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Productivity and economics of rice (*Oryza sativa*)–maize (*Zea mays*) as influenced by methods of crop establishment, Zn and S application in rice

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ABSTRACT

A field experiment was conducted during 2007-08 and 2008-09 at Hyderabad, to study the effect of three rice (*Oryza sativa* L.) establishment methods [sowing of sprouted rice under puddle condition (DS) at 25 cm x 25 cm, system of rice intensification (SRI) seedlings transplanted at 25 cm x 25 cm and conventional transplanting (CT) at 20 cm x 15 cm] as main plots and five nutrient combinations (NPK, NPK + Zn, NPK + S, NPK + Zn + S and NPK + FYM) in sub - plots on rice-maize (*Zea mays* L.) sequence in a spilt plot design with treatments replicated thrice. On an average rice under SRI recorded the higher drymatter accumulation /hill, yield attributes and yield. On an average SRI rice – maize sequence recorded the highest rice equivalent yield (11.37 t/ha on mean basis), net returns (58,346 Rs/ha) and benefit : cost ratio (BCR). Application of S, Zn and FYM improved significantly the productivity of rice and succeeding maize crop. Among nutrient management practices, NPK + Zn + S recorded higher grain yield (5.27 t/ha) and yield attributes during both years of rice cultivation, except that it was on par with NPK + FYM in 2008-09. Similar trend was also observed in uptake of nutrients. Based on the systems productivity (11.72 t/ha), net returns (58,983 Rs/ha), and BCR, NPK + Zn + S treatment excelled all other nutrient combinations. SRI method used 23 and 25% less water compared to CT and DS. NPK + FYM application to rice crop recorded significantly highest quantity of available soil N, P and K content after crop harvest. While, highest available soil S and Zn content was recorded by the treatments where in respective nutrients were applied in the previous season to rice. Thus it is concluded that SRI rice – maize is more productive, beneficial and efficient water user. Both Zn and S be applied to rice to raise the productivity of subsequent maize too.

Key words: Intensification, Maize, Productivity, Rice, Sulphur

Rice (*Oryza sativa* L.) – rice covering an area of 3.78 m ha (9% of total rice area in India) is the pre-dominant cropping sequence in Andhra Pradesh. The increasing water scarcity coupled with heavy demand for irrigation water by transplanting and wet seeding (sprouted rice) methods of rice establishment emphasizes the need for shift to water saving by rice cultivation methods such as system of rice intensification. Further, replacement of rice with maize (*Zea mays* L.) in dry season is increasing to save water and for maximum system production. However, from the view point of water economy, soil-health and maximum production potential, it became necessary and inevitable to rotate rice with an upland crop such as maize under irrigated dry conditions.

The intensification of agriculture, introduction of high-yielding varieties and multiple cropping coupled with the use of high analysis fertilizers along with restricted use of organic manures have resulted in depletion of sulphur and zinc reserves in >50% of soils in Andhra Pradesh. The information on direct and residual effect of sulphur and zinc in rice – maize sequence is meager, therefore present experiment was conducted.

MATERIALS AND METHODS

A field experiment was conducted from 2007-08 to 2008-2009 at the Directorate of Rice Research Farm, at ICRISAT (17^0 53' N, 78^0 27' N and 522 m above mean sea level), Hyderabad, India. The soil of the experimental site was sandy clay loam having pH 7.65 medium in organic carbon (0.44%), low in available nitrogen (250.9 kg/ha), available sulphur (8.1 kg/ha), DTPA extractable Zn (0.48 g/kg) and medium in available phosphorus (20.0 kg/ha) and potassium (277.8 kg/ha). The total rainfall received during *kharif* of 2007 and 2008 was 421 mm and 762.2 mm in 38 and 39 rainy days, respectively. Fifteen treatments consisted of combinations of three rice crop establishment methods viz., direct sowing of sprouted rice under puddled condition (DS), system of rice intensification

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(SRI), conventional transplanting (CT) as main plot and five nutrient combinations viz., NPK (control), NPK + Zn, NPK + S, NPK + Zn +S and NPK + FYM as sub-plot treatments to rice were tested in split plot design having three replications. The residual effects of these treatment were evaluated on zero-tilled maize in *rabi* seasons in permanent plots.

Twenty five-day old rice *'Rasi'* seedlings (three/hill) were transplanted at 20 cm x 15 cm spacing in CT method and 12-day old were transplanted at 25 cm x 25 cm spacing in SRI method (one seedling/hill) while 4-5 sprouted seeds were sown at 25 cm x 25 cm spacing under DS at the same date when the nursery sowing was done for CT and SRI method. In DS, thinning was done to maintain final plant population of three seedlings/hill. Water levels of 5 cm was maintained in CT and DS methods throughout the growing period while soil moisture saturation was maintained in SRI method. One third of N and total P and K (100-17.6-33.3 kg N-P-K/ha) was applied as basal at final puddling. Remaining N was applied in two equal splits at maximum tillering and panicle initiation stages. Sulphur @ 40 kg/ha (bentonite sulphur) and zinc @ 50 kg/ha (ZnO) and FYM (5 t/ha) having 0.5-0.2-0.5% N-P-K were applied basally at the time of final leveling.

Gramoxone was applied @ 10 ml /l in the field after harvesting of rice crop to control the existing weeds. Maize 'BH 1576' seeds were dibbled at 60 cm x 30 cm spacing in *rabi* season under zero-tilled method after harvesting of rice crop. One day after sowing of maize seeds, atrazine was applied @ 1 kg a.i./ha. N, P, K fertilizer @ 120, 17.6, 33.3 kg/ha, irrigation, pest and diseases control and other crop management practices were adopted as per the recommendations for the region. The cost of cultivation, net returns and benefit: cost ratio (net returns /cost of cultivation) were calculated on the basis of prevailing market price of different inputs and outputs. Rice equivalent yield (REY) was calculated using the price of crops. The water used in different methods of rice establishments was recorded by digital water meters and water productivity in terms of water use efficiency (yield/water applied) was also worked out.

RESULTS AND DISCUSSION

Effect on growth and yield

Plant dry weight, grains/panicle, 1,000 grain weight and biological yield of rice crop was significantly higher under SRI method during both the years when compared with DS and CT methods (Table 1). In case of maize, the cob length was not affected due to rice crop establishment methods. Significantly higher mean cob weight (228.7 g), grains/cob (546) and 100 seed weight (23.14 g) was recorded in CT followed by SRI method. The values of maize yield attributes were least in plots preceding DS rice plots.

Among nutrient management practices, NPKSZn treatment recorded significantly higher dry matter production/hill, panicles/m^2 grains/panicle and 1,000 grain weight than all other treatments. However NPK + FYM treatment was at par with NPKSZn treatment during second year and further 1,000 grain weight did not vary among treatments significantly during first year. Among the nutrient combinations imposed to the rice crop, NPK+FYM and NPKSZn and S recorded significantly higher cob length, cob weight and 100-seed weight of maize over rest of the treatments.

In both the years, SRI method produced significantly higher rice grain yield i.e. on average was 15.5 and 18.8% higher when compared with DS and CT, respectively. Both SRI and CT in rice being at par recorded significantly higher grain yield of succeeding maize over DS. As a system, SRI rice - maize with a mean rice equivalent yield (REY) of 11.35 t/ha has 5.2 and 11.6% higher REY over CT and DS rice-maize system, respectively. This might be attributable to the enhanced vegetative growth by favourable nutrient supply, which eventually led to highest filled grains / panicle with maximum grain filling compared to other methods. Besides, the square geometry with wider spacing, planting of single seedling/hill was also found to reduce the above and below ground competition, enhanced solar radiation interception and nutrients uptake, thus resulting in an increased rate of grain filling, higher test weight, more number of grains/panicle and grain yields. Rajesh and Thanunathan (2003) and Uphoff (2001) observed that the roots of rice plants have least competition under wider spacing so that growth is stimulated by sunlight and space for the canopy expansion thereby increasing the yield attributes and yield. Nissanka and Bandara (2004) also reported 9 and 12% more grain yield in SRI compared to conventional transplanting and direct sowing methods.

Rice responded significantly to the application of Zn, S and FYM during both the years (Table 1). Significantly lowest grain yield during both the years was recorded in NPK alone (4.10 t/ha). NPK + Zn + S treatment recorded the highest grain yield (5.30 t/ha) and when compared with remaining nutrient management practices in both the years except that it was at par with NPK + FYM in 2008-09. The maize yield varied significantly due to the residual effect of Zn, S and FYM applied to preceding rice crop. Maize grain yield in NPK + Zn + S treatment was highest that being on par with NPK + FYM treatment was significantly superior to Zn or S applied along with NPK and NPK alone. The variations in total biological yield of rice and maize due to different rice crop establishment methods was reflected in the grain yield during both the years of study. NPK + Zn + S treatment recorded significantly highest total biological yield (11.53 t/ha) during first year, but it was statistically similar to NPK + FYM treatment (11.41 t/ha) during second year. The treatment NPK + Zn + S recorded highest total biological yield in maize followed by NPK + FYM, NPK + Zn and NPK + S in both the years. The higher growth, yield attributes and yield under NPK + Zn + S treatment may be due to the combined effect of both Zn and S which might have triggered the overall growth of the crop since the soil was deficient in S and Zn. Similar increases in growth and yield of rice due to zinc application were also observed by Chapale and Badole (1999).

Nutrient uptake

The nutrient uptake (NPKZn and S) of crops (rice and maize) was influenced significantly due to rice establishment methods and nutrient applications to rice in both the years (Table 2). Among the rice establishment methods, SRI recorded highest uptake values when compared with DS and CT. Uptake of S and Zn also followed similar trend in both the years. In case of maize, NPK + FYM recorded highest uptake of nutrients compared to NPK + Zn + S, NPK + Zn, NPK + S and NPK. The treatment of NPK + Zn + S registered maximum sulphur uptake followed by NPK + S during first year, while NPK + FYM also recorded similar S uptake in second year. Zn uptake was maximum with NPK + Zn + S compared to NPK + Zn,

Table 1. Effect of establishment methods and nutrient application to rice on yield and yield components of rice - maize system

Treatment	Rice											
	Plant dry weight (g/hill)		Panicles/m²		Grains/panicle		1,000 grain weight (g)		Grain yield (t/ha)		Biological yield (t/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Rice establishment method												
DS	48.9	52.9	348	376	104	109	21.3	21.7	4.51	4.73	9.93	10.36
SRI	53.6	59.0	341	360	122	121	21.9	22.0	5.22	5.45	11.48	11.67
CT	40.2	46.6	334	353	106	114	21.2	21.6	4.41	4.57	9.70	9.87
SEm±	1.5	1.3	13	8	2	2	0.1	0.1	0.05	0.17	0.19	0.39
CD (P=0.05)	4.3	3.6	NS	NS	6	5	0.4	0.2	0.14	0.49	0.53	1.10
Nutrient application to rice												
NPK	37.4	41.9	286	297	89	92	21.5	21.3	4.14	4.07	9.17	8.80
NPK + Zn	47.6	50.4	345	360	113	115	21.4	21.8	4.72	4.96	10.43	10.76
NPK + S	47.4	50.9	348	356	112	114	21.2	21.6	4.79	4.77	10.61	10.37
NPK + Zn + S	57.9	60.7	396	404	128	129	22.0	22.2	5.27	5.33	11.53	11.57
NPK + FYM	47.5	60.2	332	397	117	124	21.4	21.8	4.64	5.22	10.14	11.41
SEm±	1.4	1.1	8	7	2	2	0.4	0.1	0.08	0.07	0.16	0.18
CD (P=0.05)	4.2	3.3	24	20	7	6	NS	0.4	0.24	0.23	0.48	0.53

Treatment	Maize											
	Cob length		Cob weight g/cob		Grains/cob		100 grain weight (g)		Grain yield (t/ha)		Biological yield (t/ha)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Rice establishment method												
DS	19.60	19.33	190	172	486	465	19.9	19.9	5.61	5.56	14.81	14.78
SRI	20.12	20.00	222	200	530	520	21.9	21.7	6.22	6.24	16.40	16.60
CT	20.51	20.58	241	216	551	542	23.3	23.0	6.55	6.44	17.19	16.98
SEm±	0.25	0.33	3	4	6	11	0.2	0.3	0.20	0.11	0.62	0.31
CD (P = 0.05)	NS	0.91	8	10	17	31	0.7	0.8	0.59	0.32	1.73	0.87
Nutrient application to rice												
NPK	19.78	19.67	185	167	469	460	19.7	19.6	5.53	5.42	14.39	14.33
NPK + Zn	20.04	19.97	218	203	529	520	22.1	22.0	6.02	5.93	15.80	15.81
NPK + S	20.02	19.86	213	186	512	483	21.6	21.5	5.96	5.90	15.61	15.57
NPK + Zn + S	20.24	20.17	238	214	557	547	22.6	22.3	6.64	6.64	17.66	17.53
NPK + FYM	20.28	20.97	233	208	544	534	22.6	22.2	6.48	6.49	17.20	17.28
SEm±	0.05	0.06	3	3	6	9	0.2	0.2	0.10	0.05	0.28	0.15
CD (P=0.05)	0.15	0.14	9	9	17	27	0.7	0.6	0.31	0.17	0.88	0.46

DS, Sowing sprouted rice in puddled field; SRI, System of rice intensification; CT, Conventional transplanting

NPK + FYM, NPK + S and NPK (control) during both the years.

Among the different nutrient applications, NPK + Zn + S treatment recorded significantly highest nutrient uptake by rice followed by NPK + Zn, NPK + S and NPK + FYM. During the second year, both NPK + FYM as well as NPK + ZN + S treatments recorded statistically similar plant nitrogen uptake values. NPK (Control) recorded the lowest nutrient uptake during both the years of study. The more uptake of nutrients by maize crop due to integrated use of FYM with chemical fertilizers was also reported by Reddy and Reddy (2000) in maize-soybean cropping system.

Water use and water productivity

Among the different crop establishment methods, DS recorded the highest mean water use (1,752 ha-mm) followed by CT (1,697 ha-mm) and SRI (1,304 ha-mm). The per cent reduction in water use by SRI method was 23% when compared with CT. Consequently, higher water productivity values were recorded by the SRI (0.41 kg/m^3) as compared to CT and DS. Hence, the water productivity in SRI was higher by 36% as compared to CT and DS due to higher grain yield in SRI and less water used (Table 3). Water saving in SRI have also been reported by Viraktamath and Mahender Kumar (2007). There was no significant difference among nutrient management practices in terms of water use and water productivity.

Available nutrient status in soil after harvest of maize crop

Among rice-crop establishment methods, highest soil organic matter content (SOM) after 2 years of study was recorded with CT (Table 3). Among nutrient management practices in rice, NPK + FYM treatment recorded the highest SOM content possibly due to under decomposed FYM addition in the treatment. Similar results were was also reported by Dash *et al.* (2000) after harvest of maize crop.

Available NPKS and Zn content of soil after harvesting of maize crop was highest in DS mainly due to lowest re-

Table 2. Effect of crop establishment methods and nutrient management practices on nutrient uptake (kg/ha) of rice and maize

Treatment	N		P		K		Zn (g/ha)		S	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Rice										
Rice establishment method										
DS	100.8	113.4	17.4	18.3	78.1	80.9	90.2	117.3	7.13	7.48
SRI	114.0	129.0	19.7	20.4	88.3	92.3	105.5	134.4	8.29	9.27
CT	81.1	99.4	14.2	15.7	61.3	70.1	71.0	93.1	5.65	6.44
SEm±	4.0	4.4	0.5	0.4	3.1	1.9	5.1	5.1	0.30	0.40
CD(P =0.05)	11.0	12.1	1.4	1.1	8.7	5.4	14.0	14.1	0.80	1.10
Nutrient management in rice										
NPK	74.7	84.6	12.7	13.9	57.2	62.8	37.2	43.2	5.11	6.02
NPK + Zn	101.1	108.9	16.9	17.0	73.8	77.3	122.3	148.2	6.75	6.93
NPK + S	97.3	108.3	17.2	17.5	73.1	76.8	50.6	53.5	7.23	7.63
NPK + Zn +S	123.8	131.8	21.2	21.0	94.9	93.5	163.3	209.0	8.97	9.15
NPK + FYM	96.3	136.1	17.5	21.1	80.6	95.1	71.1	120.8	7.07	8.92
SEm±	3.3	2.8	0.5	0.3	2.1	3.2	4.3	2.8	0.22	0.21
CD(P =0.05)	9.7	8.8	1.7	1.1	6.6	9.8	12.9	8.3	0.70	0.70
Maize										
Rice establishment method										
DS	183.4	172.6	38.5	34.4	120.0	111.4	218.1	204.1	18.2	16.6
SRI	201.4	190.7	43.0	37.5	138.9	142.6	253.4	245.6	23.0	18.7
CT	214.1	202.2	45.0	43.3	155.0	157.1	302.4	291.0	27.4	22.8
SEm±	1.6	2.2	0.6	1.8	1.3	3.6	4.0	3.1	1.4	2.1
CD (P=0.05)	4.4	6.0	1.5	5.0	3.5	10.1	11.1	8.7	3.8	NS
Nutrient management in rice										
NPK	177.7	168.0	39.5	36.5	118.3	106.5	143.1	134.3	13.4	10.6
NPK + Zn	198.5	187.9	42.2	39.1	135.9	128.4	351.6	336.5	14.3	12.1
NPK + S	192.6	181.3	39.5	35.1	131.0	123.9	163.7	150.4	29.0	25.7
NPK + Zn +S	211.3	198.1	43.2	36.4	149.1	141.5	400.9	384.0	31.9	25.9
NPK + FYM	218.3	207.1	46.3	44.4	155.5	149.8	230.5	228.7	25.7	22.6
SEm±	2.3	2.4	0.9	1.6	1.7	2.6	6.8	7.3	2.1	1.9
CD (P=0.05)	4.7	5.0	2.0	3.5	3.7	5.5	14.0	15.0	4.2	3.9

DS, Sowing sprouted rice in puddled field; SRI, System of rice intensification; CT, Conventional transplanting

Table 3. Available nutrient status (kg/ha) of soil of rice – maize sequential cropping system as influenced by rice crop establishment and nutrient management

Treatment	N		P		K		S		DTPA extractable Zinc (mg/kg)		Organic carbon (%)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Rice establishment method												
DS	214.3	218.0	26.41	28.65	252.8	256.0	15.50	16.27	1.17	1.15	0.61	0.63
SRI	201.3	206.0	24.92	27.93	241.0	246.2	14.63	15.21	0.93	1.13	0.65	0.67
CT	184.7	195.7	22.91	26.25	224.1	227.9	13.52	14.45	0.85	0.96	0.67	0.70
SEm.±	2.4	2.6	0.43	0.63	2.6	2.0	1.07	0.25	0.01	0.03	0.01	0.01
CD (P=0.05)	6.8	7.1	1.18	1.75	7.0	5.6	NS	0.70	0.02	0.08	0.03	0.03
Nutrient application in rice												
NPK (Control)	198.4	205.4	25.32	29.90	241.2	244.6	9.52	8.88	0.54	0.53	0.59	0.61
NPK + Zn	195.5	203.0	23.79	25.66	236.0	242.2	9.19	8.47	1.57	1.93	0.62	0.64
NPK + S	196.2	203.5	24.20	26.69	239.1	243.4	19.29	20.20	0.55	0.54	0.63	0.65
NPK + Zn + S	193.0	201.0	21.76	24.94	233.5	240.6	18.06	20.17	1.46	1.52	0.64	0.66
NPK + FYM	217.3	219.9	28.67	30.88	246.7	246.0	16.71	18.83	0.78	0.89	0.73	0.76
SEm.±	0.4	0.9	0.48	0.60	1.9	0.8	0.63	0.25	0.05	0.05	0.01	0.01
CD (P=0.05)	0.8	1.8	0.98	1.24	4.0	1.6	1.52	0.47	0.10	0.11	0.02	0.02
Initial nutrient status	250.9		20.02		277.8		8.10		0.48		0.44	

DS, Sowing sprouted rice in puddled field; SRI, System of Rice Intensification; CT, Conventional transplanting

Table 4. Rice equivalent yields (REY), economics and water productivity of rice – maize cropping system as influenced by rice establishment methods and nutrient application to rice

Treatment	REY (t/ha)		Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		Benefit Cost ratio		Total water used (ha-mm)		Water productivity (kg/m^3)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Rice establishment method												
DS	9.93	10.14	29,123	29,449	41,345	51,671	1.42	1.75	1,697	1,821	0.26	0.25
SRI	11.20	11.53	27,358	27,509	51,928	64,763	1.90	2.35	1,290	1,317	0.40	0.41
CT	10.70	10.84	31,025	31,086	44,824	55,634	1.44	1.79	1,641	1,753	0.26	0.26
Nutrient application to rice												
NPK	9.44	9.27	27,168	27,158	39,835	46,970	1.47	1.73			0.27	0.25
NPK + Zn	10.50	10.74	28,324	28,657	46,091	57,295	1.63	2.00			0.31	0.30
NPK + S	10.50	10.55	28,227	28,157	46,344	56,259	1.64	2.00			0.31	0.29
NPK + Zn + S	11.60	11.81	29,400	29,657	53,166	64,799	1.81	2.18			0.34	0.33
NPK + FYM	10.90	11.55	28,833	29,151	48,181	63,265	1.67	2.17			0.30	0.32

Price of rice, Rs 7,100/t and Rs 8,000/t in 2007-08 and 2008-09; Price of maize, Rs 6,800/t and 7,800/t in 2007 and 2008

moval of nutrients from soil. Among the nutrient management treatments, application of NPK + FYM to rice crop recorded significantly highest quantity of available soil N, P and K content after crop harvest. This may be due to the low release of nutrients in FYM and also due to chelating effect of FYM. Rathore *et al.* (1995) also observed that residual soil fertility of available nutrients increased under FYM application, where as N, P and K alone made no impact on fertility build up. Unlike soil available N, P and K content, highest available soil S and Zn content was recorded by the treatments where respective nutrients were applied in the previous season to rice possibly due to the residual effect. Further, significantly increased available soil S content was seen with combined use of NPK and FYM since all the organic sources contain S. Mineralization of organic matter during the decomposition of FYM resulting in enhanced availability g SO^{-2}_4 –S in soil was also reported by Chandravanshi (1998).

Economics

Net returns and benefit: cost ratio (58,045 Rs/ha and 2.12) were found to be highest with SRI method and least in DS. The highest returns from SRI method was due to higher grain yield and lower cost of cultivation as seed requirement is less (5 kg /ha) and less labour cost for weed control with the use of cono weeder. Similar results were also reported by Moorthy and Sanjoy Saha (1997) and Sinha and Talati (2006). Application of NPK + Zn + S recorded higher mean values of net returns (58,982 Rs/ha) and B : C ratio (1.99) followed by NPK + FYM (55,723 Rs/ha and 1.92).

Thus it is concluded that SRI method in semi arid tropics of Andhra Pradesh is more productive, profitable and efficient water user compared to conventional transplanting and sowing of sprouted seeds. Application of Zn, S and FYM in rice along with recommended dose of NPK fertilizers also benefits the succeeding maize crop.

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