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Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 12
Issue: 06

Res. Jr. of Agril. Sci. (2021) 12: 2152–2156

CARAS

Res. Jr. of Agril. Sci. (Nov-Dec 2021) 12(6): 2152–2156
www.rjas.org

Full Length Research Article

Differential Response of Rice to Nitrogen and Zinc on Phenological Traits and Yield in Typic Haplusterts Soil

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Received: 21 Aug 2021 | Revised accepted: 08 Nov 2021 | Published online: 02 Dec 2021

ABSTRACT

Field experiment was conducted in farmers field at B. Mutlur in clay loam- Typic Haplusterts soil to study the effect of different nitrogen sources and zinc on phenological traits and yield in rice. The experiment was conducted in factorial randomized block design with three replications. The treatments consisted of Factor-A- Nitrogen sources, no nitrogen (N_0), 75% mineral nitrogen + 25% organic manure (vermicompost) (N_1), 50% mineral nitrogen + 50% organic manure (vermicompost) (N_2), 25% mineral nitrogen + 75% organic manure (Vermicompost) (N_3), Factor B – Zinc application, no application (Zn_0), soil application (Zn_1), foliar application (Zn_2), soil + foliar application (Zn_3). There were totally sixteen treatments combinations. Application of nitrogen and zinc significantly increased the phenological traits and yield in rice over control. The results revealed that N_3Zn_3 recorded highest phenological traits viz., plant height (112.6cm), tiller count (18.6), LAI (4.9) chlorophyll content (46.5 SPAD value), CGR (12.8 g $m^{-2}d^{-1}$), RGR (35.7 mg $g^{-1}d^{-1}$) and NAR (1.39 g $dm^{-1}d^{-1}$) in clay loam soil. The highest grain yield (5992.4 kg ha^{-1}) and straw yield (7624.2 kg ha^{-1}) was recorded in N_3Zn_3 and lowest grain and straw yield was recorded in N_0Zn_0 (3436.7 kg ha^{-1} and 5162.5 kg ha^{-1}) than individual application of nitrogen or zinc in rice.

***Key words*:** Nitrogen, Zinc, Vermicompost, Phenological Traits, Yield, Rice

Rice (*Oryza sativa* L.) is staple food for more than 60% of world population [1]. India has the largest acreage under rice (44.6 Mha) with a production of about 90 million tones and ranks next to China [2]. Nitrogen is commonly the most limiting nutrient for crop production in the major world's agricultural areas and therefore, adoption of good N management strategies often results in large economic benefits to farmers. Use of organic manures in present agriculture is increasing day by day, because of its utility not only improving the physical, chemical and biological properties of soil but also maintaining the good soil health and supplying almost all essential plant-nutrients for growth and development of crop plants. So, it is time to look for measures to stimulate sustainability in production of rice on long- term basis. Organic manures like FYM, poultry manure and vermicompost deserves priority for sustained production and better utilization in organic rice production [3]. Vermicompost as an appropriate cost-effective organic fertilizer can be used as a suitable alternative in the sustainable agriculture and organic cultivation [4].

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Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture, coupled with use of high analysis fertilizer and low amount of organic manures. In Tamil Nadu, 22 percent soils are deficient in zinc [5]. Rice is one of highly sensitive crops to Zn deficiency and Zn limits growth and yield of rice. Increasing evidences indicate that food grown by applying adequate NPK fertilizers on soils with low levels of trace elements not only reduce the crop yield but, may also provide insufficient human dietary levels of certain elements, even though the crop plants themselves show no signs of micronutrient deficiency [6].

In addition, green revolution led-increased demand of micronutrients by the high-yielding rice varieties (especially zinc) as well as adoption of intensive cropping practices, use of high-analysis fertilizers with low micronutrient content, decreased use of organic manures, growing of crops in soils with low micronutrient reserves and other natural and anthropogenic factors adversely affecting phyto-availability of zinc aggravated the situation [7]. Keeping this in view, the present investigation was conducted to evaluate the effect of different sources of nitrogen and zinc on growth and yield in rice nutrition.

MATERIALS AND METHODS

Field experiment was conducted in farmer field at B. Mutlur in clay loam- Typic *Haplusterts* soil to study the effect of different nitrogen sources and zinc on growth and yield in rice. The experiment was conducted in factorial randomized block design with three replications. The treatments consisted of Factor A- Nitrogen sources, no nitrogen (N_0), 75% mineral nitrogen + 25% organic manure (vermicompost) (N_1), 50% mineral nitrogen + 50% organic manure (vermicompost) (N_2), 25% mineral nitrogen + 75% organic manure (vermicompost) (N_3), Factor B – Zinc application, no application (Zn_0), soil application (Zn_1), foliar application (Zn_2), soil + foliar application (Zn_3). There were totally sixteen treatments combinations with four levels of nitrogen and four levels of zinc. The soil of experimental field was clay loam in texture with pH 6.8 and E.C 0.34 d Sm^{-1}, available N, P, K (225.6, 16.3, 281.2 kg ha^{-1}), and available zinc 0.79 mg kg^{-1}. Nitrogen was applied through urea in three splits (50% basal + 25% tillering + 25% panicle initiation stage) and vermicompost as basal application. All the treatments received recommended doses of P_2O_5 and K_2O uniformly. Zinc was applied as zinc sulphate as basal and foliar spray (0.2%) at active stages of rice crop as per the treatments. Biometric observations on plant height, tillers count, LAI, chlorophyll content, CGR, RGR, NAR, number of grains $panicle^{-1}$, number of panicles m^{-2}, panicle length, and 1000 grain weight were recorded. Grain and straw yields were recorded at harvest. The data was subjected to statistical scrutiny to arrive at meaningful explanation for the effect of treatments on rice crop.

RESULTS AND DISCUSSION

Growth parameters

Plant height

Addition of nitrogen or zinc alone or their combinations significantly improved the phenological traits and yield of rice over control in clay loam soil (Table 1). Combined application of nitrogen and zinc recorded the highest plant height, tiller number, LAI, Chlorophyll content, CGR, RGR and NAR compared to their individual application. Among the different nitrogen sources, the highest plant height was observed in N_3 (104.4cm) which followed by N_1(102.2 cm) in rice. The increase in plant height might be due to stimulation of cell, elongation, division and enlargement due to integrated nitrogen application [8]. The increase in plant height in response to application of N fertilizers is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulted in more dry matter accumulation [9]. With regards to zinc application methods, the highest plant height was recorded in Zn_3 (110.0 cm) followed by Zn_1 (99.7 cm) in rice. The increased plant height may be due to adequate supply of zinc which accelerates the activity of enzyme and auxin metabolism in rice [10]. Among the treatment combinations the highest plant height was observed in N_3Zn_3 (112.6 cm) followed by N_2Zn_3 (110.4 cm) in rice. Soil and foliar application of zinc with nitrogen application might have made adequate availability of zinc which has facilitated the growth of the plant due to its involvement in many metallic enzyme system, regulatory functions and auxin metabolism, increased synthesis and transport of carbohydrates to the sink [11] which resulted increased plant height in rice.

No. of tillers/ hill

Tillering capacity is one of the most important rice components which are responsible for yield of crop. Among the different nitrogen sources alone, the highest number of tillers / plant was recorded in N_3 (16.1) which was followed by N_2 (15.7) in rice. It is the outcome of the expansion of auxiliary buds, which is closely associated with the nutritional condition of the mother culm, and a tiller receives carbohydrates and nutrients from the mother culm during its early growth period which gets improved by the application of N [12]. With regards to zinc application, the highest number of tillers was recorded in Zn_3 (17.6) followed by Zn_2(14.9) in rice. The increased tillers number/plant by the zinc application may be attributed to its role in various zinc induced enzymatic activity and auxin metabolism which control growth of rice [13]. With respect to combined treatments, the highest number of tillers / plant was recorded in N_3Zn_3 (18.6) followed by N_2Zn_3 (17.9) in rice.

Table 1a Influence of nitrogen and zinc on phenological traits in rice in clay loam soil

Treatments	Plant height	No. of productive tillers $hill^{-1}$	Leaf area index	Chlorophyll content	Crop growth rate (g m^{-2} d^{-1})	Relative growth rate (mg g^{-1} d^{-1})	Net assimilation rate (g dm^{-1} d^{-1})
				N Sources (kg/ha)			
N_o	93.5	11.5	3.7	35.5	10.5	28.1	1.24
N_1	102.2	15.3	4.2	41.1	11.5	30.5	1.30
N_2	99.1	15.7	4.0	40.2	11.3	30.0	1.28
N_3	104.4	16.1	4.3	42.5	11.6	31.6	1.32
CD @ 5%	3.12	0.63	0.08	1.70	0.35	0.94	0.05
				Zn ($ZnSO_4$ - 25 kg/ha)			
Zn_0	91.6	12.7	3.6	35.4	10.3	27.5	1.22
Zn_1	99.7	13.5	4.1	39.7	11.1	29.7	1.28
Zn_2	97.9	14.9	3.9	39.2	11.0	29.0	1.27
Zn_3	110.0	17.6	4.7	44.9	12.5	34.1	1.36
CD @ 5%	3.12	0.63	0.08	1.70	0.35	0.94	0.05

Leaf area index

Measurement of leaf area is a basic tool of growth analysis and it is directly related with both biological and economical yield. To achieve high yield, maximization of leaf area is an important factor. Higher leaf area index was attained with combined addition of nitrogen and zinc compared to sole application over control. Among the different nitrogen sources alone, the highest LAI was recorded in N_3 (4.3) followed by N_1(4.2) in rice. Higher Leaf area index is one of the important growth attributes found to be increasing with increasing level of nitrogen application and it is directly and positively related to crop photosynthesis [14]. Among the zinc application, the highest LAI was recorded in Zn_3 (4.7) followed by Zn_2 (3.9) in rice. Adequate zinc concentration in plants is likely to involve in the synthesis of tryptophan, which is a precursor for the biosynthesis of IAA, an auxin which naturally enhances leaf area [15]. With respect to combined application, the highest LAI was recorded in N_3Zn_3 (4.9) followed by N_2Zn_3 (4.8) in rice. Enhanced nutrient availability in rhizosphere could have favoured higher nutrient uptake resulting in better crop growth leading to higher LAI due to application of zinc with nitrogen application in rice [16].

Chlorophyll content

Among the nitrogen sources, the highest chlorophyll content was recorded in N_3 (42.5) followed by N_1 (41.1) treatments. Nitrogen increases the chlorophyll content at all growth stages as it is a constituent and might have increased the photosynthesis and resulted in increased plant height [17]. Among zinc treatments, the highest chlorophyll content was recorded in Zn_3 (44.9) followed by Zn_1 (39.7) treatments. Zinc helps in the formation of chlorophyll through regulation of homeostasis [18]. With respect to combined treatments, the highest chlorophyll content was recorded in N_3Zn_3 (46.5) which followed by N_2Zn_3 (45.4) in rice. Various micronutrients especially zinc are needed for catalytic activity of enzymes essential for respiration, photosynthesis and flowering which may leads to higher chlorophyll content in leaves [19].

Table 1b Interaction effect of nitrogen and zinc on growth parameters in rice in clay loam soil

Treatments	Plant height	No. of productive tillers hill^{-1}	Leaf area index	Chlorophyll content (SPAD value)	Crop growth rate (g m^{-2} d^{-1})	Relative growth rate (mg g^{-1} d^{-1})	Net assimilation rate (g dm^{-1} d^{-1})
				N × Zn			
N_oZn_0	86.5	7.3	3.4	29.1	9.4	25.4	1.19
N_oZn_1	89.7	9.9	3.5	34.2	10.2	27.1	1.21
N_oZn_2	90.4	12.1	3.5	35.6	10.3	27.3	1.22
N_oZn_3	107.7	16.8	4.6	43.2	12.2	32.8	1.34
N_1Zn_0	93.7	14.0	3.6	37.4	10.6	28.5	1.24
N_1Zn_1	104.8	14.6	4.4	42.2	11.6	30.8	1.32
N_1Zn_2	101.5	15.7	4.1	40.5	11.3	29.4	1.29
N_1Zn_3	109.5	17.1	4.7	44.6	12.4	33.4	1.36
N_2Zn_0	91.6	14.4	3.6	36.5	10.5	27.6	1.23
N_2Zn_1	98.2	14.7	3.9	39.6	11.1	29.2	1.28
N_2Zn_2	96.3	15.9	3.8	39.1	11.0	28.9	1.27
N_2Zn_3	110.4	17.9	4.8	45.4	12.6	34.4	1.36
N_3Zn_0	95.3	15.1	3.7	38.7	10.7	28.7	1.25
N_3Zn_1	106.3	14.8	4.4	43.1	11.7	31.6	1.33
N_3Zn_2	103.6	15.8	4.3	41.7	11.4	30.5	1.31
N_3Zn_3	112.6	18.6	4.9	46.5	12.8	35.7	1.39
C.D @ 5%	6.24	1.26	0.16	3.40	0.70	1.88	0.10

Growth analysis

Incorporation of nitrogen with zinc fertilizers or individual addition significantly improved crop growth rate, relative growth rate and net assimilation rate over control. Combined application recorded the highest growth attributes over individual applications. Among the nitrogen sources alone, the highest CGR (11.6 g m^{-2} d^{-1}), RGR (31.6 mg g^{-1} d^{-1}) and NAR (1.32 g dm^{-1} d^{-1}) were registered in N_3 in rice. Application of vermicompost and chemical fertilizer caused more cell development which leads to the progressive development of crop growth rate (CGR) and NAR in rice [20]. The excellent plant growth in vermicompost application was possibly due to some plant growth promoters in worm casts especially caused significant increase of many growth parameters, like crop growth rate and net assimilation rate [21]. Among the zinc application methods, the highest CGR (12.5 g m^{-2} d^{-2}), RGR (34.1 mg g^{-1} d^{-1}) and NAR (1.36 g dm^{-1} d^{-1}) were recorded in Zn_3 which followed by Zn_1 in rice. This may be due to Zn which are involved in the synthesis of growth promoting hormones and involve in auxin production, transformation of carbohydrate and regulation of sugar in rice [22]. The treatment N_2Zn_3 registered the highest value which followed by N_3Zn_3, CGR (12.8 g m^{-2} d^{-1}), RGR (35.7 mg g^{-1} d^{-1}) and NAR (1.39 gdm^{-1} d^{-1}) in rice.

Grain yield

Addition of nitrogen alone or zinc alone or both significantly improved the grain and straw yield of rice over control (Table 2a-b). Among the nitrogen treatments, the highest grain yield was recorded in N_3 (5330.4 kg ha^{-1}) which followed by N_1(5148.5 kg ha^{-1}) in rice. This may be due to the highest effective tillers hill^{-1}, more filled grains panicle^{-1} and highest no. of grains panicle^{-1} [23]. Among the zinc treatments, the highest grain yield was recorded in Zn_3 (5734.5 kg ha^{-1}) followed by Zn_1 (4918.8 kg ha^{-1}). Similar results stated that the superiority of Zn application for grain yield may be due to the improvement of soil properties to support the roots of treated plants [24]. With respect to combined treatments the highest grain yield was recorded in N_3Zn_3(5992.4kg ha^{-1}) followed by N_2Zn_3. Increase in productive tillers/m^2 might be ascribed to adequate supply of zinc that might had increased the uptake and availability of essential nutrients which resulted in improvement of plant metabolic process and finally increased the rice yield [25].

Table 2a Influence of nitrogen and zinc on grain and straw yield (kg ha^{-1}) in rice in clay loam soil

Treatments		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		N sources (kg/ha)	
N_o		3988.0	6178.0
N_1		5148.5	7078.9
N_2		4980.4	6985.3
N_3		5330.4	7180.1
	CD @ 5%	212.0	291.5
		Zn (Zinc sulphate- 25 kg/ha)	
Zn_0		4238.7	6778.2
Zn_1		4918.8	7243.3
Zn_2		4840.3	7074.8
Zn_3		5734.5	7624.2
	CD @ 5%	212.0	291.5

Table 2b Interaction of nitrogen and zinc on grain and straw yield (kg ha^{-1}) in rice in clay loam soil

Treatments		Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
		N × Zn	
N_oZn_0		3436.7	5162.5
N_oZn_1		4172.7	6345.6
N_oZn_2		4012.8	6257.6
N_oZn_3		4329.8	6946.3
N_1Zn_0		4486.5	6684.6
N_1Zn_1		5321.5	7168.2
N_1Zn_2		5142.8	6994.4
N_1Zn_3		5643.5	7468.6
N_2Zn_0		4358.3	6569.3
N_2Zn_1		4972.5	6936.4
N_2Zn_2		4758.3	6852.3
N_2Zn_3		5832.6	7583.4
N_3Zn_0		4673.6	6778.2
N_3Zn_1		5368.2	7243.3
N_3Zn_2		5287.6	7074.8
N_3Zn_3		5992.4	7624.2
	C.D @5%	424.0	583.1

Straw yield

Among the nitrogen treatments, the highest straw yield was recorded in N_3 (7180.1 kg ha^{-1}) which followed by N_1 (7078.9 kg ha^{-1}) in rice. Increased level of N application gave highest straw yield [26]. Among the zinc treatments, the highest straw yield was recorded in Zn_3 (7492.4 kg ha^{-1}) followed by Zn_1 (6901.3 kg ha^{-1}). Similar results stated that the superiority of Zn application for grain yield may be due to the improvement of soil properties to support the roots of treated plants [24]. With respect to the combined effect of nitrogen and zinc the highest straw yield was recorded in N_3Zn_3 (7624.2kg ha^{-1}) followed by N_2Zn_3. This may be due to the higher N level available to the plants that offer vigorous growth and higher tillers increasing straw yield [27].

CONCLUSION

From this study, it may be concluded that application of nitrogen and zinc (N_3Zn_3) (25% mineral nitrogen + 75% vermicompost + soil + foliar application (zinc sulphate) recorded highest phenological traits and yield in rice. Among the N sources, the highest was recorded in N_3(25% mineral nitrogen + 75% vermicompost). With respect to zinc alone, the highest was recorded in Zn_3 (soil + foliar application (zinc sulphate) in nutrients deficient soil.

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