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Influence of nano nitrogen and nano zinc fertilizers on nutrient uptake and use efficiency in paddy under different systems of establishment

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ABSTRACT

Field experiment on "Influence of nano nitrogen and nano zinc fertilizers on nutrient uptake and use efficiency in paddy under different systems of establishment". Randomised complete block design (RCBD) College of Agriculture, Vishweshwaraiah Canal Farm, Mandya, Karnataka, during summer 2022. The study included 14 treatments with various concentrations and sources of nitrogen with nano nitrogen and nano zinc under various establishment methods, including transplanted paddy and system of rice cultivation (SRI), as well as various methods of applying nano fertilisers, such as seed treatment, root dipping, and foliar spray. The results indicated that significantly higher nitrogen uptake (94.42, 79.10 and 173.52 kg ha^{-1}, respectively), phosphorous, potassium uptake and higher nitrogen, phosphorous and potassium use efficiency (58.76, 105.01 and 73.51 kg kg^{-1} nutrients applied, respectively) was obtained with the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method of establishment. SRI method of rice establishment and nano nutrient application will significantly increase the primary, secondary and micro nutrient uptake.

Key words: *Nano nitrogen, Nano zinc, System of rice intensification, Transplanted paddy, Nutrient uptake*

Introduction

Indian soils are being exhausted heavily as 30 mt of nutrients are continuously removed, while 20 mt are added by crops leaving a gap of 10 mt consistently. Fertilizer response ratio of crops has declined radically. Socio-economic issues such as exodus of people from farming, inaccessibility of labourers and raising cost of cultivation add enormous pressure on agricultural scientists to evolve technologies that target multifaceted problems of Indian agriculture. Fertilizers play a pivotal role in agricultural production. Fertilizers contribute to the tune of 35-40 per cent of the productivity of any crop.

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Nitrogen being a major food for plants is an essential constituent of protein (build from amino acids that involves in catalization of chemical responses and transportation of electrons) and chlorophyll (enable the process of photosynthesis) present in many major portions of the plant body. It encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant (Leghari *et al.,* 2016). Zinc is an essential micronutrient for humans, animals and plants. The functional role of Zn includes auxins metabolism, nitrogen metabolism, influence on the activities of enzymes, cytochrome carbon synthesis and stabilization of ribosomal fractions and protection of cells against oxidative stress.

To address all the difficulties of soil applied fertilizers like fixation, immobilization, volatilization, leaching and runoff to reduce all these losses, we should think of an alternate technology such as nanotechnology to precisely detect and deliver correct quantity of nutrients and other inputs required by crops in suitable proportion that promote productivity while ensuring environmental safety (Baruah and Dutta, 2009). In this regard, using nano fertilizer to control release of nutrients can be an effective step towards achieving sustainable agriculture and environment (Cui *et al.,* 2010).

One of the cultural practices which affect the rice crop through its effect on growth and development is method of establishment (Gopi *et al.,* 2006). Due to non availability of irrigation water and dearth of labour during peak periods, amplified labour wages make transplanting and manual weeding costly. Thus the area under transplanted rice in world is waning in recent years. Hence, there is call for exploring alternate crop establishment methods to augment the productivity of rice (Farooq *et al.,* 2011). This can be accomplished by adopting promising establishment technique in rice like SRI. SRI enables early planting and better crop stand (Malik *et al.,* 2019).

Farmers are using urea and zinc sulphate fertilizers for soil as well as foliar application to crops; however, the efficacy is lower. The present study was taken up to investigate the promotionary or inhibitory effects of N and Zn nano particles on growth and yield of paddy. Nano particles with small size and extensive surface area are expected to be the perfect forms for use as N and Zn fertilizer in plants. In view of the above facts, the present study entitled "Influence of nano nitrogen and nano zinc fertilizers on nutrient uptake and use efficiency in paddy under different systems of establishment" was taken up.

Materials and Methods

A field experiment was conducted in the *summer* season 2022 at A-block, College of Agriculture, Vishweshwaraiah Canal Farm, Mandya. The experiment was laid out in the randomized complete block design with fourteen treatments and three replications. Seeds were sown in the nursery beds and trays for manual transplanted paddy and SRI method, respectively.

The treatments included are as follows: T_1: TP+RP; T_2: SRI+RP; T_3: TP+50%N+ST; T_4: TP+50% N+RD; T_5: TP+50%N+FS; T_6: SRI+50%N+ST; T_7: SRI+50% N+RD; T_8: SRI+50%N+FS; T_9: TP+75% N+ST; T_{10}: TP+75%N+RD; T_{11}: TP+75%N+FS; T_{12}: SRI+75% N+ST; T_{13}: SRI+75%N+RD; T_{14}: SRI+75% N+FS (Note: TP: Transplanted paddy; SRI: System of Rice Intensification; RP: Recommended practice; ST: Seed treatment with 1000 ml nano nutrient / ha seed; RD: Root dipping with 1000 ml nano nutrient / ha seedling; FS: 2 Foliar sprays both N_{nano} and Zn_{nano} @ 0.4% solution at 25-30 and 45-50 DAT; Rec. FYM, 100% P and K is common to all the treatments).

Seeds were treated with nano nutrients as per the treatments. Pre-germinated seeds were treated with 1000 ml of nano nutrient per ha seeds for manual transplanted paddy. Whereas, for SRI method, nano nutrients were calculated for per kg seed basis (*i.e.*, 16 ml of nano nutrient per kg seed) to avoid toxicity imposed by nano nutrients because of the lesser seed requirement. Roots of the seedlings of particular treatments were dipped with 1000 ml nano nutrient / ha seedling and were kept for half an hour before transplanting. Foliar spray of nano nutrients at 0.4% (*i.e.*, 4 ml l^{-1}) was done according to the treatment needs.

Fifteen days prior to transplanting, 10 t ha^{-1} FYM was applied to the experimental plots. Recommended dose of 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1}, 50 kg K_2O ha^{-1} and 20 kg $ZnSO_4$ ha^{-1} fertilizers were applied for specific treatments through urea, single super phosphate (SSP), muriate of potash (MOP) and zinc sulphate ($ZnSO_4$), respectively. Full dose of recommended phosphorus and potassium were applied at the time of transplanting to all the treatments along with 50 percent N as a basal dose. The

Remaining 50 per cent N was applied in two splits at 30 and 60 DAT as top dressing according to the treatments.

Uptake of nutrients

The uptake of nutrients by the crop at harvest was estimated by multiplying the nutrient concentration and total dry matter yield of the plant as given in the following formula.

$$\text{Uptake (kg/ha}^{-1}) = \frac{\text{Nutrient concentration(\%)} \times \text{Weight of dry matter (kg/ha}^{-1})}{100}$$

$$\text{Uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)} \times \text{Weight of dry matter (kg ha}^{-1})}{100}$$

Nutrient use efficiency (NUE)

The NUE was computed from grain yield of paddy and the amount of nutrient supplied to the crop.

$$\text{NUE} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Nutrient supplied (kg ha}^{-1})}$$

The experimental data were analyzed using ANOVA technique. The significance of the treatment effect was judged with the help of 'F' table and tested at 5 per cent probability level.

Results and Discussion

Uptake of primary major nutrients (N, P and K) by the crop (kg ha^{-1})

Primary nutrient uptake as influenced by the dosage of nitrogen and method of nano nutrient application under different establishment methods are represented in Table 1.

Total uptake of nitrogen by rice varied significantly among different treatments. Application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}: 173.52 kg ha^{-1}) recorded significantly higher total nitrogen uptake followed by the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under transplanted paddy (T_{11}: 169.21 kg ha^{-1}), root dipping with nano nitrogen and nano zinc before transplanting and application of 75% N under SRI method (T_{13}: 165.25 kg ha^{-1}) and seed treatment with nano nitrogen and nano zinc before sowing and application of 75% N under SRI method (T_{12}: 155.86 kg ha^{-1}) than rest of the treatments. Similar pattern was also observed in the total uptake of phosphorus and potassium.

Higher levels of N and P content were found in grains. However, due to luxury consumption and storage ability, straw was shown to have higher K absorption than grains. Nutrient intake was impacted by various crop setup methods. SRI approach showed greater overall nutrient uptake than conventional transplanting. This could be attributed to the concentration of plant nutrients, biomass production, transplanting of young seedlings, and greater and deeper root length that assisted in nutrient uptake from deeper soil layers. In addition to that foliar spray of nano fertilizers helped in the quick and timely availability of nutrients to the plants. The results were consistent with (Shantappa, 2014; Naveen, 2022).

Uptake of secondary major nutrients (Ca, Mg and S) by the crop (kg ha^{-1})

Secondary nutrient uptake as influenced by the dosage of nitrogen and method of nano nutrient application under different establishment methods are represented in Table 1.

Total calcium uptake by rice crop varied between 20.53 to 42.74 kg ha^{-1}. Significantly higher calcium uptake in the rice was recorded by the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}: 42.74 kg ha^{-1}, respectively) which was found statistically on par with the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under transplanted paddy (T_{11}: 40.03 kg ha^{-1}, respectively) superior over rest of the treatments.

Application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}) recorded statistically superior in the total uptake of magnesium by rice (29.54 kg ha^{-1}). The same trend was followed by the rice crop in sulphur uptake.

Due to the crop's prolific root and shoot growth, the increased availability of the nutrients in the soil under the SRI approach allowed for rapid nutrient absorption by the crop (Jayadeva and Prabhakara Shetty, 2008). The use of nano fertilizers, according to (Jinghua, 2004), boosted the uptake and utilisation of nutrients by grain crops. This may be because they time the release of nutrients with the uptake by crops, reducing unfavourable nutrient losses to soil (De Rosa *et al.*, 2010).

Uptake of micronutrients (Zn, Fe, Cu and Mn) by the crop (g ha^{-1})

Micronutrient uptake as influenced by the dosage of nitrogen and method of nano nutrient application under different establishment methods are represented in Table 1.

Uptake of micronutrients in the crop varied significantly due to the treatment effects. Total uptake of zinc by the rice was found superior in the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}: 45.37 g ha^{-1}). The uptake of iron and copper also showed pattern similar to zinc.

Due to multiple zinc-regulated transporter membranes that may have regulated this process, zinc treatment through the foliar route may have increased zinc uptake by the leaf epidermis and remobilization to the rice grain through phloem (Naik and Das, 2007; Bashir *et al.,* 2012)

The enhanced nutrient absorption may also be a result of the long-term nutrient release pattern of nano fertilizers. The improved growth characteristics allowed plants to absorb soil's micronutrients much more effectively (Manikandan and Subramanian, 2016).

Nutrient use efficiency (kg kg^{-1} of nutrient applied)

Nutrient use efficiency was influenced by the dosage of nitrogen and method of nano nutrient application under different establishment methods are represented in Table 2.

Application of 50% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_8) which was at par with the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}), root dipping with nano nitrogen and nano zinc before transplanting and application of 50% N under SRI method (T_7) and seed treatment with nano nitrogen and nano zinc before sowing and application of 50% N under SRI method (T_6) (59.65, 58.76, 55.44 and 54.77 kg kg^{-1} nutrients applied, respectively) recorded significantly higher nitrogen use efficiency than the rest of the treatments.

Significantly higher phosphorus and potassium use efficiency was observed under application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method (T_{14}: 105.01 and 73.51 kg kg^{-1} nutrients applied, respectively) than the rest of the treatments.

Minimal nutrient losses and maximal nutrient uptake in grain and straw may result in higher nitrogen utilisation efficiency. These results are consistent with those of (Amrutha *et al.,* 2016). Application of phosphorus promoted root growth, which ultimately improved nitrogen and potassium absorption. The low phosphorus usage efficiency may be explained by the high rate of phosphorous fixation in this soil's Fe and Al oxides (Abekoe and

Table 2. Impact of different methods of nano nutrient application on nutrient use efficiency of paddy under different establishment methods in summer 2022

Treatments	Nutrient use efficiency		
	N	P	K
T_1: TP+ Recommended practice	35.37	75.79	53.05
T_2: SRI+ Recommended practice	41.08	88.03	61.62
T_3: TP+ 50% RDN + ST	49.98	71.42	50.00
T_4: TP+50% RDN + RD	50.60	72.32	50.62
T_5: TP+50% RDN + FS	52.67	75.32	52.72
T_6: SRI+ 50% RDN + ST	54.77	78.28	54.79
T_7: SRI+50% RDN + RD	55.44	79.23	55.46
T_8: SRI+50% RDN + FS	59.65	85.29	59.71
T_9: TP+ 75% RDN + ST	45.17	80.69	56.48
T_{10}: TP+75% RDN + RD	45.85	81.90	57.33
T_{11}: TP+75% RDN + FS	51.72	92.43	64.70
T_{12}: SRI+ 75% RDN + ST	49.76	88.88	62.22
T_{13}: SRI+75% RDN + RD	49.92	89.18	62.43
T_{14}: SRI+75% RDN + FS	58.76	105.01	73.51
S.Em.±	2.25	3.90	2.73
CD @ 5%	6.54	11.33	7.93

Table 1. Impact of different methods of nano nutrient application on total nutrient uptake of paddy under different establishment methods in summer 2022

Treatments	Primary major nutrient uptake (kg ha^{-1})			Secondary major nutrients (kg ha^{-1})			Micronutrients (g ha^{-1})		
	N	P	K	Ca	Mg	S	Zn	Fe	Cu
T_1: TP+ Recommended practice	134.67	21.31	134.82	25.58	17.76	13.62	20.80	226.46	7.47
T_2: SRI+ Recommended practice	153.93	25.79	157.98	34.58	21.81	19.33	27.09	369.84	10.98
T_3: TP+ 50% RDN + ST	128.34	17.90	126.24	20.53	13.51	12.47	18.17	198.23	4.72
T_4: TP+50% RDN + RD	130.18	20.54	129.79	22.63	15.34	13.26	19.75	212.79	6.05
T_5: TP+50% RDN + FS	134.02	20.68	133.26	22.90	16.94	13.51	19.86	218.00	6.79
T_6: SRI+ 50% RDN + ST	140.66	22.27	140.05	27.03	18.69	14.89	22.57	245.30	8.05
T_7: SRI+50% RDN + RD	146.75	23.31	146.75	29.12	19.50	15.30	25.07	276.44	8.78
T_8: SRI+50% RDN + FS	151.55	25.13	155.87	31.88	21.33	18.66	26.32	356.31	10.53
T_9: TP+ 75% RDN + ST	148.56	24.23	149.52	29.90	20.44	16.48	25.79	295.82	9.21
T_{10}: TP+75% RDN + RD	149.96	25.08	152.67	30.54	21.16	17.81	26.06	302.94	10.23
T_{11}: TP+75% RDN + FS	169.21	28.79	172.31	40.03	27.15	27.97	40.79	419.48	17.93
T_{12}: SRI+ 75% RDN + ST	155.86	26.63	159.61	36.78	23.29	20.87	29.05	392.31	12.11
T_{13}: SRI+75% RDN + RD	165.25	27.42	167.57	38.61	24.79	21.69	29.87	411.90	12.52
T_{14}: SRI+75% RDN + FS	173.52	33.32	176.06	42.74	29.54	35.43	45.37	461.69	20.88
S.Em.±	6.80	1.11	6.99	1.46	0.99	0.93	1.33	14.91	0.53
CD @ 5%	19.76	3.23	20.33	4.23	2.87	2.70	3.85	43.34	1.54

Sahrawat, 2001). Zinc and iron help the production of plant metabolites, which boosts the meristematic activity of the plant system, increases chlorophyll content within the plant, and then encourages the photosynthetic activity of the plant system. By increasing biomass production and N, P and K uptake, this improves the use efficiency of nitrogen, phosphorous and potassium.

Conclusion

SRI method of rice establishment has an important role in shaping the worlds rice production and productivity. The use of nano nutrients will not only reduce the use of bulky chemical fertilizers but significantly increase the uptake of nutrients. The results indicated that significantly higher nitrogen uptake (94.42, 79.10 and 173.52 kg ha^{-1}, respectively), phosphorous, potassium uptake and higher nitrogen, phosphorous and potassium use efficiency (58.76, 105.01 and 73.51 kg kg^{-1} nutrients applied, respectively) was obtained with the application of 75% N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT under SRI method of establishment.

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Competing Interests

Authors have declared that no competing interests exist.

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