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Research Paper

Influence of Zinc and Neem Coated Urea on Growth and Yield of Wheat under *Shiwalik* Foothills of Jammu

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ABSTRACT

Adoption of an intensive cropping system to meet the food demand of the increasing population requires high input energy. The indiscriminate and imbalanced use of these inorganic fertilizers adversely affected soil health and human well-being besides reduced factor productivity. To overcome this, an experiment was conducted under assured irrigated conditions of humid eco-region of Western Himalayas at Research Farm, Chatha, SKUAST, Jammu, India, during the winter (*rabi*) season of 2017-18 to study the efficacy of coated urea, including neem coated, zinc coated and neem + zinc coated on growth and productivity of wheat. The soil of the experimental field was sandy clay loam in texture slightly alkaline in reaction (7.42), low in organic carbon, available N, but medium in available P and K. The experiment was laid out in randomized block design (RBD) with eleven treatment combinations, replicated thrice. Different doses of coated urea fertilizers showed a significant effect on the yield of the wheat crop. Application of 100% of Rec. N through ZnCU + Rec. P, K & Zn) showed significantly better growth measured in terms of plant height, dry matter production, leaf area index, crop growth rate, grain, and straw yield, during the study and found at par with an application of 85% of Rec. N through ZnCU + Rec. P, K & Zn, 100% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn, 85% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn and 100% of Rec. N through NCU + Rec. P, K & Zn than other treatments in comparison.

HIGHLIGHTS

- 100 % of Rec. N through ZnCU + Rec. P, K & Zn was superior in terms of growth and yield parameters of wheat.
- 85% of Rec. N through ZnCU + Rec. P, K & Zn was economical.

Keywords: Wheat, neem coated urea, zinc-coated urea, slow-release fertilizers, organic carbon, yield

Wheat (*Triticum aestivum*) is the second most important cereal crop in the world after rice. It occupies a premier position in the agricultural sector and overall financial system in the world. Moreover, it is an important source of carbohydrates, protein and fiber in the human diet (Shewry and Hey, 2015; Arya *et al.* 2012), encompassing a protein content of about 13 percent, which is relatively high compared to other major cereals. Globally, wheat is cultivated in an area of 224.72 mha with production and productivity of 734.62 mt and 3.27

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t/ha, respectively (Anonymous, 2016). India is the second most important wheat-producing country after China. In India, wheat is cultivated in 31.0 mha with production and productivity of 88.9 mt and 2.87 t/ha, respectively (Anonymous, 2016a). In Jammu and Kashmir, wheat is the most popular *rabi* season crop cultivated in 290.99 thousand hectares with production and productivity of 0.58 mt and 2.0 t/ha, respectively (Anonymous, 2015). The productivity of wheat in J&K was about 30.3% less than the national productivity.

Adoption of an intensive cropping system to meet the food demand of the increasing population of 1.2 billion requires high input energy. The indiscriminate and imbalanced use of these inorganic fertilizers has adversely affected soil health, and human well-being, besides reducing factor productivity. Production cost of the fertilizers is high and is rising day by day. Further, to save foreign exchange and increase the GDP, Government of India has reduced subsidies on fertilizers. Application of Urea, DAP and MOP has been found to realize lower fertilizer use efficiency, which ranges from 20 to 50 percent for nitrogen and 10 to 25 percent for phosphorus (Chinnamuthu and Boopathi, 2009) owing to leaching losses besides volatilization, denitrification losses, and fixation. Consequently, contribute to greenhouse gases emission that leads to health hazards such as blue baby syndrome.

To overcome this low nitrogen use efficiency (NUE), various types of slow-release coated urea, such as neem coated urea (NCU), zinc-coated urea (ZnCU), sulphur coated urea (SCU), polymer-coated urea (PCU), water-soluble fertilizer, and biodegradable fertilizer materials have been developed (Ladha *et al.* 2005). Moreover, from May, 2015 the entire production of urea has been converted as neem coated urea (NCU) to check its misuse in industries and benefits accrued in terms of increased production of crops (Swami, 2015). Further, Shivay *et al.* (2015) concluded from their study that zinc-coated urea (ZnCU) is a promising fertilizer for increasing rice production besides saving a significant amount of Zn to be applied. In this context, information available on the comparative performance of different doses of various types of coated urea on the wheat crop for increased crop productivity and economics is meager. Therefore, the present field study was undertaken to evaluate the most appropriate coated urea combination that enhances the productivity of wheat cultivated under the *Shiwalik* foothills of Jammu.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* (winter) season of 2017 at the Research Farm, Sher-e-Kashmir University of Agricultural Sciences Technology of Jammu, Chatha, located at a latitude of 32°40′, the longitude of 74°58′ and a an altitude of 320 meters above mean sea-level. The mean annual rainfall of the study area is 1147 mm, and more than 80% generally occurs during the southwest *monsoon* season (July-September). The soil of the experimental field was sandy clay loam in texture with slightly alkaline reaction (7.42) and having 250.30 kg ha^{-1} of available N, 13.22 kg ha^{-1} available P, 120.40 kg ha^{-1} 1 N ammonium acetate exchangeable K and 0.38 % organic carbon. The DTPA extractable zinc was found below the critical level (0.53 mg kg^{-1}). The treatments comprised of various doses of different types of coated urea*viz.* prilled Urea, Neem coated urea (NCU), Zinc coated urea (ZnCU), and Neem+ Zinc coated urea (NCU + ZnCU). The experiment consisted of eleven treatment combinations, *viz.*, T_1: No N + Rec. P, K & Zn, T_2: 100% Rec. N through Urea + Rec. P, K & Zn, T_3: 70% Rec. N through NCU + Rec. P, K & Zn, T_4: 85% of Rec. N through NCU + Rec. P, K & Zn, T_5: 100% of Rec. N through NCU + Rec. P, K & Zn, T_6: 70% of Rec. N through ZnCU + Rec. P, K & Zn, T_7: 85% of Rec. N through ZnCU + Rec. P, K & Zn, T_8: 100% of Rec. N through ZnCU + Rec. P, K & Zn, T_9: 70% of Rec. N through NCU + ZnCU + Rec. P, K & Zn, T_{10}: 85% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn, T_{11}: 100% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn, arranged in randomized block design with three replications. Wheat crop variety HD-3086 was sown on 27th November at 20 cm row spacing and a 100 kg/ha seed rate. Sources of nitrogen application were prilled urea, NCU, ZnCU, and NCU + ZnCU. Whereas, for P and K fertilizer applications, single super phosphate and muriate of potash were used as a source of nutrients. Full dose of P_2O_5 and K_2O along with half of N was applied as basal, and the remaining N was applied in two splits at CRI stage and pre-booting stage as per the treatments. Weed control was done by applying Pendimethalin

@1.5 kg ha^{-1}, two days after sowing. Intercultural operations and plant protection measures were adopted as per the recommended package of practices whenever required, from sowing up to the crop harvest. The crop was irrigated as and when necessary to maintain the optimum moisture condition of the field. The crop was harvested and threshed manually in each plot, and necessary observations were recorded from individual plots. Data on plant height (cm), dry matter accumulation (g/m^2), leaf area index (LAI), yield attributes, and grain and straw yield of wheat were recorded as per the standard procedures. The CGR and RGR were computed from dry matter accumulated at each growth stage. The experimental results were analyzed statistically using analysis of variance (ANOVA) appropriate for randomized block design, and the treatment means were compared using the least significant difference (LSD) test at 5 % level of significance (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

Plant height

Plant height is a growth parameter and indicates the influence of various nutrients on plant metabolism. Periodic plant height recorded at 30, 60, 90, 120 days after sowing (DAS) and at harvest were presented in Table 1. Data showed that plant height increased with the advancement in crop age. The increase marked a sigmoidal growth with the highest rate of increase in plant height between 60 and 90 DAS, and thereafter, a slow rate of increase in plant height was observed. A significant effect of different types of coated urea was observed on the plant height of wheat at all the crop growth stages till the harvest stage. During initial growth stages *i.e*. 30 DAS, significantly more plant height was reported in T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) as compared to other treatments. However, it was at par with T_{11} (100% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn) and T_5 (100% of Rec. N through NCU + Rec. P, K & Zn). At 60 DAS, plant height showed a similar trend as that of 30 DAS. At later growth stages, 90 and 120 DAS and at harvest, applying different treatments proved instrumental in increasing plant height. Among the different treatments, at harvest, maximum plant height (114.61cm) was recorded in T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) than other treatments, but it remained at par with treatment T_{11} (100% of Rec. N through NCU + ZnCU + Rec. P, K & Zn), T_7 (85% of Rec. N through ZnCU + Rec. P, K & Zn) and T_5 (100% of Rec. N through NCU + Rec. P, K & Zn) with the values 112.75 cm, 111.72 cm, and 110.98cm, respectively. The lowest plant height (79.63 cm) was recorded in treatment T_1 (No N + Rec. P, K & Zn). At 90 and 120 DAS, plant height showed a similar trend as at the harvest stage. The significant increase in the plant height of wheat by use of coated urea might be explained by the fact that neem and zinc-coated urea played a major role in the shoot and root elongation due to the activation of auxin hormone in the wheat crop. Shivay and

Table 1: Effect of coated urea on plant height (cm) of wheat

Treatments	Days After Sowing (DAS)				Harvest
	30	60	90	120	
No N + Recommended P, K & Zn	17.5	34.2	71.4	78.6	79.6
100 % Recommended N through Urea + Recommended P, K &Zn	21.2	38.3	83.3	94.7	95.7
70 % Recommended N through NCU + Recommended P, K & Zn	18.0	34.8	77.7	89.9	90.0
85 % Recommended N through NCU + Recommended P, K & Zn	21.6	40.3	85.9	98.8	99.8
100 % Recommended N through NCU + Recommended P, K & Zn	23.3	43.5	89.7	109.9	111.0
70 % Recommended N through ZnCU + Recommended P, K & Zn	18.9	35.0	78.6	90.8	91.9
85 % Recommended N through ZnCU + Recommended P, K & Zn	22.3	41.2	88.2	110.7	111.7
100 % Recommended N through ZnCU + Recommended P, K & Zn	24.9	46.7	92.9	113.6	114.6
70 % Recommended N through NCU + ZnCU+ Recommended P, K & Zn	18.6	35.0	78.1	90.6	91.7
85 % Recommended N through NCU + ZnCU+ Recommended P, K & Zn	21.9	40.5	86.0	98.9	100.0
100 % Recommended N through NCU + ZnCU+ Recommended P, K & Zn	23.7	43.5	89.4	111.7	112.8
S.Em. ±	0.81	1.15	1.65	1.3	1.3
C.D. (5%)	2.33	3.22	4.72	3.8	3.8

Prasad (2012) and Kumar *et al.* (2016) also found that plant height was more enhanced when coated urea was combined with micronutrients. It can provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth. These findings corroborate Jat *et al.* (2013) and Kumar *et al.* (2016).

Dry matter accumulation (g/m row length)

Dry matter accumulation of wheat crop (Table 2) showed significant variation with applying different doses and types of coated fertilizer. Analysis of data about dry matter accumulation of wheat crop showed that a significant increase in dry matter accumulation was observed in all the treatments at different growth stages till harvest. At 30 DAS, maximum dry matter accumulated under treatment T_8 followed by T_{11}. However, the difference was non-significant. But at later growth stages, *i.e.* 60, 90, 120 DAS, and at the harvest stage, application of different doses and types of coated fertilizer proved instrumental in increasing the dry matter of wheat. At 90 DAS, maximum dry matter accumulated under the treatment T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) followed by T_{11} (100% of Rec. N through NCU + ZnCU + Rec. P, K & Zn), T_7 (85% of Rec. N through ZnCU + Rec. P, K & Zn) and T_5 (100% of Rec. N through NCU + Rec. P, K & Zn). At 60 DAS dry matter accumulation showed a similar trend as that of 90 DAS. At harvest, among the treatments, T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) resulted in significantly higher dry matter accumulation (246.06 g m^{-1} row length), which was, however, at par with T_{11} (100% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn), T_5 (100% of Rec. N through NCU + Rec. P, K & Zn), T_7 (85% of Rec. N through ZnCU + Rec. P, K & Zn) and T_{10} (85% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn) with the values 244.2, 243.6, 240.50 and 240.47 g m^{-1} row length respectively. A similar trend of dry matter accumulation was noted at 120 DAS. Lowest dry matter accumulation (174.0 gm^{-1} row length) was observed in control (No N + Rec. P, K & Zn) at harvest. This may be due to the balanced application of Zn along with NPK fertilizer, as zinc is involved in a number of physiological processes of plant growth and metabolism. Zinc Coated urea provides all the essential growth-promoting elements for shoot growth, root development, photosynthesis, cell division, and cell enlargement, due to which meristematic activity increases and results in the improved overall growth of the plant. These findings corroborate to the findings of Shivay and Prasad (2012) and Kumar *et al.* (2016).

Leaf area index (LAI)

The leaf area index is an important plant growth index that determines plants' capacity to trap solar energy for photosynthesis and crop yield. The leaf area index increased with the advancement of the crop age up to 90 DAS, and after that, it decreased and a conspicuous increase in the values of LAI

Table 2: Effect of coated urea on dry matter accumulation (g/m row length) of wheat

Treatments	Days After Sowing (DAS)				
	30	60	90	120	Harvest
No N + Recommended P, K & Zn	4.3	33.5	97.2	158.2	174.0
100 % Recommended N through Urea + Recommended P, K &Zn	5.5	45.6	116.0	205.2	237.9
70 % Recommended N through NCU + Recommended P, K & Zn	4.4	39.5	107.1	191.0	220.8
85 % Recommended N through NCU + Recommended P, K & Zn	4.6	44.2	113.7	201.1	235.3
100 % Recommended N through NCU + Recommended P, K & Zn	6.2	45.8	121.2	210.0	243.6
70 % Recommended N through ZnCU + Recommended P, K & Zn	4.9	41.1	110.5	196.1	223.3
85 % Recommended N through ZnCU + Recommended P, K & Zn	6.2	46.6	118.1	207.7	240.5
100 % Recommended N through ZnCU + Recommended P, K & Zn	8.3	50.2	123.5	214.7	246.0
70 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	4.7	39.7	108.8	193.7	222.7
85 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	5.0	44.9	115.8	205.7	240.5
100 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	6.8	46.2	122.2	210.7	244.2
S.Em.±	0.9	1.5	1.8	3.1	1.9
C.D. (5% level of significance)	NS	4.5	5.4	9.0	5.6

Table 3: Effect of coated urea on leaf area index of wheat

Treatments	Days After Sowing (DAS)				
	30	60	90	120	At harvest
No N + Recommended P, K & Zn	0.40	2.98	3.33	3.03	2.07
100 % Recommended N through Urea + Recommended P, K &Zn	0.46	3.60	3.53	3.38	2.54
70 % Recommended N through NCU + Recommended P, K & Zn	0.43	3.37	3.50	3.31	2.47
85 % Recommended N through NCU + Recommended P, K & Zn	0.47	3.55	3.74	3.56	2.68
100 % Recommended N through NCU + Recommended P, K & Zn	0.50	3.64	4.43	3.85	2.87
70 % Recommended N through ZnCU + Recommended P, K & Zn	0.43	3.40	3.50	3.35	2.49
85 % Recommended N through ZnCU + Recommended P, K & Zn	0.49	3.62	4.12	3.68	2.72
100 % Recommended N through ZnCU + Recommended P, K & Zn	0.55	3.70	4.49	3.89	2.93
70 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	0.43	3.37	3.50	3.33	2.48
85 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	0.48	3.55	3.75	3.64	2.75
100 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	0.51	3.67	4.46	3.87	2.88
SEm±	0.01	0.02	0.02	0.02	0.03
CD (5%)	0.05	0.06	0.06	0.05	0.08

Table 4: Effect of coated fertilizers on crop growth rate (g/m^2/day) of wheat

Treatments	Days After Sowing (DAS)			
	30-60	60-90	90-120	120- 150
No N + Recommended P, K & Zn	4.86	10.63	10.16	2.63
100 % Recommended N through Urea + Recommended P, K &Zn	6.69	11.73	14.87	5.45
70 % Recommended N through NCU + Recommended P, K & Zn	5.84	11.28	13.98	4.96
85 % Recommended N through NCU + Recommended P, K & Zn	6.60	11.58	14.57	5.71
100 % Recommended N through NCU + Recommended P, K & Zn	6.60	12.57	14.80	5.60
70 % Recommended N through ZnCU + Recommended P, K & Zn	6.03	11.57	14.28	4.53
85 % Recommended N through ZnCU + Recommended P, K & Zn	6.72	11.93	14.93	5.48
100 % Recommended N through ZnCU + Recommended P, K & Zn	6.99	12.21	15.37	5.07
70 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	5.84	11.51	14.15	4.83
85 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	6.65	11.82	14.82	5.97
100 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	6.57	12.66	14.75	5.58
S.Em.±	0.26	0.34	0.65	0.71
C.D.(5%)	0.76	1.02	1.94	NS

was observed between 30 and 60 DAS (Table 3). A significant effect of coated urea was observed on the leaf area index of wheat at all the crop growth stages till harvest. The application of different treatment combinations proved instrumental in increasing LAI of wheat. Among the different treatments, maximum LAI (4.49) was recorded in T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) at 90 DAS, which was at par with T_{11} (100% of Rec. N through NCU + ZnCU + Rec. P, K & Zn) and T_5 (100% of Rec. N through NCU + Rec. P, K & Zn) with the values of 4.46 of T_{11} and 4.43 of $T_{5.}$ A similar trend was obtained under 120 DAS and at harvest. However, LAI with treatments T_{11} and T_5 were statistically at par at all growth intervals and at harvest. Lowest LAI was recorded in treatment T_1 (No N + Rec. P, K & Zn) at all the growth stages. The significant increase in the leaf area index of wheat as influenced by coated urea might be explained on the basis that the slow release of coated urea led to the regulated release rate of N, synchronizing with the requirement of growing plants and efficient assimilation.

Crop growth rate (CGR)

Data with respect of periodic and final crop growth rate (CGR) indicated that the use of coated urea significantly affects CGR at all the stages of growth. The crop growth rate increased with the advancement of the crop age up to 120 DAS except for control as shown in Table 4. A perusal of data depicted that initial CGR at 30-60, 60-90 and 90-120 DAS showed a significant difference. Among the applied treatments, it was seen that significantly highest CGR at 90-120 DAS was recorded in T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) than in other treatments in comparison. However, it was at par with T_{11} (100 % of Rec. N through NCU + ZnCU + Rec. P, K & Zn) and T_5 (100 % of Rec. N through NCU + Rec. P, K & Zn) with respective values 14.75 and 14.80 (g/m^2/day.) However, CGR at 120-harvest showed non-significant difference. Treatment T_1 (No N + Rec. P, K & Zn) recorded the lowest value of crop growth rate at all the growth stages.

Relative growth rate (RGR)

The mean relative growth rate fluctuated from 30-120 DAS and declined with the advancement of crop age. A perusal of data depicted in Table 5 revealed that coated fertilizers failed to show any significant effect with respect to the wheat crop's relative growth rate at all the growth stagesowth.

Grain and straw yield

The use of different types and doses of coated urea had a significant effect on the grain and straw yield of wheat. The data depicted in Table 6 shows that Treatment T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn) though at par with treatment T_5 (100% of Rec. N through NCU + Rec. P, K & Zn), T_7 (85% of Rec. N through ZnCU + Rec. P, K & Zn), T_{10} (85% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn) and T_{11} (100% of Rec. N through NCU + ZnCU + Rec. P, K & Zn) recorded a significant increase in grain and straw yield of wheat. This may be due to the optimal supply of nutrients to the wheat crop upon using a recommended dose of fertilizers, thereby

Table 5: Effect of coated fertilizers on relative growth rate (g g^{-1}×10^{-3} m^{-2} day^{-1}) of wheat

Treatments	Days After Sowing (DAS)			
	30-60	60-90	90-120	120-150
No N + Recommended P, K & Zn	29.97	15.46	7.02	1.41
100 % Recommended N through Urea + Recommended P, K &Zn	30.88	13.54	8.26	2.14
70 % Recommended N through NCU + Recommended P, K & Zn	31.92	14.46	8.36	2.11
85 % Recommended N through NCU + Recommended P, K & Zn	33.07	13.69	8.24	2.29
100 % Recommended N through NCU + Recommended P, K & Zn	29.49	14.11	7.95	2.16
70 % Recommended N through ZnCU + Recommended P, K & Zn	31.05	14.33	8.31	1.88
85 % Recommended N through ZnCU + Recommended P, K & Zn	29.44	13.51	8.17	2.13
100 % Recommended N through ZnCU + Recommended P, K & Zn	26.38	13.03	8.07	1.92
70 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	31.23	14.59	8.35	2.02
85 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	31.98	13.73	8.24	2.34
100 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	28.18	14.08	7.88	2.14
SEm±	0.002	0.000	0.000	0.000
CD (5%)	NS	NS	NS	NS

Table 6: Effect of coated urea on Grain and Straw yield of wheat

Treatments	Grain yield (q/ha)	Straw yield (q/ha)
No N + Recommended P, K & Zn	28.16	59.87
100 % Recommended N through Urea + Recommended P, K &Zn	42.52	74.13
70 % Recommended N through NCU + Recommended P, K & Zn	39.05	69.42
85 % Recommended N through NCU + Recommended P, K & Zn	42.94	74.73
100 % Recommended N through NCU + Recommended P, K & Zn	43.98	75.32
70 % Recommended N through ZnCU + Recommended P, K & Zn	39.87	70.09
85 % Recommended N through ZnCU + Recommended P, K & Zn	44.47	76.84
100 % Recommended N through ZnCU + Recommended P, K & Zn	45.58	78.80
70 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	39.66	69.88
85 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	43.27	74.84
100 % Recommended N through NCU + ZnCU + Recommended P, K & Zn	44.94	77.17
SEm±	0.88	1.34
CD (5%)	2.62	4.00

resulting in better growth and development of the crop. Significantly higher grain and straw yield were recorded in treatment T_8 (100% of Rec. N through ZnCU + Rec. P, K & Zn), which remained statistically at par with T_{11} (100% of Rec. N through NCU + ZnCU+ Rec. P, K & Zn), T_7 (85% of Rec. N through ZnCU+ Rec. P, K & Zn), T_5 (100% of Rec. N through NCU + Rec. P, K & Zn) and T_{10} (85% of Rec. N through NCU + ZnCU + Rec. P, K & Zn). In contrast, treatment T_1 (No N + Rec. P, K & Zn) recorded lowest grain and straw yield significantly. The increase in grain and straw yield might be due to adequate quantities and a balanced proportion of plant nutrients supplied to the crop during the critical growth period causing a favourable increase in yield attributing characteristics. This, in turn, led to better nutrient absorption by plant cells resulting in optimal growth of plant parts and metabolic processes such as photosynthesis. This ultimately led to a higher accumulation of photosynthates and their translocation to the economic parts of the plant. These findings corroborate the findings of Shivay *et al.* (2015) and Kumar *et al.* (2016).

CONCLUSION

Hence, based on this study, it is concluded that among the different doses of coated urea, 100 % of Rec. N through ZnCU + Rec. P, K & Zn recorded better growth measured in terms of plant height, dry matter production, leaf area index, crop growth rate, grain, and straw yield during the study, which was, however, statistically at par with 85% of Rec. N through ZnCU+ Rec. P, K & Zn than other treatments in comparison.

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