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Effect of NPK levels and foliar application of nano TiO_2 concentrations on growth and yield of wheat (*Triticum aestivum*)

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Stagnating wheat (*Triticum aestivum* L.) yield is the major challenge for national food security (Ray *et al.* 2012). Fertilizer is one of the major contributor to enhance wheat yield but suffering from their own challenges like declining fertilizer response, depleting soil organic matter, imbalance fertilizer use, multi-nutrient deficiency, declining nutrient use efficiency and negative soil nutrient balance (Ibajanai Kurbah 2016). Simultaneously poor nutrient use efficiency especially P and K fertilizer and their 100 percent import also the major concern for all the stake holders involved in fertilizer sector like policy makers, farmers, and industries etc (Annonymus 2016). On the other hand we are applying phosphatic and potassic fertilizers since many years, which after being utilized by crop were retained by the soil system in form of soil fixation for P and exchange for K. Soil crop association naturally create some rhizospheric environment by supplying the leachate to their surroundings (Jianbo *et al.* 2013) may help to reutilize P and K retained by the soil system for better crop productivity, save P and K fertilizers which ultimately help to reduce the import. An omission plot technique was used in this experiment to delineate the response of retained soil P and K in wheat crop.

Nanotechnology is infiltrating in Indian society very fast in various sectors, agriculture is one of them. High surface volume ratio of nanoparticles provide an opportunity to reduce the quantity of inputs used in agriculture, create interest to use nanoparticles to enhance fertilizer use efficiency (Duhan *et al.* 2017). Nowadays, various researchers have studied the effects of nanomaterials on plant growth (Khot *et al.* 2012). Nanosized TiO_2 is frequently used nanoparticle in different sectors, but there is much less information on the effects of nanosized TiO_2 nanoparticles on plants. Previous studies on the effects of TiO_2 nanoparticles on plants provide information about the positive and stimulating effects as well as any negative impact (Klancnik *et al.* 2011). Despite the low availability of Ti element to plants, its beneficial effects on plants have already been proved. It's benefiting various plant physiological parameters such as biomass yield, chlorophyll content, and growth (Kuzel *et al.* 2003). Ti could activate photosynthesis, probably by changing the redox state of specific regulatory proteins and eliciting an alteration in enzyme activity. Ti can almost fully compensate the fresh and dry weight of shoots and roots, flowering time, number of flowers, chlorophyll content, and photosynthetic capacity of tomato when nitrogen doses are reduced by 50%. This has very practical application for tomato hydroponic culture by maximizing macronutrient and micronutrient absorption while lowering N concentration by half, thus making the system more cost-effective (Haghighi *et al.* 2012). Considering the above this experiment was done to delineate the effect of nano TiO_2 along with omitted nutrients on wheat crop.

A field experiment was conducted on a isolated fixed plot during the *rabi* season of 2011–12 at N. E. Borlaug Crop Research Centre of GB Pant University of Agriculture and Technology (at 29^o N, 79^{o}29 E and altitude of 243.83 m above mean sea-level), to study the effect of NPK and nano-TiO_2 concentration on the growth, yield attributes and yield of wheat. The soil of the experimental site was silty clay loam with pH (7.5), organic carbon (0.74%), available N (213 kg/ha), available P (24 kg/ha) and available K (137 kg/ha). The experiment was laid out in factorial randomized block design with three replications. Four levels of NPK fertilizer (kg/ha), viz. absolute control (No fertilizer application), recommended NPK (150:60:40 kg/ha), NP (150:60 kg/ha) and NK (150:40 kg/ha) were kept in first factor and in second factor four nano-TiO_2 concentrations, viz. 0 ppm, 200 ppm, 400 ppm and 600 ppm were kept. Full dose of phosphorus, potassium and 1/3rd nitrogen were given as basal, remaining nitrogen was given in two equal splits at CRI stage (21 DAS) and late jointing stage (55 DAS). Standard package of practices were followed for raising the crop successfully. TiO_2 anatase nano-material had a grain size of 20 nm with 99.50 % purity. Nano-TiO_2 was sprayed on the leaves twice at tillering and at booting

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stage. Standard procedures and techniques were followed to measure various growth parameters, yield attributes and grain yield. Data recorded during the experimental year were subjected to analysis of variance for factorial randomized block design with the help of statistical programme- STPR-2 developed by Department of Mathematics and Statistics, College of Basic Science and Humanities, Pant nagar. Overall differences were tested for 'F' test at 5% level of significance. In case of significant results, critical difference at 5% level of probability was taken for comparison between two treatment means as suggested by Gomez and Gomez (2010).

Crop performance in relation to application of NPK and nanoparticle application are given in Table 1. Fertilizer treated plots gave significantly more plant height as compared to absolute control plots. Maximum plant height was observed in recommended NPK at all growth stages except recommended NP at 45 DAS. The differences in plant height were non-significant within fertilizer applied plots at all the growth stages except maturity. Tillers/m^2 decreased with the omission of phosphorus and potassium; however, phosphorus omitted wheat caused more reduction in tillers/m^2 as compared to potassium omitted plots. Tillers/m^2 was found maximum at recommended NPK which was significantly higher than the recommended NP and NK at 45 and 60 DAS. Crop accumulated significantly higher dry matter with recommended NPK as compared to recommended NP and recommended NK at all the growth stages except 45 DAS. Recommended NPK took significantly more days to attain 50% heading and maturity than the other NPK levels. Recommended NP produced maximum number of spike/m^2 which was significantly superior than the control and recommended NPK. However, it remained at par with recommended NK. Spike length was maximum at recommended NPK which was found at par with recommended NP and recommended NK. Grains/spike differed significantly due to various NPK levels. Recommended NPK significantly produced more grains/spike than the control and recommended NK but at par with recommended NP. Grain weight/spike was maximum at recommended NPK which was significantly higher than the other treatments. Variation in 1000 grain weight due to NPK levels also registered a significant difference. Recommended NPK significantly produced higher weight of 1000 grains as compared to other NPK levels except, recommended NK. Recommended NPK significantly produced the highest grain yield over all the other NPK levels. NP and NK remained at par with each other and significantly superior over absolute control in terms of seed yield.

Addition of P and/or K along with N increased plant height, tiller number and dry matter accumulation over absolute control which might be due to the physiological role played by N, P and K in various metabolic activities (Yadav and Kumar 2009). Both P and K application favoured illering of wheat and reduced lodging in wheat (Liakas *et al*. 2001). Ali *et al*. (1997) also reported that phosphorus along with N resulted more number of tillers, plant height, number of grains/spike, thousand grain weight and grain yield. Effect of nano-TiO_2 concentration on plant height was found non-significant at all the growth stages.

Tillers/m^2 decreased with increase in the concentration of nano-TiO_2 showing its toxic effect. Control (no nano) gave maximum tillers/m^2 at all the growth stages which was at par with 200 ppm nano-TiO_2 but significantly higher over 400 and 600 ppm nano-TiO_2. Dry matter production was maximum in control (no nano) at 45 DAS which was significantly higher than the nano TiO2 treated plots. However, at 90 days and maturity stage, foliar application of 400 ppm nano-TiO_2 produced higher dry matter which was significantly superior to control, 200 ppm and 600 ppm application of nano TiO_2. Highest number of days taken for maturity were noticed in Nano-TiO_2 @ 400 ppm which was significantly higher than the control (no nano) but at par with 200 ppm and 600 ppm nano-TiO_2. Spikes/m^2 were maximum in control (no nano) which was statistically superior than the other treatments. Nano TiO_2 failed to give significant effect on spike length, grains/spike. Application of 400 ppm nano-TiO_2 resulted in higher grain weight/spike which was found at par with 200 ppm nano-TiO_2 and significantly higher than other nano-TiO_2 concentration. Application of 400 ppm nano-TiO_2 also produced maximum 1000 grain weight which was significantly higher than the other treatments. Nano-TiO_2 @ 400 ppm gave maximum grain yield which was statistically superior than the other nano- TiO_2 concentrations except 200 ppm which shows that nano-TiO_2 concentrations is required to get higher yield. The interaction effects between NPK levels and nano-TiO_2 concentration on grain yield was significant (Table 2). The highest grain yield was found with recommended NPK along with foliar spray of 600 ppm nano-TiO_2 which significantly superior from the other treatments combination, except recommended NPK along with 400 ppm nano-TiO_2, recommended NP with 200 ppm and 400 ppm nano-TiO_2; and recommended NK with 400 ppm nano-TiO_2. Higher grain yield in recommended NPK along with 600 ppm nano-TiO_2 might be due to the dilution effect caused by NPK which reduced the toxic effect of nano-TiO_2. Application of Nano TiO_2 benefiting various plant physiological parameters such as biomass yield, chlorophyll content, and growth (Kuzel *et al.* 2003) and also helpful in activate photosynthesis, probably by changing the redox state of specific regulatory proteins and eliciting an alteration in enzyme activity (Kiss *et al.*1985 and Daood *et al.* 1998). Haghighi *et al*. (2012) demonstrated that 1 mg/L Ti can almost fully compensate the fresh and dry weight of shoots and roots, flowering time, number of flowers, chlorophyll content, and photosynthetic capacity of tomato when nitrogen is reduced by 50%. Nanoanatase TiO_2 on exposure to sunlight could chemisorb nitrogen directly or reduce nitrogen to ammonia in leaves, transforming into organic nitrogen and improving growth of crop (Yang *et al*. 2006). Application of TiO_2-NPs at appropriate concentrations improved seedling growth of wheat as compared to the bulk and control treatments, whilst high concentrations of TiO_2-NPs, have inhibitory

Table 1 Crop performance in relation to NPK levels and nano-TiO_2 concentration

Treatment	Plant height (cm)			Tillers/m^2		Dry matter accumulation (g/m^2)			Days taken to		Spikes (m^{-2})	Spike length (cm)	Grains spike	Grain weight/ spike(g)	1,000 grain weight (g)	Grain yield (kg/ha)
	45 DAS	90 DAS	Maturity	45 DAS	60 DAS	45 DAS	90 DAS	Maturity	50% heading	Maturity						
NPK levels																
Control	27.36	52.50	78.48	255	294	7.20	215	334	96	136	219	11.52	43.61	1.02	23.49	2240
Rec. NP	34.67	67.19	82.10	422	521	10.25	552	644	97	137	332	12.89	49.43	1.77	35.77	5890
Rec. NK	34.72	66.54	89.13	411	512	8.93	572	639	95	137	329	12.92	47.28	1.77	37.60	5830
Rec. NPK	34.49	68.82	92.94	449	546	8.92	610	715	99	139	322	13.22	50.51	1.92	38.05	6120
SEm±	0.89	0.97	1.06	8	8	0.32	8	15	0.17	0.16	3	0.17	0.95	0.02	0.57	60
CD (5%)	2.57	2.81	3.05	24	22	0.92	24	45	0.50	0.47	8	0.50	2.75	0.06	1.64	180
Nano-TiO_2 concentration (ppm)																
0	32.67	63.66	87.10	424	488	11.5	450	500	96	136	312	12.76	47.73	1.52	31.62	4840
200	32.95	64.23	86.26	408	484	8.8	492	564	97	138	299	12.65	48.36	1.66	34.02	5120
400	32.48	63.56	84.64	366	460	7.9	529	651	98	138	295	12.70	47.20	1.71	36.17	5210
600	33.14	63.60	84.66	340	441	7.1	479	617	99	138	295	12.70	47.54	1.60	33.10	4890
SEm±	0.89	0.97	1.06	8	8	0.3	8.3	15	0.17	0.16	3	0.17	0.95	0.02	0.57	60
CD (5%)	NS	NS	NS	24	22	0.9	24.0	45	0.50	0.47	8	NS	NS	0.06	1.64	180

Rec.: Recommended NPK (150: 60: 40 /ha), DAS: days after sowing, ppm: parts per million

Table 2 Interaction effects of NPK levels and concentration of nano-TiO_2 on grain yield (kg/ha)

NPK levels	Nano-TiO_2 concentration			
	0 ppm	200 ppm	400 ppm	600 ppm
Control	2540	2390	2220	1790
Rec. NP	5500	6220	6230	5600
Rec. NK	5530	5940	6170	5670
Rec. NPK	5790	5940	6210	6520
SEm±	120			
CD (5%)	350			

Rec.: Recommended, ppm: parts per million

effects on the growth of wheat plants (Feizi *et al*. 2012), therefore , a proper concentration of nano-TiO_2 is required to improve the growth of crop by promoting photosynthesis and nitrogen metabolism (Yang *et al*. 2006).

SUMMARY

Field plot experiment was conducted in isolation during the *rabi* season of 2011-12 at N. E. Bourlag Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), to find out the effect of NPK levels and nano-TiO_2 concentration on growth and yield of wheat. Factorial randomized block design with three replications was used for experimentation and statistical analysis. The wheat variety UP-2572 was sown at 20 cm rows apart. Yield attributes like tillers/m^2, dry matter accumulation, spikes/m^2, grain yield significantly influenced by NPK levels and nanoTiO_2 concentrations. Recommended NPK gave better growth parameters and grain yield as compared to omission of P and K and in control. Nano-TiO_2 @ 600 ppm gave better growth parameters and grain yield as compared to control and 200 ppm nano-TiO_2 however remained at par with 400 ppm nano-TiO_2. The interaction effect between NPK levels and nano-TiO_2 concentration on grain yield was also found significant. Recommended NPK along with 600 ppm nano-TiO_2 gave maximum grain yield. However, in case of P and K omission, 400 ppm of nano TiO_2 gave better result. Therefore, experimental findings revealed that foliar spray of nano-TiO_2 along with recommended NPK can help it improve wheat growth and yield. From this experiment, it can be concluded that nano-TiO_2 alone at any concentration could not give the positive result on wheat but it interact with NPK application. Under recommended NPK level, 600 ppm nano-TiO_2 however, in case of P or K omission 400 ppm nano-TiO_2 was performed better. Since, these findings are based on one season data; investigation needs to be repeated in future for at least one more season for validation and recommendation to farming community.

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