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Nano Nitrogen and Nano Zinc Fertilizers : Impact on Sustainable Paddy Production under Different Systems of Establishment

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ABSTRACT

An investigation was carried out at College of Agriculture, V.C. Farm, Mandya during summer seasons of 2021 and 2022 to study the impact of nano nitrogen and nano zinc fertilizers on sustainable paddy production under different systems of establishment. The study consisted of fourteen treatments involving different concentration and sources of nitrogen with nano nitrogen and nano zinc under different establishment methods *viz*., transplanted paddy and system of rice cultivation (SRI) and different methods of application of nano fertilizers like seed treatment, root dipping and foliar spray. The experiment was laid out in randomised complete block design (RCBD) and replicated thrice. The results indicated that significantly higher leaf area (636.97 cm^2 $hill^{-1}$), DMA (330.64 g), productive tillers (27.05), filled grains per panicle (182.33), grain and straw yield (7045 and 9152 kg ha^{-1}, respectively) at harvest, gross returns (Rs.1,43,007 ha^{-1}), net returns (Rs.87,052 ha^{-1}) and B:C ratio (2.56) was obtained with the application of 75 per cent 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.

Keywords : Nano nitrogen, Nano zinc, System of Rice Intensification, Transplanted paddy, B:C ratio

RICE is one of the world's most important ancient cereal crops. In the world, 90 percentage of paddy is produced and consumed in Asia. The world's population is expected to reach 8.1 billion by 2025. Hence, an increase of 2 to 3 per cent of rice production must be maintained per year with the available land and water resources in order to maintain self-sufficiency in rice production. India is the world's second-largest paddy grower and consumer. India should produce additional 50 m t of rice to feed 152.3 million targeted population by 2030 (Anonymous, 2011).

Static rate in the increasing rice yield is noticed presently due to degradation of rice soils, besides inadequate or imbalanced supply of nutrients. The increment of yield was observed with increasing nutrient application (17.9 kg grain kg^{-1} nutrient applied) during green revolution period (1960-70), but later there was a gradual decline in the increment (6.3 kg grain per kg nutrient applied) is of another concern (Tandon, 2012). The lack of labour has exacerbated the situation, and paddy transplanting is a concern in the major rice-growing areas. Furthermore, the non-availability of labour during peak demand periods raises the cost of operations and slows the transplantation procedure. Hence, to enhance the rice yield, sustainable technologies are highly essential, which may include cost minimization by saving resources and adoption of low cost or non-monetary inputs. Hence, crop husbandry practices such as judicious application of fertilizer and establishment methods are of prime importance in rice production.

The System of Rice Intensification (SRI) is a new water-saving technology that increases rice production by several times. It has been demonstrated that by modifying key management strategies such as controlling water availability, planting younger seedlings and providing wider spacing, yields can be increased. SRI's major goal is to increase production by better utilising resources such as land, labour, money, and water. SRI management could benefit nitrification as well as the growth of the rhizosphere, potentially increasing nitrate intake and increasing rice yield potential (Kazunobu Toriyama and Ho Ando, 2011).

Application of fertilizers with the right quantity and balanced manner at right time is the important factor in enhancing the productivity of present-day improved genotypes (Singh and Namdeo, 2004). Nanotechnology is being viewed as a fast expanding topic with the potential to alter agricultural and food systems among scientific advancements (Roco, 2003 and Lal, 2008). Studies have been conducted to boost rice production. However, the literature involving nano materials are limited.

Nano fertilizers are appropriate alternatives to conventional fertilizers for gradual and controlled supply of nutrients in the soil. Alternative nano-fertilizers such as nano chelate with chemical fertilizers reduce pollutions which is economical (Mousavi-Fazl and Faeznia, 2008). Lowland rice crop culture causes nitrogen losses by ammonia volatilization, nitrification, denitrification, leaching, and runoff (Johnson and Milford, 2012), reducing nitrogen availability for rice plants. Therefore, this research aims to evaluate nitrogen nano fertilizers' effect on a selected rice cultivar's growth and yield.

The constant removal of significant amounts of zinc by high yielding varieties without rotation, as well as the use of excessive phosphatic fertilisers, has resulted in a depletion of accessible zinc in the soil. Increasing Zn concentration in rice grain is important from the point of human nutrition since rice is the staple food in developing countries of Asia (Shivay *et al.*, 2008). Hence, application of zinc fertilizers is essential in keeping enough available zinc in soil solution, maintaining adequate zinc transport to seeds and for increases in the crop yield (Nair *et al.,* 2010).

Recognizing the relevance of nitrogen and zinc in paddy growth while also acknowledging the seriousness of their deficiency in soils and plants, the current study aims to determine the impact of nano nitrogen and nano zinc fertilizers on sustainable paddy production under different systems of establishment.

MATERIAL AND METHODS

A field experiment was conducted in the summer seasons of 2021 and 2022 at A-block, College of Agriculture, Vishweshwaraiah Canal Farm, Mandya. It is situated in the Agro-Climatic Zone VI (Southern Dry Zone) of Karnataka at 12º 57' N latitude and 76º 83' E longitude at an altitude of 678 meter above mean sea level. The experiment was laid out in the randomized complete block design with fourteen treatments and three replications. 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 sown in the nursery beds and in trays for transplanted paddy and SRI method, respectively as per the recommendation. Recommended seed rate of

62.5 kg ha^{-1} and 8 kg ha^{-1} for transplanted paddy and SRI method were used respectively.

Seeds were treated with nano nutrients as per the treatments. Pre-germinated seeds were treated with 1000 ml of nano nutrient ha^{-1} seeds for 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^{-1} seedling and were kept for half an hour before transplanting. Foliar spray of nano nutrients @ 0.4 per cent (*i.e.,* 4 ml L^{-1}) was applied as per the treatments. Soil application of nano nutrients @ 0.4 per cent was applied by mixing nano nutrient with sand. Then it was broadcasted as per the treatments.

The recommended FYM (10 t ha^{-1}) was applied to the experimental plots at fifteen days prior to transplanting. The 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. While, full dose of recommended phosphorus and potassium were applied at the time of transplanting to all the treatments along with 50 per cent 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.

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

Leaf Area (cm² hill⁻¹)

Pooled data on the leaf area of paddy as modified by the impact of nano fertilizers at various phases of growth are reported (Table 1).

There was a significant difference among the different treatments. At 30 days after transplanting (DAT), significantly higher leaf area (185.35 cm^2 $hill^{-1}$) was observed in root dipping with nano nitrogen and nano zinc before transplanting and application of 75 per cent N under transplanted paddy (T_{10}) followed by root dipping with nano nitrogen and nano zinc before sowing and application of 50 per cent N under transplanted paddy (T_4) (179.89 cm^2 $hill^{-1}$), seed treatment with nano nitrogen and nano zinc before sowing and application of 75 per cent N under transplanted paddy (T_9) (176.16 cm^2 $hill^{-1}$) and seed treatment with nano nitrogen and nano zinc before sowing and application of 50 per cent N under transplanted paddy (T_3) (169.21 cm^2 $hill^{-1}$) than the rest of the treatments. However, at 60 DAT, 90 DAT and at harvest, the application of 75 per cent 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 significantly higher leaf area (596.62, 697.00 and 636.97 cm^2 $hill^{-1}$, respectively).

Table 1

Impact of nano fertilizers on leaf area and dry matter accumulation at different growth stages of paddy under different systems of establishment (Pooled data of 2 years)

Treatments	Leaf area (cm^2 $hill^{-1}$)			
	30 DAT	60 DAT	90 DAT	At harvest
T_1 : TP+RP	126.20	440.57	554.49	409.80
T_2 : SRI+RP	82.75	506.71	599.87	543.07
T_3 : TP+50% N+ST	169.21	340.73	503.89	381.11
T_4 : TP+50% N+RD	179.89	388.80	520.63	400.13
T_5 : TP+50% N+FS	134.14	422.46	536.70	414.11
T_6 : SRI+50% N+ST	91.34	446.15	565.72	495.03
T_7 : SRI+50% N+RD	116.07	469.01	573.43	494.12
T_8 : SRI+50% N+FS	85.58	498.04	595.80	518.29
T_9 : TP+75% N+ST	176.16	470.87	579.18	500.65
T_{10} : TP+75% N+RD	185.35	489.19	585.19	512.38
T_{11} : TP+75% N+FS	159.66	532.23	626.34	547.15
T_{12} : SRI+75% N+ST	96.55	518.88	606.51	533.29
T_{13} : SRI+75% N+RD	125.92	528.60	618.72	537.45
T_{14} : SRI+75% N+FS	87.97	596.62	697.00	636.97
F-test	**	**	**	**
S.Em.±	5.96	21.44	26.24	30.82
CD @ 5%	16.91	60.78	74.41	87.39

Dry Matter Accumulation (g hill^{-1})

Dry matter accumulation was significantly influenced by the impact of nano fertilizers on paddy (Table 2).

TABLE 2

Impact of nano fertilizers on dry matter accumulation of paddy under different systems of establishment (Pooled data of 2 years)

Treatments	Dry matter accumulation (g hill^{-1})			
	30 DAT	60 DAT	90 DAT	At harvest
T_1 : TP+RP	3.17	33.82	176.52	197.17
T_2 : SRI+RP	1.74	39.75	245.30	258.86
T_3 : TP+50% N+ST	3.81	28.14	143.48	161.73
T_4 : TP+50% N+RD	4.74	29.35	152.38	172.79
T_5 : TP+50% N+FS	3.34	31.84	165.53	182.30
T_6 : SRI+50% N+ST	2.65	34.74	184.40	208.68
T_7 : SRI+50% N+RD	2.81	35.70	196.54	216.59
T_8 : SRI+50% N+FS	2.22	38.52	239.90	248.42
T_9 : TP+75% N+ST	4.06	37.13	202.39	221.12
T_{10} : TP+75% N+RD	4.92	37.57	236.72	241.75
T_{11} : TP+75% N+FS	3.51	43.85	265.55	286.18
T_{12} : SRI+75% N+ST	2.71	41.10	254.73	266.33
T_{13} : SRI+75% N+RD	2.97	42.34	262.03	275.72
T_{14} : SRI+75% N+FS	2.54	49.83	305.13	330.64
F-test	**	**	**	**
S.Em.±	0.14	1.56	9.61	10.62
CD @ 5%	0.41	4.43	27.25	30.12

At 30 DAT, root dipping with nano nitrogen and nano zinc before transplanting and application of 75 per cent N under transplanted paddy (T_{10}) recorded significantly higher dry matter accumulation (4.92 g) which was on par with root dipping with nano nitrogen and nano zinc before transplanting and application of 50 per cent N under transplanted paddy (T_4) (4.74 g). However, at 60, 90 DAT and at harvest, the application of 75 per cent 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}) (49.83, 305.13 and 330.64 g, respectively) than the rest of the treatments.

Adequate supply of applied nano fertilizers at right concentration would help in production of more number of leaves due to reduced competition among the plants for nutrients and it helped to realize higher leaf area (Fathi *et al*., 2017). Among different methods of establishment, due to transplanting of younger seedlings with wider spacing in SRI, root growth was better and hence improved availability of nutrients throughout the crop growth period, which influenced the leaf area and dry matter accumulation (Shantappa, 2014). The results are in line with the findings of Beeresha (2018) and Vanitha & Dass (2014).

Yield and Yield Parameters of Paddy

The yield and yield parameters of paddy were significantly influenced by nano fertilizers under different systems of establishment are presented in Table 3.

Number of Productive Tillers per Hill and Number of Filled Grains per Panicle

The number of productive tillers (27.05) and the number of filled grains per panicle (182.33) was significantly higher in the application of 75 per cent 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}). While, lower number of productive tillers (9.64) and the number of filled grains per panicle (132.56) was recorded in seed treatment with nano nitrogen and nano zinc before sowing and application of 50 per cent N under transplanted paddy (T_3).

Grain Yield and Straw Yield (kg ha^{-1})

Significantly higher grain and straw yield (7045 and 9152 kg ha^{-1}, respectively) was observed in the application of 75 per cent 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}) compared to rest of the treatments (4787 to 5931 and 6210 to 7793 kg ha^{-1}, respectively). However, lesser grain and straw yield (4787 and 6210 kg ha^{-1}, respectively) was obtained in seed treatment with nano nitrogen and nano zinc before sowing and application of 50 per cent N under transplanted paddy (T_3).

The large root volume, profuse and strong tillers with big panicles and well filled spikelets with higher grain weight contributed to higher yield parameters. The

TABLE 3

Impact of nano fertilizers on yield and yield parameters of paddy under different systems of establishment (Pooled data of 2 years)

Treatments	Number of productive tillers $hill^{-1}$	Number of filled grains $panicle^{-1}$	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
	Yield and Yield parameters			
T_1 : TP+RP	12.73	138.89	5038	6487
T_2 : SRI+RP	19.63	150.93	5688	7336
T_3 : TP + 50 % N + ST	9.64	132.56	4787	6210
T_4 : TP + 50 % N + RD	10.36	132.73	4885	6288
T_5 : TP + 50 % N + FS	11.88	138.11	4998	6437
T_6 : SRI + 50 % N + ST	13.41	141.06	5196	6730
T_7 : SRI + 50 % N + RD	14.02	141.44	5267	6775
T_8 : SRI + 50 % N + FS	18.51	147.38	5580	7137
T_9 : TP + 75 % N + ST	14.22	143.45	5347	6883
T_{10} : TP + 75 % N + RD	17.12	144.77	5423	7094
T_{11} : TP + 75 % N + FS	24.38	160.96	6161	8155
T_{12} : SRI + 75 % N + ST	21.41	153.54	5843	7616
T_{13} : SRI + 75 % N + RD	23.53	155.07	5931	7793
T_{14} : SRI + 75 % N + FS	27.05	182.33	7045	9152
F-test	**	**	**	**
S.Em.±	0.83	6.49	249.25	319.59
CD @ 5%	2.35	18.39	706.70	906.16

results are in confirmation with the study of Shantappa (2014). Application of nano fertilizers enhanced the photosynthetic activity which results in translocation of photosynthates from source to sink (Uma *et al*., 2019). Higher straw yield was contributed to the significant increase in leaf area and dry matter accumulation. The lower yield in TP was due to lesser production of yield attributing characters because of competition by closer spacing. The results were in conformity with the findings of Barison and Uphoff (2011) and Elamathi *et al*. (2012).

Economics

Higher gross returns were found in the application of 75 per cent 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}) (Rs.1,43,007 ha^{-1}) followed by the application of 75 per cent 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}) (Rs.1,25,214 ha^{-1}). However, a lower gross returns was found in seed treatment with nano nitrogen and nano zinc before sowing and application of 50 per cent N under transplanted paddy (T_3) (Rs.97,163 ha^{-1}). Higher gross returns in those treatments might be due to the higher yields that are obtained in those treatments.

Application of 75 per cent 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 higher net returns (Rs.87,052 ha^{-1}). While, the application of 75 per cent 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}) recorded higher cost of cultivation (Rs.61,258 ha^{-1}). Higher cost of cultivation was mainly due to the combined cost incurred for the cultivation practices of transplanted paddy and the cost of fertilizers that are needed for this treatment.

TABLE 4

Impact of nano fertilizers on economics of paddy under different systems of establishment (Pooled data of 2 years)

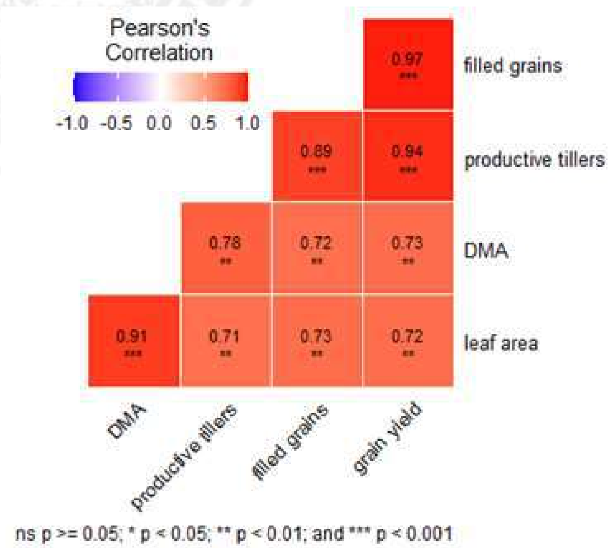
Treatments		Economics			
		Gross returns	Net returns	Cost of cultivatiton	B:C ratio
T_1	: TP + RP	102209	42,909	59,300	1.72
T_2	: SRI+RP	115408	61,440	53,968	2.14
T_3	: TP + 50 % N + ST	97163	39,717	57,446	1.69
T_4	: TP + 50 % N + RD	99103	41,657	57,446	1.73
T_5	: TP + 50 % N + FS	101399	42,609	58,790	1.72
T_6	: SRI + 50 % N + ST	105454	53,035	52,419	2.01
T_7	: SRI + 50 % N + RD	106848	54,429	52,419	2.04
T_8	: SRI + 50 % N + FS	113157	59,394	53,763	2.10
T_9	: TP + 75 % N + ST	108476	48,562	59,914	1.81
T_{10}	: TP + 75 % N + RD	110131	50,217	59,914	1.84
T_{11}	: TP + 75 % N + FS	125214	63,956	61,258	2.04
T_{12}	: SRI + 75 % N + ST	118633	64,022	54,611	2.17
T_{13}	: SRI + 75 % N + RD	120482	65,871	54,611	2.21
T_{14}	: SRI + 75 % N + FS	143007	87,052	55,955	2.56

B:C Ratio

Application of 75 per cent 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 higher B:C ratio (2.56). B:C ratio is higher in this treatment because of the increased gross returns due to the production of significantly higher grain and straw yield. Lower B:C ratio (1.69) was recorded in seed treatment with nano nitrogen and nano zinc before sowing and application of 50% N under transplanted paddy (T_3). It is mainly because of the reduced yield caused by the severe reduction of applied dose of fertilizers. Results were in line with Mishra *et al*. (2020) and Uma *et al.* (2019).

Positive correlation with high level of significance existed among the parameters. Highly positive correlation was found between leaf area and dry matter accumulation (DMA), filled grains per panicle and productive tillers, grain yield was highly positively

Correlation between growth, yield and yield parameters



Note : Colour indicates nature of correlation

Dark blue- highly negative correlation; **Light blue**- low level negative correlation; **White**- no correlation; **Light red**- low level positive correlation; **Dark red**- highly positive correlation correlated with filled grains per panicle and productive tillers. It indicates that the increase in leaf area helped in increasing the DMA of the plant and increase in yield parameters like filled grains and productive tillers helped in increasing the grain yield significantly in a positive manner. Increased leaf area, dry matter accumulation, filled grains per panicle and productive tillers were attributed to the application of nano nitrogen and nano zinc at right concentration and right stages.

Application of 75 per cent N and two foliar sprays of nano nitrogen and nano zinc at 25 to 30 and 45 to 50 DAT were very beneficial in improving growth and yield parameters of paddy under SRI method of establishment. This particular treatment is also found economically beneficial than the rest of the treatments.

References

Anonymous, 2011, Agricultural statistics at a glance. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi, pp. : 88 - 89.

Barison, J. and Uphoff, N., 2011, Rice yield and its relation to root growth and nutrient-use efficiency under SRI and conventional cultivation: an evaluation in Madagascar. *Paddy Water Environ.*, **9** : 65 - 78.

Beeresha, K. J., 2018, Studies on the effect of nano potassium on growth and yield of maize (*Zea mays* L.). *M.Sc. Thesis*, Univ. Agric. Sci., Bengaluru.

Elamathi, S., Balasubramanian, P., Pandian, B. J., Chellamuthu, S. and Sundarapandian, T., 2012, Effect of improved production technology on rice yield in tank irrigated regions of Giridhamal sub basin, Tamil Nadu. *International symposium on 100 years of rice science and looking beyond,* TNAU, pp. : 492 - 493.

Fathi, A., Morteza Zahedi, Shahram, T. and Amirhossein, K., 2017, Response of wheat genotypes to foliar spray of ZnO and Fe_2O_3 nanoparticles under salt stress. *J. Plant Nutr.,* **40**(10) : 1376 - 1385.

Johnson and Milford, 2012, Effect of drip irrigation frequency on grain yield, water use efficiency of maize. *Season Res.*, **36** (6) : 111 - 119.

Kazunobu Toriyama and Ho Ando, 2011, Towards an understanding of the high productivity of rice with system of rice intensification (SRI) management from the perspectives of soil and plant physiological processes. *Soil Sci. Plant Nutr.,* pp. : 1 - 14.

Lal, R., 2008, Soils and India's food security. *J. Indian Soc. Soil Sci.,* **56** : 129 - 138.

Mishra, B., Sahu, G. S., Mohanty, L. K., Swain, B. C. and Hati. S., 2020, Effect of nano fertilizers on growth, yield and economics of tomato variety *Arka Rakshak*. *Indian J. Pure App. Biosci.,* **8**(6) : 200 - 204.

Mousavi-Fazl, S. H. and Faeznia, F., 2008, Effect of different moisture regimes and nitrogen on the yield and nitrate concentrations in potato tubers. *Iran. J. Soil Res.,* **22**(2) : 243 - 250.

Nair, R., Varghese, S. H., Nair, B. G., Maekawa, T., Yoshida, Y. and Kumar, D. S., 2010. Nanoparticulate material delivery to plants. *J. Plant Sci.,* **179** : 154 - 163.

Roco, M. C., 2003, Broader societal issues of nano technology. *J. Nanoparticle Res.,* **5** : 181 - 189.

Shivay, Y. S., Kumar, D., Prasad, R. and Ahlawat, I. P. S., 2008, Relative yield and zinc uptake by rice from zinc sulphate and zinc oxide coating onto urea. *Nutrient cycling in Agroecosystem*, **80** :181 - 188.

Shantappa, D., 2014, Studies on establishment techniques, irrigation water levels and weed management practices on productivity and emission of green house gasses (Ghgs) in rice (*Oryza sativa* L.). *Ph.D. Thesis,* Univ. Agric. Sci., Raichur.

Singh, R. K. and Namdeo, K. N., 2004, Effect of fertility levels and herbicides on growth, yield and nutrient uptake of direct-seeded rice (*Oryza sativa*). *Indian J. Agron.,* **49**(1) : 34 - 36.

Tandon, 2012, Soil testing for balanced fertilization. FDCO, New Delhi, pp. : 170.

Uma, V., Jayadeva, H. M., Atheekur Rehaman, Kadalli, G. G. and Umashankar, N., 2019, Influence of nano zinc oxide on yield and economics of maize (*Zea mays* L.) *Mysore J. Agric. Sci*., **53**(4) : 44 - 48.

Vanitha, K. and Dass, M. S., 2014, Effect of humic acid on plant growth characters and grain yield of drip fertigated aerobic rice (*Oryza sativa* L.). *Int. Qual. J. Life Sci*., **9** : 45 - 50.