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Effect of Nutrient Levels and Biofertilizer on Growth and Yield of Paddy under System of Rice Intensification (SRI) and Conventional Methods of Cultivation

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ABSTRACT. *A field experiment was conducted at Agricultural Research Station, Gangavati of University of Agricultural Sciences, Dharwad, Karnataka, India during the summer 2007 to study the effect of nutrient levels and biofertilizers on growth and yield of rice (Oryza sativa L.) under System of Rice Intensificaton (SRI) and conventional methods of cultivation. The experiment was laid out on medium deep black clay (Calciustert) soil by adopting split-split-plot design with twenty treatments with three replicates. The treatments consisted of two methods of cultivation (SRI and conventional) as main plots and five nutrient levels with and without biofertilizers (Azospirillum and Pseudomonas striata) (100% Recommended Dose of Fertilizer (RDF), 75% RDF, 75% RDF + biofertilizers, 50% RDF and 50% RDF + biofertilizers) as sub plots and two Zn levels (10 kg $ZnSO_4$ and 25 kg $ZnSO_4$ ha^{-1}) as sub sub plots.*

Significantly taller plants with higher number of tillers and dry matter production were recorded in SRI method of cultivation at all the growth stages as compared to conventional method. The SRI method resulted significantly higher productive tillers m^{-2}, 1000 grain weight, grain and straw yield as compared to conventional method. The treatment receiving 75 percent RDF + biofertilizers with 25 kg $ZnSO_4$ ha^{-1} resulted significantly tall plants with highest number of tillers, dry mater, yield attributes, grain and straw yield irrespective of method of cultivation. Application of biofertilizers recorded higher growth and yield due to nitrogen fixation, phosphorus solubilization and supply of growth substances in both the methods of cultivation.

INTRODUCTION

Rice is the staple food for about 50 percent of the world's population in Asia, where 90 percent of the world's rice is grown and consumed. It is an important staple food that provides 66 – 70 percent body calorie intake of the consumers (Barah and Pandey, 2005). The world paddy production was 614.65 million tonnes in 2004 – 2005 from an area of 153.51 million ha with an average yield of 3.87 t ha^{-1}. To assure food security in the rice

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consuming countries of the world, rice production should be increased by 50 percent in year 2025. This additional rice will have to be produced on less land with less usage of water, labour and agrochemicals (Zheng *et al.,* 2004). Similarly, to achieve the projected targets of 680 and 771 million tonnes by 2015 and 2030, respectively, the productivity of rice fields has to be increased through adoption of suitable and newer technologies (Badawi, 2004).

In Asia, India has the largest extent under rice (44.3 million ha) accounting for 29.4 percent of the global rice extent. India would need to produce 143 million tonnes of rice to meet the growing population by 2030 (Subbaiah *et al.,* 2001). This increase in production could be achieved by intensification of paddy cultivation rather than increasing the area under rice. The System of Rice Intensification (SRI), developed in Madagascar, is a new methodology for increasing the productivity of irrigated rice. Careful transplanting of young seedlings at wide spacing on a precise grid with only one seedling per hill, water management that keeps the soil moist but not continuously flooded, frequent (*i.e.* three to four times) manual or mechanical weeding before canopy closure and use of compost with limited use of chemical fertilizers are the main principles of SRI method (Willem, *et al.,* 2002). The System of Rice Intensification has shown that by changing the soil, water, nutrients and management of rice plants, the yields could be increased by 25-50% or more while reducing water requirements by an equivalent percent. This gives farmers an incentive to reduce the use of irrigation water in rice cultivation. Furthermore, SRI method can reduce the cost of production and increases the net income ha^{-1} (Satyanarayana *et al.,* 2007). The management of plants, soil, water and nutrients results in both healthy soil and plants, supported by greater root growth and the soil microbial abundance and diversity. Conventional lowland rice production has been done under continuously flooded conditions for millennia. It needs more water. The main practices of the conventional method are transplanting 25-30 days old seedlings in narrow spacing on a row with 2-3 seedlings per hill, keep the soil continuously in a flooded condition, manual weeding (based on its need) and use of chemical fertilizer. The hypoxic condition, caused by standing water, limits the ability of the roots to respire and slows down its metabolism, creates low solubility of some nutrient ions and high solubility of some other nutrient ions (Fe, Mn), ion transport and growth (Ponnamperuma, 1972).

To improve the production efficiency of rice and to synchronize the application of nutrients with the demand of the plant, it is necessary to apply the required dose of NPK fertilizers at the correct time. With the intensification of paddy cultivation, soils have been depleted of several plant nutrients including micronutrients. Among the micronutrients, Zn is the most limiting nutrient, where Zn deficiency is a widespread nutritional disorder of wetland rice (Breemen *et al.,* 1980). Biofertilizers, an alternate low cost resource have gained prime importance in recent decades and play a vital role in maintaining long term soil fertility and sustainability. Nitrogen fixing and P-solubilizing inoculants are important biofertilizers used in rice. Therefore, the present investigation was taken up to study the effect of nutrient levels and biofertilizers on growth and yield of paddy under SRI and conventional methods of cultivation.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural Research Station, Gangavati of University of Agricultural Sciences, Dharwad, Karanataka state of India, during summer 2007. The station is situated in the Northern Dry Zone of Karnataka between 15^0-15'-40''

North latitude and 76^0-31'-40" East longitude at an altitude of 419 m above the mean sea level. The station comes under Tungabhadra command area representing the irrigated transplanted rice belt in Karnataka. The mean maximum temperature varied between 31.2 to 41.2 ^{0}C and the mean minimum temperature varied between 16.6 to 25.3 ^{0}C and no rains were received during the crop growth period of January to May. The soils of the experimental site was medium deep black clay (Calciustert) with pH 8.40, 0.18 dS/m of EC, organic carbon 0.69%, 800 mg kg^{-1} of total N, 8 mg kg^{-1} of Olsen P and 0.21 meq/100g of exchangeable K.

The hybrid rice variety KRH-2 was used for the experiment. The KRH-2 is a popular medium duration (130-135 days) hybrid rice variety in Karnataka state released in 1996. This variety is giving long bold grains with yield a of 7.4 t ha^{-1}, resistant to brown plant hopper, blast disease and suitable for irrigated areas. In this experiment split-split-plot design was adopted and the treatments were replicated thrice. The treatments consisted of two methods of cultivation [M_1=System of Rice Intensification (SRI) and M_2=conventional] as main plots and five fertilizer levels; with and without biofertilizers (*Azospirillum* and *Pseudomonas striata*) [S_1=100% Recommended Dose of Fertilizer (RDF), S_2=75% RDF, S_3=75% RDF + biofertilizers, S_4=50% RDF, S_5=50% RDF + biofertilizers] as sub-plots and two Zn levels (Z_1=10 kg $ZnSO_4$ and Z_2=25 kg $ZnSO_4$ ha^{-1}) as sub sub plots. A recommended fertilizer dose of $N:P_2O_5:K_2O$ = 150:75:75 kg ha^{-1} and Zn were given in the form of urea, Di Ammonium Phosphate (DAP), Muriate Of Potash (MOP) and $ZnSO_4.7H_2O$ in the respective treatments. Although no change in land preparation practices is required for SRI, good land preparation is needed when planting younger seedlings. Therefore, ploughing and puddling were done in the same way in both the cultivation methods. More leveling was done in SRI method to prepare smooth and leveled plots compared to conventional method. Before transplanting, plots of the respective treatments in both the methods of cultivation were inoculated with *Azospirillum* and *Pseudomonas striata* at the rate of 2.5 kg ha^{-1} of each by broadcasting biofertilizer mixed with dried FYM at the ratio of 1:25. Seedlings were raised in dry seedbed for both cultivation methods. In SRI method of cultivation 10 days old seedlings were transplanted in the main field with one seedling per hill. Seedlings were removed carefully from the nursery bed without disturbing the roots of the plants and planted 1-2 cm deep into soil that was muddy with a wide spacing of 25 cm x 25 cm in square pattern using a roller marker. After transplanting, the soil was kept moist with no stagnating water. In conventional method, one month old seedlings were transplanted in the main field with 2-3 seedlings per hill. Seedlings were transplanted 2-3 cm deep into soil which flooded up to 2-3 cm depth with spacing of 20 cm x 10 cm in square pattern. Fertilizer treatments were imposed one week after transplanting in both the methods of cultivation. Only 50 percent of the nitrogen fertilizer (in the treatments) was applied as basal dose. Other 50 percent of nitrogen fertilizer applied in two equal doses at maximum tillering stage and panicle initiation stage.

After transplanting in SRI method of cultivation, the soil was kept moist for a period of 5 - 6 days (with no standing water) and kept dry for a period of 4 -5 days. This water management practice was followed throughout the growing period until flowering stage. After flowering, soil was kept continuously kept moist until 10-15 days before harvest. In conventional method, the field was flooded with water up to 5 cm depth and maintained throughout the growing period until 10 -15 days before harvest. In SRI method, frequent weeding was done with *cono weeder* six times with an interval of ten days starting from two weeks after transplanting. In conventional method, hand weeding was done for three times based on its need starting from two weeks after transplanting up to flowering stage. Five hills per plot were selected randomly from each sampling at 30, 60 and 90 days after transplanting (DAT). Average plant height, number of tillers hill^{-1} and dry matter production (t ha^{-1}) were worked out from five hills. The productive tillers m^{-2} was recorded at physiological maturity. The crop was harvested treatment wise and grain yield (14% moisture), straw yield and 1000 grain weight were recorded. The Dry Soft Design programme was used to find out the Analysis Of Variance of the experimental data.

RESULTS AND DISCUSSION

Effect of method of cultivation

Significantly higher plant height (52.4 cm) was recorded with SRI method of cultivation at 30 DAT as compared to conventional method (35.3 cm). A similar trend was observed in 60, 90 DAT and at harvest (Table 1).

Table 1. Effect of SRI and conventional method of cultivation, fertilizer levels and biofertilizer on plant height

Fertilizer levels	Plant height (cm)											
	30 DAT			60 DAT			90 DAT			At Harvest		
	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean
M_1 (SRI method of cultivation)												
S_1	56.6	65.7	**60.9**	76.2	82.4	**79.3**	90.4	97.5	**94.0**	96.5	101.2	**98.8**
S_2	51.0	56.5	**53.8**	67.6	73.0	**70.3**	85.1	87.8	**86.5**	88.0	90.4	**89.2**
S_3	63.3	71.8	**67.5**	78.9	88.8	**83.9**	94.6	103.2	**98.9**	99.9	107.9	**103.9**
S_4	31.8	38.7	**35.3**	46.0	60.1	**53.0**	73.0	77.5	**75.2**	74.7	76.6	**75.6**
S_5	40.3	48.9	**44.6**	56.5	69.2	**62.9**	78.4	81.3	**79.9**	81.2	85.9	**83.5**
Mean	**48.5**	**56.3**	**52.4**	**65.0**	**74.7**	**69.9**	**84.3**	**89.5**	**89.9**	**88.0**	**92.4**	**90.2**
M_2 (Conventional method of cultivation)												
S_1	38.6	50.0	**44.3**	58.2	61.0	**59.6**	78.5	87.1	**82.8**	83.0	88.7	**85.9**
S_2	30.2	33.4	**31.8**	47.8	63.4	**55.6**	70.3	76.5	**73.4**	75.4	84.6	**80.0**
S_3	42.9	54.4	**48.6**	52.9	60.7	**56.8**	80.4	89.2	**84.8**	86.9	92.8	**89.8**
S_4	23.5	27.0	**25.3**	35.2	41.4	**38.3**	55.4	60.6	**58.0**	58.3	63.5	**60.9**
S_5	26.2	28.2	**27.2**	41.7	49.2	**45.4**	64.1	67.9	**66.0**	68.2	70.8	**69.5**
Mean	**32.2**	**38.6**	**35.3**	**47.2**	**55.1**	**51.1**	**69.7**	**76.3**	**73.0**	**74.3**	**80.1**	**77.2**
Fertilizer and Zn interaction over method of cultivation												
S_1	47.4	57.8	**52.6**	67.2	71.7	**69.4**	84.4	92.3	**88.4**	89.8	94.9	**92.3**
S_2	40.6	45.0	**42.8**	57.7	68.2	**62.9**	77.7	82.2	**79.9**	81.7	87.5	**84.6**
S_3	53.1	63.1	**58.1**	65.9	74.8	**70.3**	87.5	96.2	**91.0**	93.4	100.3	**96.8**
S_4	27.7	32.9	**30.3**	40.6	50.7	**45.6**	64.2	69.0	**66.6**	66.5	70.0	**68.2**
S_5	33.2	38.5	**35.9**	49.1	59.2	**54.1**	71.2	74.6	**72.9**	74.7	78.4	**76.5**
Mean	**40.2**	**44.1**	**43.8**	**56.1**	**64.9**	**60.5**	**77.0**	**82.9**	**79.9**	**81.2**	**86.2**	**83.6**

Source	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%
M	0.571	3.472	0.701	4.266	0.721	4.387	0.561	3.413
S	1.150	3.446	0.720	2.158	0.940	2.818	0.807	2.418
Z	0.651	1.921	0.487	1.437	0.437	1.290	0.417	1.229

S_1-100% RDF, S_2-75% RDF, S_3-75% RDF + biofertilizer, S_4-50% RDF, S_5-50% RDF + biofertilizer, Z_1-10 kg $ZnSO_4$ ha^{-1}, Z_2-25 kg $ZnSO_4$ ha^{-1}
DAT – Days After Transplanting

Under SRI method of cultivation number of tillers hill^{-1} varied from 20.9 at 30 DAT to 50.6 at harvest whereas under conventional method it was 9.9 at 30 DAT to 11.7 at harvest (Table 2). Increase in number of tillers m^{-2} by planting younger seedlings has been observed (Yamah, 2002). The rice seedling transplanted before the fourth phyllochron stage, when they are around 8 - 12 days produced the highest number of tillers and rooting (Nemoto *et al.,* 1995; Uphoff, 2001). Significantly higher dry matter production of the crop was recorded in SRI method at 30 DAT (4.56 t ha^{-1}) as compared to conventional method of cultivation (1.96 t ha^{-1}).

A similar trend was observed in 60, 90 DAT and at harvest (Table 3 & 4). Rice seedlings when carefully planted at younger stage by minimizing transplanting shock are to be provided enough space to express their full potentials in terms of growth of leaves, tillers and roots. These plants recovered fast enough and started absorbing nutrients and water to support faster growth and higher dry matter production. A higher shoot and root dry matter production with planting of younger seedlings than with older seedlings was also reported by Sarath and Thilak (2004).

Table 2. Effect of SRI and conventional methods of cultivation, fertilizer levels and biofertilizer on number of tillers hill^{-1}

Fertilizer levels	Number of tillers hill^{-1}											
	30 DAT			60 DAT			90 DAT			At Harvest		
	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean
M_1 (SRI method of cultivation)												
S_1	26.3	29.3	**27.8**	51.0	66.3	**58.6**	53.0	67.0	**60.0**	51.6	64.6	**58.1**
S_2	16.6	21.3	**19.0**	44.0	55.3	**50.1**	45.6	57.0	**51.3**	44.3	55.0	**49.6**
S_3	29.3	35.3	**32.3**	56.0	70.0	**63.0**	58.3	72.6	**65.5**	57.3	70.3	**63.8**
S_4	10.0	12.3	**11.1**	34.0	43.3	**38.6**	36.0	45.0	**40.5**	33.0	42.6	**37.8**
S_5	13.0	16.0	**14.5**	37.6	50.3	**44.0**	39.0	49.6	**44.3**	37.6	50.0	**43.8**
Mean	**19.0**	**22.8**	**20.9**	**44.5**	**57.2**	**50.9**	**46.4**	**58.2**	**52.3**	**44.7**	**56.5**	**50.6**
M_2 (Conventional method of cultivation)												
S_1	11.0	15.0	**13.0**	12.6	17.6	**15.1**	15.0	20.3	**17.6**	11.2	14.3	**12.7**
S_2	6.0	10.0	**8.0**	11.0	13.0	**12.0**	15.3	14.6	**13.5**	10.0	13.0	**11.5**
S_3	16.6	21.0	**18.8**	17.0	24.0	**20.5**	20.6	26.0	**22.3**	15.2	17.3	**16.2**
S_4	2.3	5.0	**3.6**	5.0	9.0	**6.6**	6.6	10.3	**8.5**	6.3	9.0	**7.6**
S_5	4.0	8.6	**6.3**	8.6	11.6	**10.1**	10.3	12.6	**11.5**	9.0	12.0	**10.5**
Mean	**7.9**	**11.9**	**9.9**	**10.8**	**14.9**	**12.9**	**13.5**	**16.8**	**14.7**	**10.3**	**13.1**	**11.7**
Fertilizer and Zn interaction over method of cultivation												
S_1	18.6	22.1	**20.4**	31.8	42.0	**36.9**	33.0	43.6	**38.8**	31.4	39.4	**35.4**
S_2	11.3	15.6	**13.5**	27.5	34.6	**31.0**	29.0	35.8	**32.4**	27.1	34.0	**30.5**
S_3	22.9	28.1	**25.5**	36.5	47.0	**41.7**	38.5	49.3	**43.9**	36.2	43.8	**40.0**
S_4	6.1	8.6	**7.4**	19.5	25.8	**22.6**	21.3	27.6	**24.5**	19.6	25.8	**22.7**
S_5	8.5	12.3	**10.4**	23.1	31.0	**27.0**	24.6	31.1	**27.9**	23.3	31.0	**27.1**
Mean	**13.4**	**17.3**	**15.4**	**27.7**	**36.1**	**31.9**	**29.5**	**37.5**	**33.5**	**27.5**	**34.8**	**31.1**
Source	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
M	0.638		3.880	0..912		5.549	0.557		3.391	1.027		6.246
S	0.866		2.596	0.757		2.268	0.981		2.939	0.736		2.206
Z	0.424		1.249	0.418		1.232	0.418		1.232	0.679		2.002

S_1-100% RDF, S_2-75% RDF, S_3-75% RDF + biofertilizer, S_4-50% RDF, S_5-50% RDF + biofertilizer, Z_1-10 kg $ZnSO_4$ ha^{-1}, Z_2-25 kg $ZnSO_4$ ha^{-1}
DAT – Days After Transplanting

In SRI, specific water management practices include providing alternate oxidized and reduced conditions to the soil that both aerobic and anaerobic microorganisms can grow and die in alternating conditions and their continuous decomposition supplies nutrients to the soil (Ceesay *et al.,* 2006). Nitrogen losses through nitrification and denitrification can also occur due to alternate wetting and drying conditions. But not much nitrogen losses expected in SRI compared to conventional method due to rapid change of wetting and drying conditions in soil. Milkha *et al.,* (1997) revealed that N losses from nearly saturated soil were 14 percent lower than from flooded soil. Sufficient space, along with other favorable conditions, allows the plant roots to grow profusely both vertically and horizontally to cover a larger area. When roots are spread to a large volume of soil, they tap more nutrients, which results in the development of taller and larger plants with larger numbers of tillers, dry matter and grains (Barison, 2002).

Table 3. Effect of SRI and conventional method of cultivation, fertilizer levels and biofertilizer on dry matter production (t ha^{-1}) of rice

Fertilizer levels	Dry matter production (t ha^{-1})								
	30 DAT			60 DAT			90 DAT		
	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean
M_1 (SRI method of cultivation)									
S_1	4.63	6.13	**5.38**	9.72	12.05	**10.88**	12.13	15.46	**13.79**
S_2	3.73	5.08	**4.40**	9.05	11.15	**10.10**	10.84	13.53	**12.18**
S_3	5.85	6.97	**6.41**	11.24	14.57	**12.90**	14.94	17.31	**16.12**
S_4	2.48	3.67	**3.07**	7.63	9.80	**8.71**	7.95	10.56	**9.25**
S_5	3.03	4.09	**3.56**	8.25	10.37	**9.31**	9.43	12.23	**10.83**
Mean	**3.94**	**5.18**	**4.56**	**9.17**	**11.58**	**10.37**	**11.05**	**13.81**	**12.43**
M_2 (Conventional method of cultivation)									
S_1	1.93	3.37	**2.65**	3.56	6.14	**4.85**	4.42	8.12	**6.27**
S_2	1.15	2.40	**1.77**	2.74	4.91	**3.82**	3.02	5.84	**4.43**
S_3	2.31	3. 97	**3.14**	5.39	7.54	**6.46**	6.05	9.91	**7.98**
S_4	0.60	1.41	**1.00**	1.54	3.88	**2.71**	2.38	4.67	**3.52**
S_5	0.67	1.82	**1.24**	1.99	4.03	**3.01**	2.76	5.03	**3.89**
Mean	**1.33**	**2.59**	**1.96**	**3.04**	**5.30**	**4.17**	**3.72**	**6.71**	**5.21**
Fertilizer and Zn interaction over method of cultivation									
S_1	3.28	4.75	**4.01**	6.64	9.09	**7.86**	8.27	11.79	**10.03**
S_2	2.44	3.74	**3.08**	5.89	8.03	**6.96**	6.93	9.68	**8.30**
S_3	4.08	5.47	**4.77**	8.31	11.05	**9.68**	10.49	13.61	**12.05**
S_4	1.54	2.54	**2.03**	4..58	6.84	**5.71**	5.16	7.61	**6.38**
S_5	1.85	2.95	**2.40**	5.12	7.20	**6.16**	6.09	8.63	**7.36**
Mean	**2.54**	**3.88**	**3.17**	**6.01**	**8.44**	**7.22**	**7.38**	**10.26**	**8.82**

Source	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**	**S.Em±**	**CD at 5%**
M	0.071	0.4.36	0.165	1.009	0.099	0.603
S	0.086	0..258	0.352	1.056	0.311	0.933
Z	0.046	0.136	0.168	0.497	0.136	0.402

S_1-100% RDF, S_2-75% RDF, S_3-75% RDF + biofertilizers, S_4-50% RDF, S_5-50% RDF + biofertilizer, Z_1-10 kg $ZnSO_4$ ha^{-1}, Z_2-25 kg $ZnSO_4$ ha^{-1}
DAT – Days after Transplanting

In the conventional method, transplanting 30 days older seedling in more dense, with transplanting shock and improper root development in the initial stage and more N losses by leaching and denitrification in flooded conditions, the applied nutrients particularly N might not have been absorbed in sufficient quantities resulted in lower plant height, fewer number of tillers hill^{-1} and lower dry matter production. The number of productive tillers m^{-2} (792), 1000 grain weight (26.9 g), grain yield (7.25 t ha^{-1}) and straw yield (7.85 t ha^{-1}) in SRI method differed significantly as compared to conventional method of cultivation (Table 4). The higher grain yield recorded in the SRI method might be the result of increased yield attributes such as productive tillers m^{-2} and 1000 grain weight which resulted due to planting of younger seedlings. Many researchers reported increased grain and straw yields by planting younger seedlings than older seedlings (Yamah, 2002; Sarath and Thilak, 2004 and Uphoff, 2005). The difference in straw yield between SRI method and conventional method may be related to the variations in number of tiller production in plant.

Effect of nutrient levels

Nutrient levels had significant effect on plant height, number of tillers hill^{-1} and dry matter production at all the growth stages. At 30 DAT, the application of 75 percent RDF + biofertilizer recorded significantly increased plant height (58.1 cm), number of tillers hill^{-1} (25.5) and dry matter production (4.77 t ha^{-1}) (Table 1, 2 & 3).

Similar trend was obtained at other growth stages. Similarly, the significantly highest productive tillers m^{-2} (873), 1000 grain weight (28.8 g), grain yield (7.63 t ha^{-1}) and straw yield (9.56 t ha^{-1}) were recorded in 75 percent RDF + biofertilizer (Table 4). This higher response of rice plants was mainly due to low NPK status of the site (800 mg kg^{-1} of total N, 8 mg kg^{-1} of Olsen P and 0.21 meq/100g of exchangeable K). The above ground biomass production to a greater extent depends upon the production of sufficient numbers of tillers per plant which are a function of N availability (Devasenamma *et al.,* 1999). The availability of required quantity of nitrogen for long period of time was probably responsible for producing more number of effective tillers. In the present study, it was observed that 75 percent RDF + biofertilizer significantly promoted tiller production at different stages and inturn contributed to higher dry matter production.

The highest growth and yield parameters achieved in treatment receiving 75 per cent RDF + biofertilizers could be due to continuous supply of nutrients and growth promoting substances throughout its growth stages from RDF and biofertilizers. *Azospirillum* inoculation control of plant pathogens, proliferation of beneficial organisms in the rhizosphere enhanced the nitrogen availability to rice plants as it can fix 25 to 40 kg N ha^{-1} yr $^{-1}$ (Ikisan, 2000).

In addition to its high N fixation, *Azospirillum* is known to synthesize growth substances like IAA and other auxins and vitamin B which might have also helped in increasing the plant height, number of tillers, dry matter production and ultimately yield (Tien *et al.,* 1979)**.** In FYM applied with mixing with biofertilizer in treatment 75 percent RDF + biofertilizer also improved the physical and microbiological conditions of the soil, supply nitrogen and enhanced fertilizer use efficiency (Reddy *et al.,* 2006). Inoculation of phosphobacteria, produced a phytohormone, IAA, capacity of nutrient extraction and converted insoluble form of P into soluble forms and made them available to plants which resulted in increased

Table 4. Effect of SRI and conventional method of cultivation, fertilizer levels and biofertilizer on yield and yield attributes

Fertilizer levels	Yield and Yield attributes of rice											
	Productive tillers m^{-2}			1000-grain weight (g)			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean	Z_1	Z_2	Mean
					M_1 (SRI method of cultivation)							
S_1	808	1020	**914**	28.5	30.2	**29.3**	8.26	9.67	**8.96**	8.65	10.83	**9.74**
S_2	700	872	**786**	25.1	28.2	**26.6**	6.23	7.66	**6.95**	7.01	8.62	**7.81**
S_3	898	1121	**1009**	30.2	33.8	**32.0**	8.65	10.94	**9.80**	9.75	11.85	**10.80**
S_4	520	674	**597**	21.8	22.9	**22.3**	3.82	5.22	**4.52**	4.12	5.55	**4.83**
S_5	594	792	**693**	23.3	25.9	**24.6**	5.50	6.57	**6.04**	5.74	7.03	**6.38**
Mean	**688**	**896**	**792**	**25.7**	**28.2**	**26.9**	**6.49**	**8.01**	**7.25**	**7.05**	**8.66**	**7.85**
					M_2 (Conventional method of cultivation)							
S_1	532	702	**617**	23.1	26.5	**24.8**	4.27	5.25	**4.76**	5.84	7.95	**6.89**
S_2	487	628	**557**	21.2	22.3	**21.7**	3.41	4.36	**3.88**	4.36	6.23	**5.29**
S_3	624	850	**737**	24.1	27.3	**25.7**	4.47	6.45	**5.46**	7.11	9.55	**8.33**
S_4	302	428	**365**	20.3	21.0	**20.6**	1.61	2.99	**2.30**	3.50	4.75	**4.12**
S_5	431	586	**508**	22.2	23.0	**22.6**	2.84	3.68	**3.26**	3.63	5.63	**4.63**
Mean	**475**	**639**	**557**	**22.1**	**24.0**	**23.0**	**3.32**	**4.54**	**3.93**	**4.88**	**6.82**	**5.85**
					Fertilizer and Zn interaction over method of cultivation							
S_1	670	861	**765**	25.8	28.3	**27.0**	6..26	7.46	**6.86**	7.24	9.39	**8.31**
S_2	593	750	**671**	23.1	25.2	**24.1**	4.82	6.01	**5.41**	5.68	7.42	**6.55**
S_3	761	985	**873**	27.1	30.5	**28.8**	6.56	8.69	**7.63**	8.43	10.70	**9.56**
S_4	411	551	**481**	21.0	21.9	**21.4**	2.71	4.10	**3.41**	3.81	5.15	**4.48**
S_5	512	689	**600**	22.7	24.4	**23.5**	4.17	5.12	**4.65**	4.68	6.33	**5.50**
Mean	**581**	**767**	**674**	**23.9**	**26.0**	**24.9**	**4.90**	**6.27**	**5.59**	**5.96**	**7.74**	**6.85**
Source	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**	**S.Em±**		**CD at 5%**
M	15.780		96.010	0.331		1.011	0.075		0.456	0.080		0.487
S	12.019		36.016	1.345		3.03	0.064		0.094	0.080		0.259
Z	10.182		30.032	0.293		0.663	0.056		0.165	0.069		0.203

S_1-100% RDF, S_2-75% RDF, S_3-75% RDF + biofertilizers, S_4-50% RDF, S_5-50% RDF + biofertilizer, Z_1-10 kg $ZnSO_4$ ha^{-1}, Z_2-25 kg $ZnSO_4$ ha^{-1}

growth and yield (Ikisan, 2000). Phosphorus played an important role in the translocation of assimilates to the panicles and also as a constituent of protoplasm (Ishizuka, 1971). The significant response may be due to the supply of two major nutrients (N and P) with growth promoting substances to low N (800 mg kg^{-1}) and P (8 mg kg^{-1}) status soil as compared to critical soil N values of 1000 mg kg^{-1} and 0.17 mg kg^{-1} of Olsen P (Bado *et al.,* 2008).
The lowest growth and yield parameters were recorded due to application of 50 percent RDF at all the growth stages. This poor growth of plants could be due to the supply of lower levels of NPK to low fertile soils (800 mg kg^{-1} of total N, 8 mg kg^{-1} of Olsen P and 0.21 meq/ 100g of exchangeable K).

Significantly higher growth and yield parameters were observed with increase in Zn level from 10 kg $ZnSO_4$ ha^{-1} to 25 kg $ZnSO_4$ ha^{-1} at all the growth stages (Table 1, 2, 3 & 4). As Zn is an important part of various enzymes and hormones, it favored increased synthesis of enzymes and hormones along with the metabolization of major nutrients which would in turn promote growth components. The Zn level of the soil was 0.45 mg kg^{-1} before cultivation and it was below the soil critical Zn value of 0.83 mg kg^{-1} (Buri *et al.*, 2004). The favorable effect of Zn might be due to its direct influence on the quantity of auxin production, which in turn enables the plants to grow better (Srinivasan and Naidu, 1998). Number of tillers was influenced by Zn application due to high auxin production (Reddy *et* *al.,* 1984). The combined application of NPK, $ZnSO_4$ and biofertilizers had beneficial effect over their single application. This may be due to the supply of N, P, K and Zn along biofertilizer which supply growth promoting substances, fixing nitrogen and solubilizing phosphates in soil.

CONCLUSIONS

SRI method recorded significantly higher growth and yield as compared to conventional method of cultivation. Application of 75 percent RDF + biofertilizer with 25 kg $ZnSO_4$ ha^{-1} showed significantly higher growth and yield than other treatment tested.

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