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Performance evaluation of rice varieties and their response to zinc nutrition in uplands.

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Abstract
The experiment was conducted during *Kharif* 2019 (May – August 2019) at Coconut Research Station, Balaramapuram in randomized block design with varieties as first factor and zinc sulphate application as second factor in three replications with an objective to evaluate the performance of varieties under uplands and their response to Zn nutrition. Among the varieties, Prathyasa (V_3) recorded higher number of panicles m^{-2} and filled grains per panicle, but it was on par with APO 1 (V_2). The yield was also the highest in V_3. Among the different method of Zn application, application of zinc sulphate application through seed priming and foliar application resulted in higher number of panicles m^{-2}, filled grains per panicle and the lowest sterility percentage. The uptake of N was not significant among the varieties; however, P and K uptake were the highest for V_3. Amongst the method of application, S_3 resulted in the highest N and Zn uptake, however, P and K uptake were the highest for S_4. Hence, it could be concluded from the results that Prathyasa was the best variety for uplands and among the method of application of zinc sulphate, seed priming of zinc sulphate (2 g kg^{-1}seed) followed by foliar application of zinc sulphate (0.5%) at active tillering and panicle initiation was found the best.

Key words: Grain yield, Upland rice, Varieties, Zinc sulphate application.

Rice (*Oryza sativa* L.) is the world's second most important cereal crop and it is the staple food of 50 per cent of world population. With the growing population the demand for rice is also escalating. To fulfil this demand the production from the existing rice growing regions should be increased. But the main constraining factor in rice production is the water demand of the crop, as water scarcity is building up in all areas. The water scarcity threatening the sustainability of rice production. So, deviation from the traditional rice cultivation method is inevitable. One of the methods that can be adopted is the upland rice cultivation. But there are many constraints associated with this cultivation method like low productivity, susceptibility to pest and diseases, prone to drought and lack of suitable varieties. When the yield stability of the upland varieties were compared, it was found that the individual yield components was more influenced by the environmental factors than the genetic factors (Shreshta et al., 2012). Developing new varieties through breeding program should be done by understanding about genetic variability of yield contributing traits, interrelationship among them and their relation with yield (Singh et al., 2013). While adopting upland rice cultivation selection of variety is a very crucial step. Zinc (Zn) is one of the essential micronutrients which is required for the normal growth and establishment of crop plants. It is involved in synthesis of nucleic acids, specific proteins such as hormones and their receptors, regulation of several biological and physiological process of the plant. Though only twelve percent of soils are deficient in Zn, high content of P results in reduced uptake of Zn and induces deficiency in plants. Deficiency of Zn can lead to total crop

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failure. The effect of Zn on crop plant differs with the method of application. Among the different method of application, foliar application and seed priming were effective in enhancing the Zn uptake (Nadim et al., 2012) Selection of suitable Zn source and method of application will lead to favourable results.

The experiment was conducted during *Kharif* 2019 (May – August 2019) at Coconut Research Station, Balaramapuram in Randomized Block Design with varieties as first factor and zinc sulphate application as second factor in three replications. Three varieties used for the experiment were Anna 4 (V_1), APO 1 (V_2), and Prathyasa (V_3) and the zinc sulphate application comprised of seed priming with $ZnSO_4$ @ 2g kg^{-1} seed (s_1), foliar application with $ZnSO_4$ @ 0.5 per cent at active tillering stage and panicle initiation stage (S_2), combination of S_1 and S_2 (S_3), soil application of $ZnSO_4$ @ 20 Kg ha^{-1} (s_4), and control (without $ZnSO_4$ application) (S_5). The seeds were dibbled at a spacing of 20 cm × 10cm. Seed rate adopted was 80 kg ha^{-1}. Lime was applied @ 650 kg ha^{-1}. Crop was manured with FYM @ 5 t ha^{-1} and N:P:K @ 90:30:45 kg per ha (Suman, 2018). Nitrogen was applied in three equal splits, K in two equal splits and entire P as basal. The crop was raised under rainfed condition by providing lifesaving irrigation to field capacity when rainfall was not received for a week. Productive tillers were recorded by placing a quadrate of size 0.25 m x 0.25 m from two spots in each treatment plot. Ten panicles were randomly selected from each treatment plot to record the grains per panicle, sterility per cent and 1000 grain weight. Grain yield was recorded from the net plot area and recorded in kg ha^{-1}. Economics was worked out based on the prevailing price of input and market price of grain and straw. All data were statistically analysed except net income and B:C ratio. The treatment means were compared at 5 per cent probability level.

The varieties had significant differences in growth parameters like plant height, tillers m^{-2}, leaf area index, root shoot ratio and dry matter production (Table 1). The variety APO 1 (V_2) recorded the tallest plant, higher root shoot ratio and higher LAI during 40 DAS. However, the variety Prathyasa (V_3) recorded higher tillers m^{-2}, the highest LAI during 60 DAS and the highest dry matter production. Alam et al. (2009a) reported that the difference in the performance of the varieties was due to their difference in growth pattern from seedling stage to harvest stage and its rate of growth. Application of $ZnSO_4$ also significantly influenced the growth parameters except plant height. The enhanced production of indole acetic acid (IAA) might have enhanced the growth characteristics of the crop. Nadim et al. (2012) reported that increase in the availability of zinc enhanced the enzymatic activity,

Table 1. Effect of varieties and zinc sulphate application on growth characters of rice

Treatments	Plant height (cm)			Tillersm^{-2}			LAI		Root shoot ratio	Dry matter production (kg ha^{-1})
	40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS	40 DAS	60 DAS		
Varieties (V)										
V_1	61.27	77.61	97.05	181.33	281.60	330.4	3.34	5.88	0.539	7,863.70
V_2	63.12	89.38	113.17	155.46	290.13	382.7	3.11	6.36	0.632	9,041.28
V_3	61.86	82.18	94.17	185.60	299.46	395.2	3.04	7.07	0.540	9,479.59
SE m (±)	0.85	1.59	2.07	12.112	11.187	16.476	0.12	0.530	0.019	137.51
C.D (0.05)	NS	4.637	6.045	1.60	3.84	4.93	NS	0.18	0.054	400.433
Zinc sulphate application (S)										
S_1	61.12	83.80	99.81	167.11	278.22	368.889	2.48	6.58	0.458	8,745.67
S_2	60.46	83.91	100.67	170.22	293.33	371.556	3.30	6.79	0.594	8,607.40
S_3	63.68	85.37	105.32	182.22	316.00	379.556	3.81	6.59	0.652	9,985.12
S_4	63.17	80.12	100.98	188.44	311.11	370.222	3.61	6.81	0.727	10,237.33
S_5	61.98	82.08	100.53	162.66	253.33	356.889	2.61	5.41	0.423	6,398.76
SE m (±)	1.10	2.05	2.68	15.63	4.96	6.37	0.15	0.23	0.024	177.53
C D (0.05)	NS	NS	NS	2.07	14.443	NS	0.460	0.684	0.070	516.957

metabolic activity and auxin production. Among the method of application, soil application of zinc sulphate @ 20 kg ha^{-1} (S_4) recorded higher root shoot ratio, dry matter production (DMP) and LAI during 60 DAS. However, tillers m^{-2} was found to be higher in S_3

Nutrient uptake was significantly affected by both varieties and zinc sulphate application. Among the varieties, Prathyasa (V_3) resulted in the highest uptake of phosphorous and the potassium uptake was the highest in APO 1 (V_2). The uptake of nitrogen was not significantly affected by varieties (Table 2). The difference in the uptake of NPK and Zn by the varieties were due to the differential ability of varieties to absorb the nutrients. The genetic makeup of the variety, the concentration of nutrients in grain and straw and dry matter production of the crop, all contributed to total uptake of nutrients (Graham and Rengel, 1993; Xie et al., 2008). Zinc sulphate application significantly affected the nutrient uptake, the uptake varied with the method of application also. Uptake of nitrogen and zinc were also found to be higher with soil application of zinc sulphate, meanwhile the uptake of phosphorus and potassium was higher in the treatment, seed priming with zinc sulphate followed by foliar application of zinc sulphate at active tillering and panicle initiation stage. The antagonistic relation between phosphorus

Table 2. Effect of varieties and zinc sulphate application on nutrient uptake of rice

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Zn uptake (kg ha^{-1})
Varieties (V)				
V_1	96.54	80.90	140.93	0.191
V_2	105.64	65.49	171.53	0.236
V_3	106.60	82.90	150.00	0.329
SE m (±)	3.651	1.672	4.056	0.007
C.D (0.05)	NS	4.853	11.809	0.021
Zinc sulphate application (S)				
S_1	80.56	64.62	124.77	0.122
S_2	91.86	89.39	142.55	0.223
S_3	125.78	91.84	199.55	0.377
S_4	143.75	83.44	188.11	0.450
S_5	72.69	55.88	115.77	0.088
SE m (±)	4.714	2.164	5.236	0.009
C D (0.05)	13.725	6.265	15.246	0.028

Table 3. Interaction effect of varieties and zinc sulphate application on nutrient uptake of rice

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Zn uptake (kg ha^{-1})
v_1s_1	82.56	67.22	123.00	0.081
v_1s_2	101.41	87.58	138.00	0.175
v_1s_3	100.57	88.37	165.33	0.308
v_1s_4	122.53	89.00	157.33	0.315
v_1s_5	75.65	72.36	121.00	0.075
v_2s_1	74.42	56.05	133.33	0.139
v_2s_2	82.25	80.93	152.66	0.148
v_2s_3	149.09	91.47	238.00	0.336
v_2s_4	159.15	71.50	216.66	0.493
v_2s_5	63.32	27.98	117.00	0.065
v_3s_1	84.72	70.60	118.00	0.145
v_3s_2	91.93	90.67	137.00	0.346
v_3s_3	127.69	95.67	195.33	0.486
v_3s_4	149.59	90.27	190.33	0.541
v_3s_5	79.11	67.30	109.33	0.125
SE m (±)	23.773	10.852	9.069	0.016
C.D (0.05)	8.164	3.747	26.406	0.048

and zinc might be the reason for low uptake in soil application of zinc sulphate. Srivastava et al. (2013) observed that, an increase in the concentration of zinc in the soil affects the phosphorus uptake.

The varieties and zinc sulphate application resulted in significant difference in yield parameters (Table 4) and the yield (Table 6). The number of panicle m^{-2} was found to be higher in the variety Prathyasa (V_3) and it was on par with Apo 1 (V_2). The varieties also recorded higher tiller m^{-2} at all stages of growth, which might be the reason for higher productive tillers. Better metabolic activity in the early stages of crop growth also contributed to higher tillers and productive tillers (Kohli et al., 1997; Khalifa et al., 2014). Variety V_1 (Anna 4) recorded the highest panicle length and the variety V_2 (APO 1) recorded the highest panicle weight, this was due to the genetic makeup of the varieties. Lestari et al. (2015) observed that the characters like panicle length and panicle weight were more influenced by the genetic makeup. Prathyasa (V_3) resulted in higher number of filled grains per panicle and it was on par with V_2 (Apo 1). This might be due to enhanced production of photosynthates, translocation, better development of sink and accumulation of photosynthates in sink (Mobasser et al., 2007).

Table 4. Effect of varieties and zinc sulphate application on yield attributing characters of rice

Treatments	Number of panicles m^{-2}	Panicle length (cm)	Panicle weight (g)	Filled grains per panicle (No.)	Sterility percentage		Thousand grain weight (g)
Varieties (V)							
V_1	291.73	26.72	12.57	140.1	10.05	(18.49)	29.6
V_2	346.66	24.88	13.46	146.2	10.81	(19.20)	28.9
V_3	358.13	23.94	11.15	156.6	13.62	(21.66)	28.1
SE m (±)	5.785	0.602	0.454	3.594	0.409		0.675
C.D (0.05)	14.369	1.753	1.321	10.465	1.191		1.09
Zinc sulphate application (S)							
S_1	324.44	23.85	10.97	144.4	15.01	(22.80)	29.1
S_2	327.77	25.00	13.77	136.0	9.8	(18.25)	28.6
S_3	386.66	24.98	13.44	163.4	7.8	(16.32)	30.0
S_4	338.88	25.17	12.47	160.5	10.83	(19.22)	27.7
S_5	303.55	26.91	11.32	134.0	14.42	(22.32)	29.0
SE m (±)	7.461	0.777	0.586	4.640	0.528		0.871
C D (0.05)	18.550	NS	1.705	13.511	1.538		1.41

Values in parentheses are original values

Sterility percentage was also found to be significantly affected by varieties. Among the varieties, variety V_1 (Anna 4) recorded the lowest, this could be attributed to the genetic makeup of the variety (Obaidullah, 2007) and its adaptability to stress conditions (Alam et al., 2009b). Anna 4 also recorded higher thousand grain weight compared to other varieties.

While considering the effect of zinc sulphate application, the number of panicles m^{-2} and filled grains per panicle were found to be significantly higher in the treatment, seed priming with zinc sulphate followed by foliar application. Higher number of panicles observed in the treatment was due to better growth, establishment and higher production of tillers and also due to better translocation of assimilates from source to sink (Ghoneim, 2016). Among the treatment combination, the highest number of productive tillers and filled grains per panicle were recorded in v_3s_3, it was because of the fact that the variety V_3 and the method of zinc sulphate application S_3 resulted in the highest number of panicles m^{-2}. The

Table 5. Interaction effect of varieties and zinc sulphate application on yield attributing characters of rice

Treatments	Number of panicles m^{-2}	Panicle length (cm)	Panicle weight (g)	Filled grains per panicle (No.)	Sterility percentage		Thousand grain weight (g)
v_1s_1	262.00	24.43	8.70	144.0	16.82	(24.22)	29.39
v_1s_2	307.33	25.93	13.85	105.3	6.02	(14.21)	30.33
v_1s_3	328.66	27.26	15.46	151.3	4.95	(12.86)	31.76
v_1s_4	280.00	26.36	12.24	168.7	10.7	(19.12)	29.39
v_1s_5	280.66	29.63	12.60	131.3	14.0	(22.01)	26. 91
v_2s_1	344.66	22.96	11.80	134.3	13.04	(21.17)	29.73
v_2s_2	320.00	23.76	14.80	146.3	9.8	(18.26)	28.17
v_2s_3	366.22	25.10	13.24	163.6	8.88	(17.34)	29.26
v_2s_4	368.00	25.76	14.15	152.0	9.82	(18.27)	27.98
v_2s_5	314.00	26.83	13.30	135.0	12.78	(20.95)	29.77
v_3s_1	366.66	24.16	12.40	155.0	15.26	(23.00)	30.62
v_3s_2	356.00	25.30	12.65	156.3	14.37	(22.28)	27.21
v_3s_3	383.33	22.60	11.63	175.3	10.33	(18.75)	29.11
v_3s_4	368.66	23.40	11.03	161.0	12.40	(20.62)	25.85
v_3s_5	316.00	24.26	8.05	135.6	16.54	(24.00)	27.86
SE m (±)	12.924	1.346	1.014	8.036	0.915		1.50
C.D (0.05)	32.129	NS	2.953	23.401	2.664		2.44

Table 6. Effect of varieties and zinc sulphate application on yield and economics of rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Net income (₹ ha^{-1})	B:C Ratio
Varieties (V)				
V_1	2554.07	5,309.63	13,750	1.20
V_2	2,948.82	6,092.46	25,233	1.38
V_3	3,524.03	5,955.55	38,921	1.58
SE m (±)	47.967	132.146	-	-
C.D (0.05)	139.671	384.788	-	-
Zinc sulphate application (S)				
S_1	2700.00	6,045.67	19,103	1.31
S_2	3053.08	5,554.32	26,430	1.39
S_3	3,877.71	6,107.40	47,897	1.71
S_4	3,760.99	6,476.33	47,041	1.70
S_5	1653.08	4,745.67	-10,630	0.83
SE m (±)	61.925	170.600	-	-
C D (0.05)	180.315	496.759	-	-

lowest sterility percentage and the highest thousand seed weight were also recorded in S_3, this implying better accumulation of photosynthates from source to sink and better partitioning of photosynthates with the application of zinc sulphate application as reported by Yin et al. (2016) and Sarwar *et al.* (2017). Panicle weight was the highest in foliar application of $ZnSO_4$@0.5 % during active tillering and panicle initiation stage (S_2). This was due to better absorption of zinc by the leaves and better accumulation of photosynthates and development of sink (Gupta et al., 2016).

The grain yield and straw yield were also found to be significantly affected by the varieties (Table 6). Grain yield was the highest in V_3 (Prathyasa). The reason for higher grain yield observed in V_3 was due to higher number of panicles m^{-2} and filled grains per panicle. Khalifa et al. (2014) and Sultana et al. (2020) observed that enhancement in the production of yield attributes resulted in higher grain yield. But higher straw yield was recorded in the variety V_2 (APO 1) and it was the result of better vegetative growth as evident from the data on plant height (Table 1). Alam et al. (2009b) reported that higher straw yield obtained was the result of better accumulation of biomass by the variety.

The highest grain yield was recorded with the application of zinc sulphate through seed priming and foliar spraying and it was followed by application of soil application. Yield parameters like number of panicles m^{-2}, filled grains per panicle and thousand grain weight were found to be higher in the treatment, seed priming with zinc sulphate followed by foliar application which also contributed to better grain yield in S_3. Similar observations were made by Sarwar et al. (2017). The interaction effect was also found to be significant (Table 7) and the treatment combination v_3s_3 recorded the highest grain yield. This was due to higher number of panicles m^{-2} and filled grains per panicle. This could be attributed to the better expression of growth attributes. The interaction effect was found significant and among the treatment combinations, v_2s_4 recorded higher straw yield due to higher dry matter production recorded in the treatment.

The net income (₹ 38,921.56 ha^{-1}) and B C ratio (1.58) were also higher for the variety V_3 (Prathyasa) because of higher grain yield. Among the method of zinc sulphate application, S_3 resulted in the highest net income (₹ 47,897.11 ha^{-1}) and B:C ratio (1.71) when compared to soil application of zinc

Table 7. Interaction effect of varieties and zinc sulphate application on yield and economics of rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Net income (₹ ha^{-1})	B:C Ratio
v_1s_1	2,444.4	5811.11	13,234	1.19
v_1s_2	2,900.0	5,322.22	21,906	1.32
v_1s_3	2,977.7	5,577.78	23,809	1.35
v_1s_4	2,922.2	5,637.04	23,554	1.35
v_1s_5	1,525.9	4200.00	-13,753	0.78
v_2s_1	2377.7	6611.11	10,297	1.21
v_2s_2	2,640.7	5444.60	15,791	1.23
v_2s_3	4270.3	6,418.52	58,646	1.87
v_2s_4	4199.6	7,532.70	61,177	1.91
v_2s_5	1,255.5	4,455.55	-19,746	0.69
v_3s_1	3,277.78	5714.81	33,778	1.51
v_3s_2	3,618.5	5,896.29	41,591	1.62
v_3s_3	4,384.99	6,325.92	61,234	1.91
v_3s_4	4,161.11	6,259.26	56,393	1.84
v_3s_5	2,177.76	5,581.48	1,608	1.02
SE m (±)	107.257	295.488	-	-
C.D (0.05)	312.315	860.412	-	-

sulphate @ 20 kg per ha (S_4). This was due to higher grain yield recorded in the treatment. Soil application of zinc sulphate recorded the net income of ₹ 47,041.95 and the B:C ratio was 1.70. Among the treatment combinations, the highest net income and B:C ratio were recorded in the treatment combination v_3s_3. This was due to higher yield resulting from the production of higher number of panicles m^{-2} and filled grains per panicle.

Considering the yield, economics and B:C ratio, variety Prathyasa (V_3) performed well with application of NPK @ 90:30:45 kg ha^{-1}, seed priming with zinc sulphate 2 g kg^{-1} seed + foliar application of zinc sulphate 0.5 per cent at active tillering and panicle initiation stage (S_3) in the uplands of red loam tracts of Kerala.

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