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Growth and Yield Response of Rice to Various Levels of Fertility, Sulfur and Zinc under Transplanted Condition

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Abstract

Morpho-physiological analysis of growth and yield in rice as affected by fertility levels with sulfur and zinc application revealed that increasing fertility levels manifested significantly higher total tiller/m^2, leaf area index, dry matter production, crop growth rate and straw yield upto 160-80-80 kg N-P_2O_5-K_2O/ha. Significant increase in grain yield was, however, recorded only upto 120-60-60 kg N-P_2O_5-K_2O/ha while the relative growth rate and net assimilation rate showed declining trend with increasing fertility levels. Increasing sulfur level upto 25 kg S/ha significantly improved total tiller/m^2, dry matter production/hill, crop growth rate and grain yield, while, leaf area index and straw yield showed significant response upto 50 kg S/ha. Sulfur application failed to cause significant variation in physiological characters i.e. relative growth rate, net assimilation rate and harvest index. Foliar spray of Zn EDTA upto 0.75 kg Zn EDTA/ha resulted in significant increase in total tiller/m^2, dry matter production, grain and straw yield while leaf area index improved significantly upto 1.5 kg Zn EDTA/ha. The crop growth rate increased with increase in zinc application only between tillering to panicle initiation while relative growth rate and net assimilation rate were not affected due to zinc application.

Key words : Crop growth rate, Leaf area index, Net assimilation rate, Relative growth rate.

Agricultural production being an interactive effect of soil-water-fertilizer-climate continuum, a wise scientific management of this complex system is crucial for enhancing crop productivity on a sustained basis without any detrimental effect to the environmental ecology. Among the various inputs inputs, the mineral nutrition of plants is considered as the key input in making maximum contribution to the crop productivity (1) as nearly 55% of increase in food grain production during the last two decades has come through increased fertilizer use. However, the total annual removal of plant nutrient by the crops and cropping systems being much higher than the amount added through the fertilizers, has resulted in a negative nutrient balance. This gap between nutrient removal and their replenishment along with imbalanced use of NPK fertilizers and emerging deficiency of sulfur and micronutrients specially zinc in the submerged rice have led to a decline in rice productivity and deleterious effect on soil productivity and health (2). So, if prompt action is not taken to solve the problem, the unavoidable consequences will be reduction in yield and production. This will result in, reduced efficiency of other inputs with increased production cost. So, now the time has come when proper weightage on secondary and micronutrients along with recommended NPK must be given to make rice production sustainable, productive and nutritious. Keeping in view the significance of balanced fertilization, a field experiment was conducted to study the efficacy of fertility levels with sulfur and zinc application on growth and yield of rice to formulate a sound fertilizer schedule in rice grown in alluvial soils of Varanasi.

Methods

A field experiment was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to study the effect of various levels of fertility, sulfur and zinc application on growth and yield of transplanted rice. The experiment was laid out in split plot design with three replications keeping three fertility levels (80-40-40 ; 120-60-60 and 160-80-80 kg N-P_2O_5-K_2O/ha) in the main plot, three sulfur levels (control, 25 and 50 kg S/ha) in the sub-plot and three zinc levels (control, 0.75 and 1.50 kg Zn EDTA/ha as foliar spray) in the ulti-

Table 1. Effect of fertility, sulfur and zinc levels on tiller number and leaf area index at different growth stages of rice.

	Total tiller//m^2 (No.)							
	Tillering stage		Panicle initiation stage		Flowering stage		Maturity stage	
Treatments	2000	2001	2000	2001	2000	2001	2000	2001
Fertility Levels N-P_2O_5-K_2O (kg/ha)								
80-40-40	318.96	343.10	407.98	434.82	331.30	356.81	263.96	304.33
120-60-60	385.52	420.23	487.75	530.84	406.55	424.94	334.30	366.07
160-80-80	432.24	459.97	539.49	578.65	455.97	465.73	387.26	394.48
SE ±	11.54	9.29	11.42	8.05	9.17	5.51	11.23	5.23
CD (*P* = 0.05)	45.30	36.46	44.82	31.59	35.98	21.61	44.10	20.54
Sulfur Levels (kg/ha)								
0	353.12	378.00	444.03	481.77	357.38	386.87	296.41	330.19
25	383.64	409.70	483.80	520.62	410.87	424.08	335.33	359.89
50	399.96	435.60	507.39	541.91	425.58	436.53	353.78	374.81
SE ±	8.82	8.62	8.89	7.63	5.46	4.69	6.07	5.14
CD (*P* = 0.05)	27.18	26.55	27.40	23.50	16.84	14.46	18.69	15.84
Zinc EDTA Foliar Spray (kg/ha)								
0	373.04	403.20	464.61	503.75	382.51	404.25	314.85	342.56
0.75	380.32	408.80	481.80	517.93	399.67	418.83	330.48	356.19
1.5	383.36	411.30	488.81	522.63	411.64	424.39	340.19	366.15
SE ±	7.18	6.68	9.08	5.51	5.69	4.65	5.23	3.99
CD (P = 0.05)	NS	NS	NS	NS	16.35	13.37	15.03	11.47

Table 1. Continued.

	Leaf area Index (LAI)							
	Tillering stage		Panicle initiation stage		Flowering stage		Maturity stage	
Treatments	2000	2001	2000	2001	2000	2001	2000	2001
Fewrtility Levels N-P_2O_5 -K_2O (kg/ha)								
80-40-40	1.13	1.36	2.56	2.95	3.20	3.46	1.74	1.84
120-60-60	1.54	1.85	3.41	4.07	4.26	4.93	2.34	2.82
160-80-80	1.75	2.10	3.95	4.58	4.90	5.64	2.78	3.26
SE ±	0.05	0.06	0.06	0.06	0.10	0.12	0.09	0.08
CD (*P* = 0.05)	0.19	0.22	0.25	0.24	0.38	0.45	0.34	0.31
Sulfur Levels (kg/ha)								
0	1.30	1.59	2.91	3.32	3.61	3.95	2.03	2.23
25	1.49	1.79	3.37	3.96	4.21	4.79	2.33	2.67
50	1.64	1.93	3.64	4.31	4.54	5.28	2.50	3.01
SE ±	0.04	0.04	0.04	0.05	0.06	0.08	0.04	0.04
CD (P = 0.05)	0.11	0.13	0.14	0.14	0.18	0.23	0.12	0.14
Zinc EDTA Foliar Spray (kg/ha)								
0	1.45	1.74	3.16	3.68	3.95	4.34	2.16	2.46
0.75	1.48	1.77	3.33	3.91	4.13	4.72	2.30	2.67
1.5	1.50	1.80	3.43	4.01	4.28	4.97	2.40	2.79
SE ±	0.02	0.02	0.04	0.04	0.05	0.05	0.03	0.03
CD (P = 0.05)	NS	NS	0.11	0.11	0.14	0.14	0.08	0.08

Table 2. Effect of fertility, sulfur and zinc levels on dry matter production and crop growth rate at different growth stages of rice.

Treatments	Dry weight/hill (g) Tillering stage		Panicle initiation stage		Flowering stage		Maturity stage		Crop growth rate (g/m^2/day) Tillering stage to Panicle initiation stage		Panicle initiation stage to Flowering stage		Flowering stage to Maturity stage	
	2001	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Fertility Levels $N-P_2O_5-K_2O$ (kg/ha)														
80-40-40	1.96	2.37	7.94	10.76	19.92	25.67	26.84	29.06	6.64	9.33	13.30	16.56	9.23	4.04
120-60-60	2.90	3.37	10.66	13.59	24.50	30.88	33.59	35.34	8.62	11.36	15.38	19.20	12.12	5.32
160-80-80	3.61	4.00	12.55	15.23	28.23	34.04	37.56	38.56	9.94	12.49	17.41	20.90	12.11	5.37
SE ±	0.12	0.14	0.41	0.33	0.62	0.51	0.76	0.60	0.33	0.21	0.46	0.53	0.97	0.44
CD (P = 0.05)	0.49	0.54	1.62	1.28	2.42	2.00	2.97	2.37	1.30	0.83	1.82	2.08	NS	NS
Sulfur Levels (kg/ha)														
0	2.42	2.82	9.08	12.06	22.18	27.98	29.93	31.62	7.40	10.26	14.56	17.69	10.33	4.33
25	2.89	3.30	10.65	13.36	24.75	30.65	33.47	34.89	8.63	11.18	15.66	19.21	11.63	5.05
50	3.17	3.61	11.43	14.17	25.72	31.96	34.35	36.46	9.17	11.74	15.88	19.77	11.51	5.35
SE ±	0.12	0.13	0.29	0.29	0.35	0.45	0.54	0.52	0.24	0.22	0.44	0.23	0.80	0.37
CD (P = 0.05)	0.37	0.39	0.88	0.88	1.07	1.38	1.67	1.61	0.73	0.68	NS	0.71	NS	NS
Zinc EDTA Foliar Spray (kg/ha)														
0	2.74	3.13	9.77	12.77	23.13	29.03	31.06	32.87	7.80	10.71	14.85	18.07	10.57	4.57
0.75	2.85	3.27	10.52	13.26	24.40	30.41	32.78	34.57	8.52	11.10	15.42	19.05	11.17	4.95
1.5	2.88	3.33	10.87	13.56	25.12	31.15	33.91	35.53	8.87	11.37	15.83	19.55	11.73	5.21
SE ±	0.06	0.07	0.19	0.24	0.33	0.44	0.46	0.40	0.17	0.21	0.31	0.52	0.52	0.16
CD (P = 0.05)	NS	NS	0.54	0.68	0.94	1.27	1.33	1.16	0.49	NS	NS	NS	NS	0.47

mate plot. Rice variety Swarna (MTU-7029) was taken as the test crop. The soil of the experimental field was Gangetic alluvial (Ustochrept) with pH 7.3. It was moderately fertile being low in organic carbon (0.42%), available nitrogen (210.0 kg/ha), sulfur (18.10/kg ha) and zinc (0.45 kg/ha) and medium in available P_2O_5 (27.6 kg/ha) and K_2O (235.0 kg/ha). Nutrients were applied based on treatment. Requisite quantity of full P_2O_5 in the form of diammonium phosphate. K_2O through muriate of potash, S (50% each through ammonium sulfate and elemental sulfur) along with half nitrogen (DAP, ammonium sulfate and urea) was applied as basal application. Foliar spraying of 0.02% Zn-EDTA was done at 20, 35 and 50 days after transplanting. Plant sampling was made at tillering, panicle initiation, flowering and at harvest to record the growth parameters such as total tiller/m^2, leaf area index, dry matter production/hill, crop growth rate, relative growth rate and net assimilation rate while the grain yield, straw yield and harvest index were recorded at harvest. The grain and straw yields were recorded from the net plot (12 m^2) of each treatment to compute the yield per hectare.

Results and Discussion

Number of Tillers

The results of the growth parameters revealed that tiller production increased sharply from active tillering to panicle initiation stage and declined gradually towards flowering and at maturity stage. The reduction in tillers after panicle ignition stage was due to intraspecies competition for higher space and nu-

Table 3. Effect of fertility, sulfur and zinc levels on relative growth rate and net assimilation rate at different growth stages of rice.

	Relative growth rate (g/g/day)						Net assimilation rate (g/m^2/day)					
	Tillering stage to Panicle initiation stage		Panicle initiation stage to Flowering stage		Flowering stage to Maturity stage		Tillering stage to Panicle initiation stage		Panicle initiation stage to Flowering stage		Flowering stage to Maturity stage	
Treatments	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Fertility Levels N-P_2O_5-K_2O (kg/ha)												
80-40-40	0.0468	0.0511	0.0308	0.0291	0.0123	0.0044	3.80	4.58	4.63	5.27	3.99	1.62
120-60-60	0.0438	0.0467	0.0280	0.0274	0.0125	0.0049	3.69	4.05	4.08	4.34	3.74	1.42
169-80-80	0.0415	0.0448	0.0273	0.0268	0.0111	0.0045	3.67	3.97	4.01	4.12	3.25	1.25
SE ±	0.0006	0.0008	0.0009	0.0008	0.0009	0.0004	0.19	0.15	0.17	0.17	0.32	0.17
CD (P = 0.05)	0.0023	0.0032	NS	NS	NS	NS	NS	NS	NS	0.66	NS	NS
Sulfur Levels (kg/ha)												
0	0.0450	0.0493	0.0298	0.0283	0.0125	0.0044	3.72	4.44	4.48	5.04	3.99	1.50
25	0.0443	0.0471	0.0283	0.0279	0.0120	0.0047	3.77	4.13	4.21	4.48	2.68	1.44
50	0.0427	0.0462	0.0279	0.0272	0.0114	0.0047	3.67	4.03	4.03	4.22	3.31	1.34
SE ±	0.0010	0.0008	0.0011	0.0003	0.0008	0.0004	0.13	0.09	0.14	0.08	0.25	0.13
CD (P = 0.05)	NS	NS	NS	0.0009	NS	NS	NS	0.28	NS	0.24	NS	NS
Zinc EDTA Foliar Spray (kg/ha)												
0	0.0427	0.0478	0.0293	0.0275	0.0119	0.0045	3.57	4.23	4.29	4.70	3.62	1.43
0.75	0.0440	0.0473	0.0285	0.0279	0.0119	0.0046	3.75	4.18	4.24	4.53	3.66	1.42
1.5	0.0452	0.0475	0.0282	0.0279	0.0121	0.0047	3.84	4.19	4.20	4.50	3.69	1.42
SE ±	0.0006	0.0006	0.0006	0.0007	0.0006	0.0002	0.07	0.09	0.11	0.12	0.19	0.05
CD (P = 0.05)	0.0018	NS	NS	NS	NS	NS	0.21	NS	NS	NS	NS	NS

trients which are responsible for degeneration of late formed tillers (Table 1). Irrespective of growth stages, graded fertility levels manifested marked variation in the number of tillers/m^2 and were significantly higher under high fertility level (160-80-80 kg N-P_2O_5-K_2O/ha). Significant enhancement in tillers/m^2 was also recorded due to sulfur application upto 25 kg/ha. Zinc levels did not cause significant differences in tillers production at tillering and panicle initiation stage, as 50 days were required for the completion of foliar spray of zinc. However, at flowering and maturity stage significant improvement in total tillers/m^2 was recorded upto 0.75 kg Zn EDTA/ha. Increase in zinc application enhanced the activity of fructose 1-5 biphosphate and aldolase which regulated the transfer of photosynthate affecting the sucrose synthesis facilitating better nutritional benefits from the mother culm to the developing tillers resulting in increase in the number of tillers as reported by Shrotri et al. (3).

Leaf Area Index

The leaf area index of crop increased successively with each increment in fertility levels and the maximum leaf area index was recorded with the highest fertility levels (160-80-80 kg N-P_2O_5-K_2O/ha) but the extent of increase was found maximum at panicle initiation stage followed by flowering stage of plant growth (Table 1). Similarly, the higher sulfur level (50 kg S/ha) manifested significantly higher leaf area index as compared to their lower level (25 kg S/ha and control). Among the zinc levels, foliar spraying of 1.5 kg Zn EDTA/ha registered significantly higher leaf area index than those of 0.75 kg Zn EDTA/ha and control at all stages except at tillering stage where the magnitude of variation in leaf area index was statistically not significant.

Table 4. Effect of fertility, sulfur and zinc levels on grain yield, straw yield and harvest index of rice.

Treatments	Grain yield (kg/ha) 2000	Grain yield (kg/ha) 2001	Straw yield (kg/ha) 2000	Straw yield (kg/ha) 2001	Harvest index 2000	Harvest index 2001
Fertility Levels N-P_2O_5-K_2O (kg/ha)						
80-40-40	4343	4728	6609	7007	39.82	40.41
120-60-60	5146	5583	8352	8633	38.27	39.31
160-80-80	5425	5889	9360	9629	36.69	38.01
SE ±	121	121	219	247	0.75	0.40
CD (P = 0.05)	475	477	859	970	2.94	1.56
Sulfur Levels (kg/ha)						
0	4634	5074	7342	7792	39.01	39.65
25	5054	5472	8221	8545	38.25	39.26
50	5226	5654	8759	8932	37.52	38.82
SE ±	72	61	186	223	0.53	0.49
CD (P = 0.05)	223	188	574	688	NS	NS
Zinc EDTA Foliar Spray (kg/ha)						
0	4784	5228	7564	8036	39.04	39.54
0.75	5023	5469	8253	8514	38.10	39.29
1.5	5106	5503	8504	8718	37.64	38.90
SE ±	59	65	100	114	0.33	0.29
CD (P = 0.05)	170	188	287	328	0.96	NS

Dry Matter Accumulation

The dry matter production/hill increased as the growth progressed value being maximum at harvest. There was signifiant increas in dry weight/hill with corresponding increase in fertility levels upto 160-80-80 kg N-P_2O_5-K_2O/ha at all growth stages in both the years (Table 2). Increasing sulfur level tended to increase the dry weight/hill upto the highest sulfur level i.e. 50 kg/ha. However, significant increase in dry weight/hill was recorded only upto 25 kg S/ha at all the growth stages. Foliar application of Zn EDTA though did not caused significant difference in dry weight/hill at tillering, but at later growth stage the dry matter accumulation was significantly enhanced with increasing zinc level upto 0.75 kg Zn EDTA/ha. The mineral nutrients are directly involved in the synthesis of proteins, chloroplast pigments and electron transfer, thus increasing NPK rates, sulfur and zinc resulted in an increased photosynthetic efficiency of rice plant which naturally accounts for higher dry matter accumulation.

Crop Growth Rate

Pronounced improvement in the crop growth rate was observed between panicle initiation-flowering stage and thereafter declined till harvest. Fertility levels had positive influence on crop growth rate and application of higher fertility level (160-80-80 kg N-P_2O_5-K_2O/ha) resulted in significantly higher crop growth rate than that of 120-60-60 kg N-P_2O_5-K_2O/ha level between tillering-panicle initiation stage in both the years and between panicle initiation-flowering stage in the first year only (Table 2). However, application of 120-60-60 kg N-P_2O_5-K_2O/ha was significantly superior over 80-40-40 kg N-P_2O_5-K_2O/ha between tillering-panicle initiation stage and panicle initiation-flowering stage during both the years. The crop growth rate increased with the increasing sulfur levels and the highest crop growth rate was observed with the highest sulfur level. However, significant improvement in crop growth rate could be obtained only upto 25 kg S/ha between tillering-panicle initiation stage in both the years and between panicle initiation-flowering stage during second year. The significant increase in crop growth rate was recorded upto 0.75 kg Zn EDTA/ha at tillering-panicle initiation stage in the first year and at flowering stage-harvest during the second year. Application of 1.5 kg Zn EDTA/ha proved superior over control but remained at par with 0.75 kg Zn EDTA/ha between flowering stage to harvest during second year while, at other stages the zinc level failed to cause significant effect on crop growth rate.

Relative Growth Rate

Relative growth rate showed the declining trend from the start till maturity of the crop. Contrary to the crop growth rate, an inverse relationship was observed between fertility level and relative growth rate. Between tillering-panicle initiation, the fertility level caused significant reduction in relative growth rate upto 160-80-80 kg N-P_2O_5- K_2O/ha and 120-60-60 kg N-P_2O_5-K_2O/ha during first and second year respectively. However, at other stages the variation in relative growth rate due to fertility level was found to be non-significant (Table 3). The relative growth rate decreased significantly with increase in sulfur rate from control to 50 kg S/ha between panicle initiation-flowering stage during the second year. At other stages, the variation in relative growth rate due to sulfur levels could not reach to the level of significance. The relative growth rate decreased with increase in zinc rate upto 1.5 kg Zn EDTA/ha which was significantly lower than control but remained at par with 0.75 kg Zn EDTA/ha between tillering-panicle initiation during the first year. At other stages the zinc level failed to cause significant effect on relative growth rate.

Net Assimilation Rate

Marked improvement in the net assimilation rate were observed between panicle initiation-flowering stage and thereafter declined till harvest. Fertility levels failed to cause significant variation in net assimilation rate between different growth stages except between panicle initiation-flowering stage during second year where application of 120-60-60 kg N-P_2O_5-K_2O/ha and 160-80-80 kg N-P_2O_5-K_2O/ha levels caused significant reduction in net assimilation rate as compared to 80-40-40 kg N-P_2O_5-K_2O/ha fertility level (Table 3). The net assimilation rate also decreased significantly with application of sulfur at 25 kg S/ha and 50 kg S/ha between tillering-panicle initiation stage and panicle initiation-flowering stage respectively, during the first year while, at other stages, the variation in net assimilation rate due to sulfur levels could not reach to the level of significance. The net assimilation rate decreased with increase in zinc rate upto 1.5 kg Zn EDTA/ha which was significantly lower than control but remained at par with 0.75 kg Zn EDTA/ha between tillering-panicle initiation stage during the first year. At other stages the zinc level failed to cause significant effect on net assimilation rate. Increasing rates of nutrient application i.e. fertility, sulfur and zinc favored higher vegetative growth resulting in higher leaf area so that the lower leaves of the plant were unable to photosynthesize and to grow below the compensation point and the photosynthate synthesized by the upper leaves were utilized by themselves thus lowering down the relative growth rate and net assimilation rate.

Grain and Straw of Rice

There was significant increase in grain yield with the increasing fertility level upto 120-60-60 kg N-P_2O_5-K_2O/ha while, the straw yield significantly increased upto 160-80-80 kg N-P_2O_5-K_2O/ha (Table 4). Increasing fertility levels delays senescence and increases the life cycle of plant resulting in higher economic yield. Marked improvement in grain and straw yield were also noticed with the application of 25 kg S/ha and 50 kg S/ha which produced significantly higher grain and straw yield, respectively. In zinc levels, foliar application of 0.75 kg Zn EDTA/ha was found to be most effective in enhancing grain and straw yield. The harvest index was significantly higher under low nutrients level (80-40-40 kg N-P_2O_5-K_2O/ha) than under high level of nutrient fertilization (120-60-60 kg N-P_2O_5-K_2O/ha and 160-80-80 kg N-P_2O_5-K_2O/ha). Whereas, sulfur levels failed to cause significant variation in harvest index. Increasing zinc level resulted in reduction of harvest index culminating to significant difference between control and highest level (1.5 kg Zn EDTA/ha). The decrease in harvest index may be attributed to source-sink efficiency factor. Such observation was also made by Saravanam and Ramanathan (4).

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