif* crop as it enhanced performance of succeeding rice and rice fallow blackgram and soil fertility status and therefore sunnhemp-rice-rice fallow blackgram was found to be the best system for North Coastal Zone of Andhra Pradesh.

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