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Enhancing Growth and Yield of Indian Mustard Through Foliar Application of Nano Urea and Nano Zinc: A Field Study

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Abstract

A field experiment was conducted crop research farm, Department of Agronomy, Vivekananda Global University, Jaipur (Rajasthan) to find out the influence of foliar application of nano urea and nano zinc on growth and yield traits of Indian mustard. The experiment consisted 10 treatment combinations i.e., T_1- Control, T_2-100% RDN and $ZnSO_4$ @20 kg ha^{-1}, T_3- 50% RDN and $ZnSO_4$@10 kg ha^{-1}+1st spray of nano urea at 25 DAS, T_4- 50% RDN and $ZnSO_4$@10 kg ha^{-1}+1st spray of nano urea and nano Zn at 25 DAS, T_5- 50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS+ 2nd spray of nano urea only at 40DAS, T_6- 75% RDN and $ZnSO_4$@10 kg ha^{-1}+1st spray of nano urea at 25 DAS, T_7- 75% RDN and $ZnSO_4$@10 kg ha^{-1} +1st spray of nano urea and nano Zn at 25DAS, T_8- 75% RDN and $ZnSO_4$@10 kg ha^{-1}+1st spray of nano urea and nano Zn at 25DAS+ 2nd spray of nano urea only at 40DAS, T_9- 100% RDN and $ZnSO_4$ @20 kg ha^{-1}+1st spray of nano urea and nano Zn at 25DAS and T_{10}- 100% RDN and $ZnSO_4$ @20 kg ha^{-1}+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS. The experiment was laid out in Randomized Block Design and replicated thrice. Results show that application of 100% RDN and $ZnSO_4$ @20 kg ha^{-1}+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS (T_{10}) had significant effect with respect to growth, yield (seed yield (3721.35 kg/ha), and maximum gross returns of (Rs. 100,633 ha^{-1}), net return (Rs 57,289 ha^{-1}) and B: C ratio (2.32). However, treatment T_9 and T_8 showed at par with T_{10} for most of the traits. Hence, treatment (T_{10}) 100% RDN and $ZnSO_4$ @20 kg ha^{-1}+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS, may be recommended to farmers for higher productivity and net return of mustard.

Keywords: Growth, foliar application, nano zinc, nano urea and yield

Introduction

Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] is the third most important source of edible oils in the world after soybeans and oil palms. Indian mustard (*Brassica juncia* L.) is the most important oilseed crop of India, occupying the first rank in area and second in production next to China. In India, mustard is cultivated on an area of 8.06 million hectares with production of 11.75 million tonnes and productivity of 1458 kg/ha [1]. In Rajasthan, it occupies 3.94 million hectares area and produces 6.26 million tonnes yield with productivity of 1587 kg/ha [2].

After nitrogen, phosphorus and potassium, zinc is fourth most yield limiting nutrient, globally as well as in Indian condition [3]. It is estimated that 36.5% of Indian soils are deficient in Zn. Zinc is one of the essential micro nutrients, necessary for crop nutrition as it plays an important role in metabolic processes such as carbohydrate, nucleic acid, lipid and protein synthesis as well as their degradation. Foliar application is a technique of feeding plants by spraying liquid fertilizers directly to the leaves, which is accompanied with better absorption in the aerial parts [4]. The efficacy of foliar fertilization is higher than that of soil fertilizer application under drought and salinity condition due to supply of required nutrient directly to the leaves, its relatively quick absorption, independence of root activity and soil water availability. Foliar application of nano zinc, copper and iron fertilizers application on grain crops increases growth parameters of wheat relative to other fertilizer sources [5].

Nano-fertilizers are essential to reduce the use of inorganic fertilizers and reduce their antagonistic effects on the environment. Nano-fertilizers have better nutrient use efficiency due to their better penetration ability and translocation within plant parts [6], moreover, they prevent undesirable loss of nutrient via direct utilization by crops, and thereby, avoid the interaction of nutrients with soil, water, air and microorganisms [7]. Nano fertilizers also have controlled release and targeted delivery of effective nano scale ingredients/nutrients and have the ability to improve plant productivity and minimize environmental pollution [8]. It offers generous visions for sustainable agriculture

crop production through improvement of quality food production with minimizing its negative impact on human health as well as environment [9]. Due to huge population and increasing food demand within restricted land, by increasing nutrient use efficiency and using innovative technologies over conventional methods can help to solve the issue of food availability [10].

Methods

There are 10 treatments combinations were laid out in Randomized Block Design and Treatments details of experiment are presented under following heads

Table 1 Details of treatments.

Treatments	Symbols
Control	T_1
100% RDN and ZnSO4 @20 kg ha-1	T_2
50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	T_3
50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS	T_4
50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS+ 2nd spray of nano urea only at 40DAS	T_5
75% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	T_6
75% RDN and ZnSO4@10 kg ha-1 +1st spray of nano urea and nano Zn at 25DAS	T_7
75% RDN and @10 kg ha-1+1st spray of nano urea and nano Zn at 25DAS+ 2nd spray of nano urea only at 40DAS	T_8
100% RDN and ZnSO4 @20 kg ha-1+1st spray of nano urea and nano Zn at 25DAS	T_9
100% RDN and ZnSO4 @20 kg ha-1+1stspray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS	T_{10}

Treatments application

The dose of nitrogen (N), phosphorus (P), potash (K) and zinc (Zn) were applied as per treatment recommendations as basal application at the time of sowing through urea, di-ammonium phosphate (DAP), murate of potash (MOP) and zinc sulphate. Half dose of nitrogen was applied as basal application and remaining was given in two equal halves. First split applied during first irrigation and second split applied during second irrigation. The recommended dose of fertilizer was 60 kg nitrogen, 40 kg P_2O_5, 40 kg K_2O and 5 kg $ZnSO_4$ ha^{-1}. The foliar spray of nano urea and zinc were done as per treatment recommendation. The foliar spray of nano urea @4 ml L^{-1} and nano zinc @ 2 ml L^{-1} water was applied as per treatments. First foliar spray of nano fertilizers was applied at 30 DAS and second at 45 DAS. The foliar spray made on plant leaves or above ground tissues. Seeds of mustard variety "NRCDR 02" were sown manually at rate of 5.0 kg ha-1 maintaining row to row distance of 30 cm and plant to plant distance of 10 cm placed at depth of 3-4 cm and sowing was done at 20th October 2023. Fertilizers were placed beneath the seed, after placing the seed in furrows it was covered with soil for uniform germination.

Statistical analysis

The experimental data obtained during the course of study was subjected to statistical analysis by applying the technique of Analysis of Variance (ANOVA) prescribed for "Randomized Block Design" to test the significance of the overall differences among the treatments. By the "F" value in the analysis of variance table was drawn at 5 percent probability level. When "F" value in the analysis of variance table was found to be significant, the critical difference (CD) was computed to test the significance of the difference between two treatments [11].

Result and Discussion

Influence of nano urea and nano zinc on growth parameters

The growth of mustard is governing by plant population, plant height and dry matter accumulation which were influenced by foliar application of nano urea and nano zinc presented in preceding chapters (Table 2). However, plant population at 20 DAS and harvest index was non-significantly influenced by foliar application of nano urea and nano

zinc, while plant height and dry matter accumulation at 60 DAS, 90 DAS and harvest index significantly influenced. The data showed the highest plant height at 60 DAS, 90 DAS and at harvest were significantly higher in treatment of T_{10}-100% RDN and $ZnSO_4$ @20 kg ha-^{1}+1stspray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40 DAS with the corresponding value of 103.20 cm, 139.70 cm and 208.55 cm at 60 DAS, 90 DAS and at harvest, respectively. The growth of mustard has increased as a result of the most effective nutrient delivery methods being combined with the most effective application technique, foliar application, and the provision of nutrients by nano fertilizers. When Nano nutrients are administered topically to leaves, stomata and cuticles are the main entry points for nutrients. According to [12], greater nanoparticles follow the stomatal pathway, whereas smaller ones follow the cuticular pathway. They subsequently go to the conducting system, which, because they are 100% soluble, facilitates the quick and easy absorption of nutrients by leaves [13]. Plant growth in terms of height was enhanced by the provision of nano zinc, which is essential to plant physiology and helps to improve photosynthetic efficiency under nano zinc above traditional $ZnSO_4$. Because of their tiny size, nanoparticles exhibit high specific surface area and high reactivity, which may be used to boost the reactivity of a rise in plant height or the density of reactive regions. Nanoparticles have also been shown to have the capacity to penetrate plant cells and leaves, hence speeding up growth and development [14].

Table 2. Effect of different treatments on plant population, plant height and dry matter accumulation of Indian mustard

Treatments		Plant population per meter row length		plant height (cm)			Dry matter accumulation (g m^{-2})		
		20 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T_1	Control	8.10	8.00	72.21	102.10	159.50	120.21	172.10	196.50
T_2	100% RDN and $ZnSO_4$ @20 kg ha-1	8.40	8.30	85.50	116.25	178.50	135.50	190.25	220.50
T_3	50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	8.35	8.30	82.20	113.20	177.20	130.21	185.10	211.58
T_4	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS	8.40	8.20	89.90	122.60	184.80	132.00	186.90	222.58
T_5	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS+ 2nd spray of nano urea only at 40DAS	8.40	8.30	94.00	123.40	188.60	146.90	196.30	231.58
T_6	75% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	8.50	8.30	92.40	128.20	189.10	134.90	191.60	230.68
T_7	75% RDN and $ZnSO_4$@10 kg ha-1 +1st spray of nano urea and nano Zn at 25DAS	8.45	8.40	96.40	132.50	196.80	138.00	194.40	240.38
T_8	75% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25DAS+ 2nd spray of nano urea only at 40DAS	8.60	8.50	97.89	136.40	198.70	143.40	202.40	247.58
T_9	100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25DAS	8.60	8.55	102.54	138.60	204.55	147.40	207.50	253.88
T_{10}	100% RDN and $ZnSO_4$ @20 kg ha-1+1stspray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS	8.70	8.55	103.20	139.70	208.55	145.50	206.40	259.48
S.Em.±		0.29	0.28	1.75	2.06	2.78	2.31	3.23	3.64
C.D. at 5%		NS	NS	5.20	6.12	8.25	6.83	9.62	10.84

Influence of nano urea and nano zinc on yield and yield attributes

It is evident the results (Table 3) that effect of foliar application of nano urea and nano zinc was significant on yield and yield attributes like number of siliquae per plant, seeds per siliquae, test weight, seed yield, stover yield and biological yield. The maximum siliquae plant per plant (369.89) seeds per siliquae (16.23), test weight (5.70 g), seed yield (3721.35 kg ha-1), stover yield (5899.53 kg ha-1) and biological yield (9620.88 kg ha-1) was obtain under treatment of T_{10} - 100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS. The great potentialities of nano fertilisers have increased the yield attributes and yield of mustard by guaranteeing the high availability of nutrients to plants in a controlled manner throughout the entire crop growth period. High photosynthetic activity resulted in the translocation of assimilate products in seed, resulting in a

Table 3 Effect of different treatments on branches per plant, yield contributing traits and yields of Indian mustard.

Treatments		Branches per plant		Yield contributing traits			Yields			
		Primary branches per plant	Secondary branches per plant	No. of siliquae per plant	No. of seeds per siliqua	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
T_1	Control	6.47	16.00	290.58	13.23	4.19	2005.50	3120.24	5125.74	39.13
T_2	100% RDN and $ZnSO_4$ @20 kg ha-1	8.04	18.46	307.41	15.38	5.28	2889.30	4452.65	7341.95	39.35
T_3	50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	8.14	18.35	307.20	15.00	5.30	2990.73	4309.33	7300.06	40.97
T_4	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS	8.98	19.69	324.50	15.54	5.32	3007.06	4696.59	7703.65	39.03
T_5	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS+ 2nd spray of nano urea only at 40DAS	8.93	19.73	326.25	16.13	5.44	3231.55	4835.80	8067.35	40.06
T_6	75% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	8.38	19.84	297.79	14.83	5.50	3452.98	5044.63	8497.61	40.63
T_7	75% RDN and $ZnSO_4$@10 kg ha-1 +1st spray of nano urea and nano Zn at 25DAS	8.31	20.12	327.85	15.48	5.56	3506.04	5299.53	8805.57	39.82
T_8	75% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25DAS+ 2nd spray of nano urea only at 40DAS	9.24	21.46	339.88	15.93	5.59	3629.51	5530.90	9160.41	39.62
T_9	100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25DAS	9.34	21.88	348.30	16.08	5.62	3675.43	5701.49	9376.92	39.20
T_{10}	100% RDN and $ZnSO_4$ @20 kg ha 1+1stspray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS	9.49	22.13	369.89	16.23	5.70	3721.35	5899.53	9620.88	38.68
S.Em.±		0.29	0.54	12.12	0.26	0.17	53.96	175.62	243.98	0.53
C.D. at 5%		NS	NS	35.9964	0.7722	NS	160.25	521.60	724.62	NS

higher siliquae plant-1, seeds siliquae-1, and weight of seed, among other things. As a fundamental element, nitrogen has a noticeable impact on photosynthesis by increasing leaf area and number. Additionally, it increases the rate at which photosynthesis uses solar radiation, which promotes vegetative development and raises biomass and grain output. Due to its high surface area to volume ratio, which speeds up nutrient absorption and lowers leaching losses, nano nitrogen enhanced mustard yield and yield qualities. This also boosts the nitrogen's efficiency of use. By improving pollen and seed production, which would have boosted plant reproduction, the usage of zinc may have increased grain output. Comparable to [15] findings, the current study's yield and features were shown to significantly enhance when conventional $ZnSO_4$ and ZnO NP treatments were combined. The results of this study are similar to those of [15], who found that combining conventional $ZnSO_4$ and ZnO NP treatments significantly improved rice yield characteristics and yield. [16] also found that by increasing growth hormone activity and enhancing metabolic processes, which in turn prompted flowering and grain formation, foliar application of NPK nano-fertilizers enhanced chickpea production and yield characteristics. ZnO nanoparticles significantly enhanced crop biomass, which raised wheat crop yield, according [17, 18 and 19] in mustard reported similar results.

Influence of nano urea and nano zinc on economics

The results showed (Table 4) that the application of 100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS (T_{10}) obtained significantly higher net returns, gross return and benefit cost ratio over the control as well as rest of treatments, however treatment T_9-100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25DAS showed at par with T_{10} for higher net returns, gross return and benefit cost ratio. This trend in economic return is mainly due to the lower cost and treatment effect on the seed and stover yield of mustard.

Table 4 Effect of different treatments on economics of Indian mustard.

	Treatments	Cost of cultivation (Rs ha^{-1})	Gross Income (Rs ha^{-1})	Net Income (Rs ha^{-1})	B:C Ratio
T_1	Control	31,249	61,719	30,470	1.98
T_2	100% RDN and $ZnSO_4$ @20 kg ha-1	39,965	80,541	40,576	2.02
T3	50% RDN and ZnSO4@10 kg ha-1+1st spray of nano urea at 25 DAS	38,849	78,324	39,475	2.02
T_4	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS	39,974	82,914	42,940	2.07
T_5	50% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS+ 2nd spray of nano urea only at 40DAS	41,099	87,468	46,369	2.13
T_6	75% RDN and ZnSO4@10 kg ha-1+1^{stk2} spray of nano urea at 25 DAS	39,972	85,152	45,180	2.13
T_7	75% RDN and $ZnSO_4$@10 kg ha-1 +1st spray of nano urea and nano Zn at 25DAS	41,101	89,605	48,504	2.18
T_8	75% RDN and $ZnSO_4$@10 kg ha-1+1st spray of nano urea and nano Zn at 25DAS+ 2nd spray of nano urea only at 40DAS	42,222	93,797	51,575	2.22
T_9	100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25DAS	42,219	96,392	54,173	2.28
T_{10}	100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS	43,344	100,633	57,289	2.32
	S.Em.±	-	1781.62	1084.04	0.03
	C.D. at 5%	-	5291.40	3222.60	0.10

Conclusion

On the basis of experimental findings of the present investigation conducted during *Rabi*, 2023-24, it was concluded that application of 100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS (T_{10}) had significant effect with respect to growth, yield and maximum gross returns of (Rs. 100,633 ha^{-1}), net return (Rs 57,289 ha^{-1}) and B:C ratio (2.32). Hence, treatment (T_{10}) 100% RDN and $ZnSO_4$ @20 kg ha-1+1st spray of nano urea and nano Zn at 25 DAS + 2nd spray of nano urea only 40DAS, may be recommended to farmers for higher productivity and net return of mustard. However, these results are only indicative and require further experimentation for confirmation before making final recommendation to the farmers.

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