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Research Article

Effect of rhizospheric nutrient management on root growth, yield, and nutrient use efficiency of wheat (*Triticum aestivum* L.) under *Tarai* region of Uttarakhand, India

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Abstract

Rhizospheric nutrient management and fertilizer placement can be a useful measure to improve wheat crops productivity in *Tarai* regions of India. An experiment was conducted to evaluate the effects of rhizospheric nutrient management on wheat (*Triticum aestivum* L.) to explore the relationship between root proliferation, grain yield and NUE in *Tarai* region of Uttarakhand, India. It comprised 3 fertilizer application (P1 to P3) and 6 nutrient management treatments (T1 to T6) with absolute control in a randomized complete block design and replicated thrice. Experimental results indicated that P1 (1.29 and 1.47; 1.84 and 2.29 mg/cc) produced greater root density, and compared to P3 (1.39 and 1.49; 1.74 and 2.17 mg/cc), P2 (1.24 and 1.36; 1.68 and 1.97 mg/cc) and absolute control (0.85 and 1.19; 1.42 and 1.69 mg/cc) at maximum tillering and flowering stage in year 2017-18 and 2018-19, respectively .The root proliferation also influenced the grain yield (5.4 and 5.5; 5.3 and 5.3; 5.1 and 5.2; 3.5 and 3.3 t/ha) in P1, P3, P2 and absolute control in the year 2017-18 and 2018-19, respectively. However, the grain yield and root distributions (at the flowering stage) recorded significantly (p=0.05) maximum in T4 (5.8 and 5.7 t/ha; 1.84 and 2.32 mg/cc) followed by T3, T6, T1, T5, T2 treatments and minimum in absolute control (3.5 and3.3 t/ha; 1.42 and 1.69 mg /cc) in the year of 2017-18 and 2018-19, respectively. Thus, the rhizospheric nutrient management (75% RDF+ vermicompost + PSB) with fertilizer placement can be a feasible approach for increasing grain yield and NUE in *Tarai* regions of Uttarakhand, by promoting deep root development and reducing fertilizer inputs in wheat.

Keywords: Grain yield, Nutrient use efficiency, Rhizospheric nutrient management, Root growth, *Triticum aestivum* L., Wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.), is the most important staple food crop after rice which triggered the green revolution in the Indian subcontinent. Globally, Billion of people depends on wheat for a substantial part of their diet. The nutritional importance of wheat protein should not be underestimated, particularly in a developing country like India (Kumar *et al*., 2011). Globally, wheat was cultivated over an area of 222.7 mha with production is 742.1 mt and productivity of 3.33 t/ha (FAO, 2017). India stands second among wheat-producing countries in terms of area and production. In India, wheat was grown over an area of 30.2 mha with a production of 97.44 mt and a productivity of 3.09 t/ha (GOI, 2016). Uttarakhand consists of hilly tracts as well as *Tarai/Plains* areas where wheat is grown as a *rabi* crop. Overall, the state has occupied the area of 0.34 mha which produced 0.76 mt of wheat during 2012-2013 with a productivity of 2.22 t/

ha (GOI, 2016).

The population growth, overuse of chemical inputs and reduction in agricultural land are placing divesting pressure on Indian agriculture and natural resources for satisfying the increasing food demand (Foley *et al*., 2011). Both food production and soil fertility can be improved with the efficient supply of soil nutrients (Mi *et al*., 2010 and Zhang *et al*., 2010). The high yielding varieties and excessive use of chemical fertilizers shrink the soil production capacity (Fan *et al*., 2012). So, efficient inputs management is the prime necessity for improving soil health and wheat (*T. aestivum* L.) productivity which can be possible through exploiting the rhizospheric potential of soil by carbon management/ carbon degradation. The soil bio-geophysical properties and root proliferation with the acceleration of agronomic practices (Cultivation, Residue management, localized fertilizer applications and fertilization regulate microbial activities). All these activities regulated the soil nutrient cycling, mobilization, and uptake by plants (Marschner, 2012). The development of roots and rhizospheric system are much efficient when it is empowered with fertilizer placement and timing that fulfils aim to intensify the root-soil nutrient pool. Therefore, the different fertilizer application methods *viz*., Broadcasting, Band placement, and Deep placement are used to accelerate the better root- nutrient contact. Various studies of last decades suggested that the fertilizer placement helps us to short out the nutrient losses from the soil, direct contact of fertilizer with seed and ensure better nutrient availability to plant roots (Nkebiwe *et al*., 2016). However, the other study conducted on major nutrient application showed that combined use of NPK fertilizers with the localized application have a positive response to wheat *T. aestivum* productivity and soil quality due to better root development and improved nutrient uptake. In this endeavour, conjoint use of organic and inorganic fertilizers with biostimulants are effective either for increasing yield or sustaining soil health (Weber *et al*., 2008; Pullicinoa *et al*., 2009; Aggarwal *et al*., 2003 and Bhatt *et al*., 2016). The microbial inoculants and organic manure are applied along with the reduced level of fertilizer to enhance the crop growth and yield (Kumar *et al*., 2019 and Mengual *et al*., 2014). Therefore, Better soil, crop and nutrient management practices play a pivotal role to achieve the goal of improving soil health and nutrient use efficiency of wheat. It should be narrow down the yield gap between achievable and actual yields of wheat.

So, a judicious combination of organic manures and bio-fertilizers as a carbon source with chemical fertilizers placed into the rhizosphere facilitates profitable and sustainable wheat production. The responses of the organic sources of nutrients are variable with location and soil fertility status. So, the analyses of various field studies on fertilizer sources and placement raised an important question that "which fertilizer source and placement can be chosen for improving wheat productivity and soil health?" Rhizospheric nutrient management provides a unique opportunity to improving crop productivity and soil health along with the reduction of environmental pollutions. Therefore, this study was focused on: 1) to determine the effectiveness of rhizospheric nutrient management options to improving wheat *T. aestivum* grain yield by manipulating the rhizospheric environment; 2) to improve our understanding of efficient fertilizer placement for wheat; 3) to assess the variation in root traits and the rhizospheric environment with relationship to yield in wheat; and 4) to assess the effectiveness of fertilizer placement and rhizospheric nutrient management options for improving nutrient use efficiency of wheat in Pantnagar, *Tarai* region of Uttarakhand .

MATERIALS AND METHODS

Site description: The field experiment was performed from 2017-18 to 2018-19 at the D-3 block of Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar (29° N latitude and 79.3° E longitudes, 243.84 m A.M.S.L.) in Uttarakhand, India. The experimental soil is aquic hapludoll, and comprise 32% sand, 39% silt, and 29% clay (Deshpande *et al*. 1971). The soils typically had a pH of 7.4 and a bulk density of 1.3 g cm-3. Analyses of soil at the experimental field prior to planting in 2017-18 indicated that the top 20 cm contained 0.77% organic matter, 21.6 kg/ha available phosphorus, 189 kg/ha available potassium, and 296 kg/ha total nitrogen. The dominant crop production system in this region was based on conventional tilling and rice (*Oryzae sativa*)-wheat (*T. aestivum* L.) cropping system. The annual average rainfall amounts at Pantnagar station is 1421.8 and 1572.2 mm during 2017-18 and 2018-19, respectively of which approximately 80-90% was during the June to October each year (Fig. 1 and 2).

Experimental design and treatments: The wheat (*T. aestivum* L.) cultivars were subjected to six rhizospheric nutrient management treatments, in triplicate, using a randomized complete block design with 57 plots in total, each covering 13.14 m^2 (7.30 m×1.80 m). The six rhizospheric nutrient management treatments [100% RDF (150:60:40 kg/ha NPK) (T1), 75% RDF (T2), 75% RDF+ vermicompost (2q/ha) (T3), 75% RDF+ vermicompost (2q/ha) + PSB (10 kg/ha)(T4), 75% RDF+ Poultry manure (2q/ha) (T5) and 75% RDF+ Poultry manure (2q/ha) + PSB (10 kg/ha) (T6)] were applied underlying the deep placement (P1), surface application (P2), band placement (P3) and an absolute control. In each plot of the experiment, different nutrient management was applied by a different combination of inorganic, organic and biofertilizers. Fertilizer placement was done according to Fig. 3. In the surface application treatment, the fertilizer was surface broadcast and then ploughed into the soil. In the deep placement treatment, the fertilizer mix was applied in seed row at a depth of 12-14 cm, and then seed placed in the same row above the fertilizer mix. In the band placement treatment, P was furrowed in 3-5 cm below the soil surface, in 20-cm-wide rows (between rows). The recommended dose of fertilizers was kept 150:60:40 kg/ha NPK. Wheat (*Triticum aestivum* L.)seed was placed in 20 cm-wide rows at a seeding rate of 100 kg ha^{-1} (WH-1105) on 25 September 2017 and 29 September 2018, respectively.

Sampling procedures and measurements: Root samples were collected from soil samples taken from each plot at 2 stages of growth at jointing and booting. Root studied was done to know the response of rhizospheric nutrient management on root growth. Root weight (g) and root density (g/cm^3) was measured at the time of maximum tillering stage and at the flowering stage during each year of experimentation. The root sampler of 15 cm in height and 10cm in diameter was used to volumetric measurement of root volume. Firstly the plants from the target area were cut and core was hammered into the soil. Then, it was removed along with soil. The soil along with roots was transferred to a nylon net bag. It was washed under a water jet to remove soil and separate out the roots. The roots were oven-dried and weighed. The root density was reported in mg/cc.

Root weight : Wheat (*T. aestivum*) roots were collected from two randomly selected rows by root sampler with soil-root mass, washed and weighted. The root weight averaged for root weight in grams.

Root density: Root density was obtained by dividing the root weight (g) from the volume of root sampler (cm^3). Following formula was used for root density (mg/cm^3).

$$\text{Root density } (g/cm^3) = \frac{\text{Root weight (g)}}{\text{Volume of root sampler } (\pi r^2 h)} \qquad \text{Eq.......1}$$

Where, π, *r* and *h* were having the value of 3.14, radius *r* (5 cm) and height *h* (15 cm), respectively.

Grain yield (t/ha): Crop was harvested from each plot in April 2018 and April 2019 for measurements of grain yield (t/ha).

Calculations and statistical analyses: The data obtained from various observations was statistically analyzed as per the procedure of factorial randomized block design using the standard techniques of Analysis of Variance (ANOVA) as per the procedures given by Rangaswamy (2005). The critical difference at 5% level of probability was calculated for testing the significance of the difference between any two means wherever 'F' test was found significant. One sample of absolute control was taken from each net plot. Thus, a total of three samples of absolute control was compared with differential fertilizer placement with and without carbon management separately using 'F' test as per the method given by Rangaswamy (2005). Wherever the calculated 'F-value' exceeded the tabulated value (2.028), the difference between the treatments was significant.

RESULTS

Grain yield (t/ha): Fertilizer placement methods influenced the wheat grain yield significantly during 2017-18 and 2018-19 (Table 1). In fertilizer placement methods, P1 (5.4 and 5.5 t/ha) recorded the maximum grain yield and significantly higher over P2 (5.1 and 5.2 t/ha) and P3 (5.3 and 5.3 t/ha) during 2017-18 and 2018-19, re-

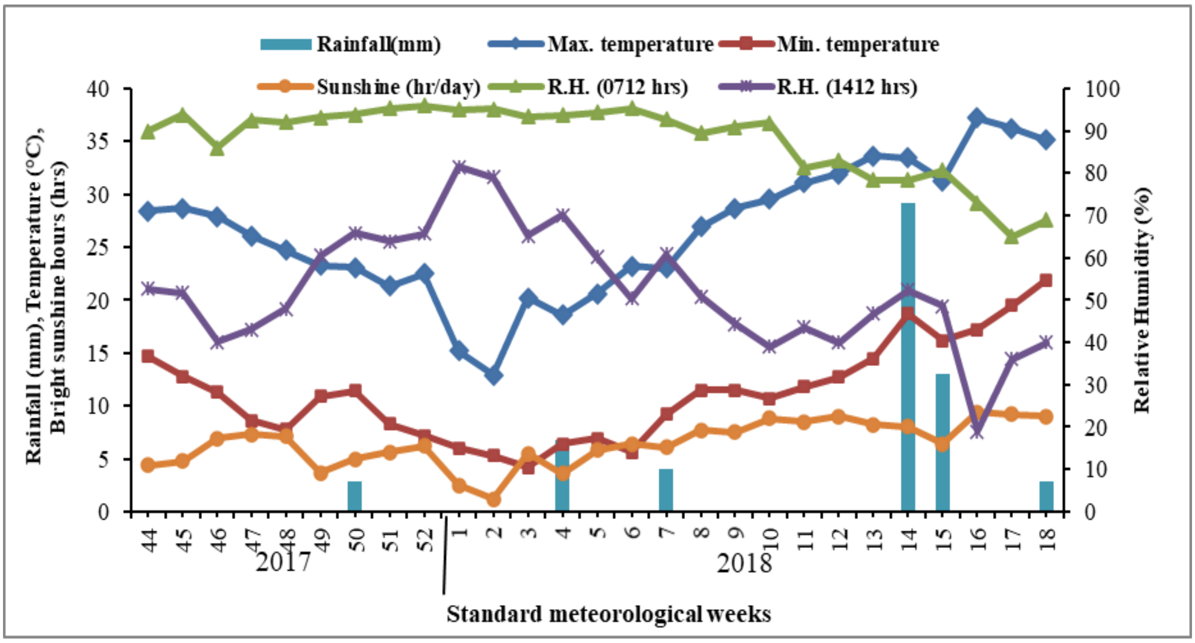

Fig. 1. *Weekly data of weather parameters during rabi season (2017-18). (Source: Agromet observatory, GBPUA&T, Pantnagar,Uttrakhand, India).*

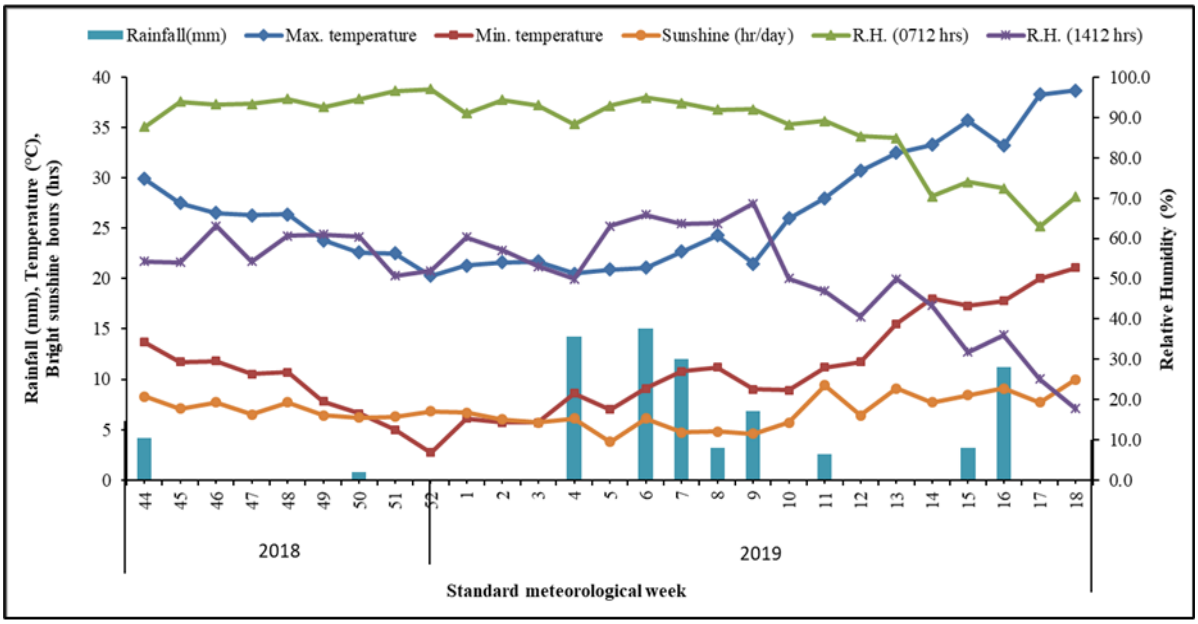

Fig. 2. *Weekly data of weather parameters during rabi season (2018-19). (Source: Agromet observatory, GBPUA&T, Pantnagar,Uttrakhand, India).*

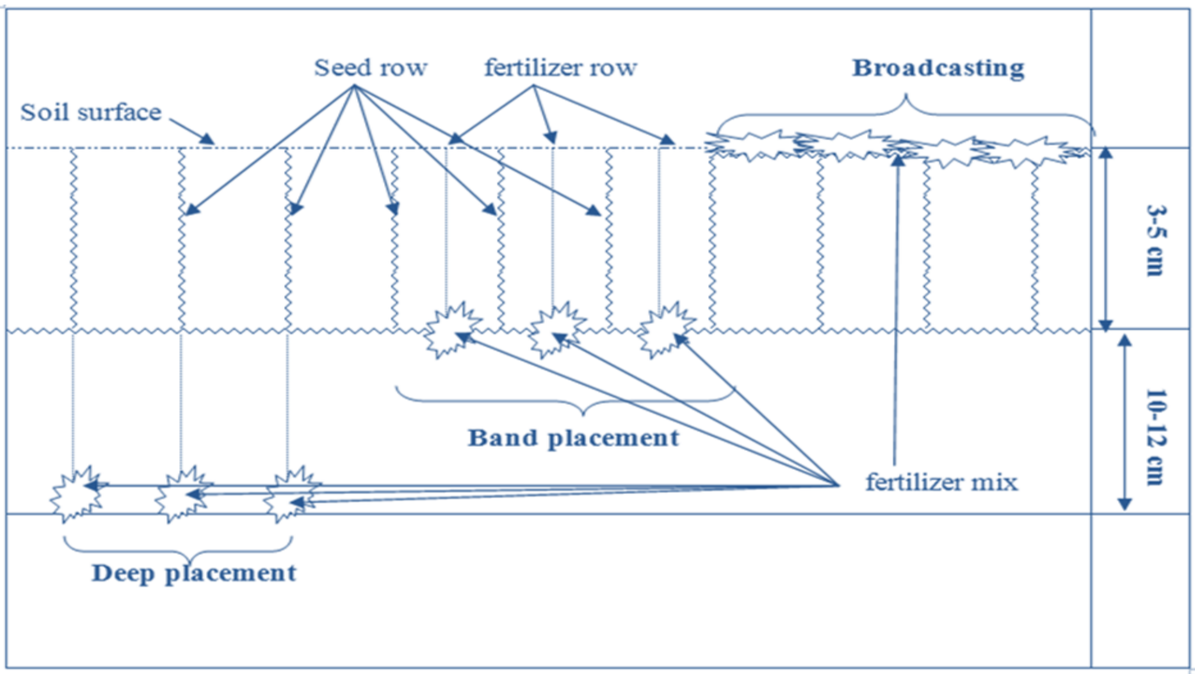

Fig. 3. *Targeted view of different fertilizers application methods in experimental plots.*

spectively. The magnitude of increase in grain yield by P1 over P2 was higher than P3. However, P3 was found at par with P1 during 2017-18. Whereas, P2 and P3 were found at par during 2018-19. The reasons for higher grain yield in deep placement during both years were attributed due to higher dry matter accumulation, effective tillers/m^2, number of grains/spike and 1000-grain weight. This might be attributed due to better utilization of nutrient in the localized supply of nutrients. These findings were supported by the Ali *et al*. *(*2012); Chen *et al*. (2016) and Wu *et al*. (2017). They reported with use of organic and inorganic fertilizers and biofertilizers that maximum grain yield was observed with fertilizers placement due to high concentration of solute at fertilizer placement sites inhibited nitrification by the osmotic potential of the solutes thus provides long term bioavailability of nutrients. This provided efficient uptake of nutrient and higher grain yield in wheat (*T. aestivum* L.) by fertilizer placement compared to broadcasting (Rehim *et al*., 2012). The similar response was also reported in this findings where deep placement of combined fertilizer mix was found more efficient than band placement and surface application. However, differential environmental conditions also favoured the importance of fertilizers placement for efficient utilization of nutrient resources, as shown in

Table 1. Grain yield (t/ha) of wheat (*T. aestivum* L.) as influenced by rhizospheric nutrient management.

Treatment	Grain yield (t/ha)	
	2017-18	2018-19
Placement methods		
Deep placement (P1)	5.4	5.5
Surface application (P2)	5.1	5.2
Band placement (P3)	5.3	5.3
CD (P=0.05)	0.2	0.2
Nutrient management		
100% RDF (T1)	5.2	5.2
75% RDF (T2)	4.9	5
75% RDF + VC (T3)	5.4	5.4
75% RDF + VC + PSB (T4)	5.8	5.7
75% RDF + PM (T5)	5.1	5.2
75% RDF + PM + PSB (T6)	5.4	5.4
CD (P=0.05)	0.3	0.3
Control vs rest		
Control	3.5	3.3
Rest	5.3	5.3
CD (P=0.05)	0.4	0.4
C.V. (%)	6	6.7

Table 2. Changes in root dry weight and root density in the 0-20 cm soil profile in wheat (*T. aestivum* L.).

Treatment	Root weight (g/cc)				Root weight density (mg/cc)			
	At maximum tillering stage		At flowering stage		At maximum tillering stage		At flowering stage	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Placement methods								
Deep placement (P1)	1.52	1.73	2.17	2.69	1.29	1.47	1.84	2.29
Surface application (P2)	1.46	1.60	1.98	2.32	1.24	1.36	1.68	1.97
Band placement (P3)	1.64	1.75	2.05	2.55	1.39	1.49	1.74	2.17
CD (P=0.05)	0.13	0.12	0.10	0.19	0.11	0.10	0.09	0.16
Nutrient management								
100% RDF (T1)	1.50	1.71	2.09	2.60	1.27	1.45	1.77	2.21
75% RDF (T2)	1.35	1.52	1.91	2.25	1.14	1.29	1.62	1.91
75% RDF + VC (T3)	1.61	1.71	2.12	2.50	1.36	1.45	1.80	2.13
75% RDF + VC + PSB (T4)	1.63	1.77	2.17	2.73	1.39	1.51	1.84	2.32
75% RDF + PM (T5)	1.53	1.68	2.09	2.49	1.30	1.43	1.77	2.11
75% RDF + PM + PSB (T6)	1.65	1.76	2.02	2.56	1.40	1.50	1.72	2.17
CD (P=0.05)	0.19	0.16	0.14	0.27	0.16	0.14	0.12	0.23
Control vs rest								
Control	1.00	1.40	1.68	1.99	0.85	1.19	1.42	1.69
Rest	1.54	1.69	2.07	2.52	1.31	1.44	1.75	2.14
CD (P=0.05)	0.23	0.21	0.18	0.34	0.20	0.18	0.15	0.29
C.V. (%)	12.90	10.28	7.34	11.47	12.90	10.28	7.34	11.47

Data in boxes mean the proportions of root weight in soil layer (0-20 cm).

Fig. 1 and 2.

Nutrient management was significantly influencing the grain yield during 2017-18 and 2018-19. Although, the maximum grain yield (5.8 and 5.7 t/ha) was recorded significantly under T4 followed by T6 (5.4 and 5.4 t/ha), T3 (5.4 and 5.4 t/ha), T1 (5.2 and 5.2 t/ha), T5 (5.1 and 5.2 t/ha) and T2 (4.9 and 5 t/ha) during 2017-18 and 2018-19, respectively. Whereas, T6, T4, T3 and T1 were found at par with each other. 75% RDF + poultry manure was also observed at par with 75% RDF alone and 100% RDF. It revealed that integration of nutrient helps in better soil environment with respect

Table 3. Effect of rhizospheric nutrient management on partial factor productivity in wheat (*T. aestivum* L.).

Treatment	Partial factor productivity (kg/kg nutrient applied)					
	Nitrogen		Phosphorus		Potassium	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Placement methods						
Deep placement (P1)	44.8	45.1	114.1	114.9	170.1	171.2
Surface application (P2)	41.8	42.4	106.4	108	158.6	161
Band placement (P3)	43.5	43.9	110.9	111.9	165.4	166.8
CD (P=0.05)	1.8	2	4.5	5.1	6.7	7.6
Nutrient management						
100% RDF (T1)	34.4	34.7	86.1	86.7	129.1	130.1
75% RDF (T2)	43.4	44.1	108.5	110.2	162.8	165.3
75% RDF + VC (T3)	45.6	46.2	116.4	117.9	173.1	175.4
75% RDF + VC + PSB (T4)	49	48.3	125.1	123.3	186.1	183.4
75% RDF + PM (T5)	42.4	43.9	109.7	113.5	163.1	168.7
75% RDF + PM + PSB (T6)	45.2	45.5	117	117.8	173.9	175
CD (P=0.05)	2.5	2.8	6.3	7.2	9.4	10.7
Control vs rest						
Control	0	0	0	0	0	0
Rest	43.3	43.8	110.5	111.6	164.7	166.3
CD (P=0.05)	3.1	3.5	7.9	9	11.8	13.5
C.V. (%)	6.3	7.1	6.3	7.1	6.3	7.1

to moisture and nutrient release, which was evident from better growth and yield attributing characters, particularly the spike number and grain per spike. Optimal nutrition with combined application of chemical fertilizers and organic manures along with rhizobacteria might be play important role in exploiting high yield potential of wheat (*T. aestivum*) through its favourable effect on nutrient supply and soil biophysical environment (Chesti *et al*., 2013). Bahadur *et al*. (2013) reported that the grain yield of wheat (*T. aestivum*) increased along with increasing total uptake of N, P and K in the plant due to the improvement in the rhizospheric environment. The integration of NPK fertilizers with organic sources significantly increased in plant dry matter accumulation, a number of tillers/m^2, spike length and 1000-grain weight along with higher grain and straw yield of wheat (*T. aestivum*) (Bhoite, 2005). These similar findings curve were also observed in this experiment where 75% of RDF and vermicompost/ poultry manure with PSB reported higher grain yield and NUE of wheat (*T. aestivum* L.) than fertilizers alone and other lower-dose combination without PSB.

In case of control vs rest, control plot observed lowest grain yield than other treatments due to low availability of nutrients, reduction in plant biomass production and nutrient utilization. The non-significant interaction effect was recorded on grain yield of wheat (*T. aestivum* L.) during the year 2017-18 and 2018-19.

Root distribution studies: The data pertaining to root studies of wheat at maximum tillering and flowering stages under different fertilizer placement methods and nutrient management are furnished in Table 2 and Fig. 3.

Root weight (g/cc) and root density (mg/cc): Fertilizer placement methods influenced the root weight of wheat significantly (p=0.05) at maximum tillering and flowering stages during both the years of experimentation. P3 (1.64 and 1.75 g/cc) being at par with P1 (1.52 and 1.73 g/cc) recorded significantly higher root weight over P2 (1.46 and 1.60 g/cc) at maximum tillering stage during the 2017-18 and 2018-19, respectively. However, at flowering stage, P1 (2.17 and 2.69 g/cc) was recorded significantly higher root weight compared to P3 (2.05 and 2.55 g/cc) and P2 (1.98 and 2.69 g/cc) during the 2017-18 and 2018-19, respectively. But, during 2017-18, P3 and P2, and during 2018-19, P1 and P3 were at par with each other. The similar trend was also recorded with root density at maximum tillering stage and flowering stage during 2017-18 and 2018-19. This might be due to various nutrient spatial-temporal environments. It was also notified by Zhang *et al*., (2010) that The fertilizer banding enriches the narrow zone of root with nutrient which enhanced the P bioavailability, accelerate root proliferation and crop productivity of wheat (*T. aestivum* L.). The root distribution takes place from lower nutrient concentration to nutrient-rich environment for better nutrient utilization in *T. aestivum* crop under localized application of inorganic and organic fertilizers combinations (Shen *et al*., 2013; Shu *et al*., 2007). These findings also supported the experimental findings where organic and inorganic fertilizers combination favoured the localized application of fertilizers for improving crop yield and NUE of wheat.

The localized nutrient supply regulates root development and modifies the physicochemical processes of the rhizospheric environment which influenced the rhizospheric interfaces through physiological and metabolic activities to enhance the nutrient availability of soil and root growth of wheat (*T. aestivum* L.) (Ma *et al*., 2013 and Jing *et al*., 2010).

Nutrient management influenced the root weight significantly at maximum tillering and flowering stages during both the years of experimentation. T4 (1.63 g/cc) was recorded the highest root weight at the maximum tillering stage which was followed by T6 (1.65 g/cc), T3 (1.61 g/cc), T5 (1.53 g/cc), T1 (1.50 g/cc), and T2 (1.35 g/cc), respectively during 2017-18. However, The T4 (1.77 g/cc) was gain significantly maximum root weight followed by T6 (1.76 g/cc), T1 (1.71 g/cc), T3(1.71 g/cc), T5 (1.68 g/cc) and T2 (1.52 g/cc), respectively during 2018-19. This similar trend was also observed in root weight at the flowering stage during 2018-19 and root weight density at maximum tillering and flowering stage during 2017-18 and 2018-19. The better root density under nutrient management might be due to the loose and friable rhizospheric conditions created by the decomposition of organic manure and biological activity which further decreased the root penetration resistance by decreasing the cohesive and massive structure of the soil, particularly in the topsoil. The root growth of wheat increased due to increases in nutrient availability into the rhizospheric soil and crop productivity (Jing *et al*., 2010).

Absolute control observed the lowest root weight and root weight density at both maximum tillering and flowering stage during the year 2017-18 and 2018-19, respectively. Moreover, Interaction effect did not found significant on both root weight and root weight density of wheat (*T. aestivum* L.) during the year 2017-18 and 2018-19, respectively.

Nutrient use efficiency: Data pertaining to nutrient use efficiency is given in Table 3. Data revealed that P1 was found to be efficient in improving crop nutrient use efficiency as followed by P3 and P2. Nutrient use efficiency/partial factor productivity (PFP) was recorded highest in P1 in the case of N, P and K fertilizers use followed P3 and P2, respectively. However, P1 was found at par with P3 respective to partial factor productivity of N, P and K. Among the nutrient management treatments, combined use of 75% RDF + vermicompost + PSB recorded higher crop nutrient use efficiency and PFP for N, P, K that was followed by the application of other nutrient management options. All these parameters were observed lowest in the application of RDF without supplementation with organic manure and PSB. The efficient management of rhizospheric processes and root system accelerated the efficiency of crop genotypes, microbial interactions, nutrient use efficiency by localized application of fertilizers. It was also observed by Shen *et al.,* (2013) and Cakmakci *et al*., (2014). Whereas, Zhang *et al*., (2010) and Jiao *et al*., (2016) recorded that root and root mediated rhizosphere processed modifying the root exudation, and intensified the rhizospheric interactions due to localized fertilizer application with combined use of fertilizer in wheat (*T.* aestivum L.) crop.

Conclusion

We found that wheat *T. aestivum* growing in *Tarai* soil (*beni* series) was highly responsive to rhizospheric nutrient management. The deep placement and 75% RDF+ Vermicompost+ PSB treatments resulted in higher grain yield and nutrient use efficiency than surface application due to improved root proliferation and distribution in >20cm depth surface soil than surface application. Since the deep placement offered no significant growth or yield advantages over the band placement, we recommended the fertilizer placement and 75% RDF + Vermicompost+ PSB application in the soil to hasten the wheat productivity. However, integration of organic and inorganic fertilizers along with biofertilizers proved their efficiency to a reduction in inorganic fertilizer cost because it did not possess significant difference with the application of inorganic fertilizers alone (100% RDF) in wheat yield. Experimental results concluded that the rhizospheric nutrient management (fertilizer placement and nutrient management) practices could boost yields of wheat *T. aestivum* in *Tarai* region Of Uttrakhand state. These results indicated that deep placement of fertilizer was a feasible and practical means of increasing grain yield and nutrient use efficiency of wheat by promoting the growth of deep roots in *Tarai* regions of Uttarakhand.

Conflict of interest

The authors declare that they have no conflict of interest.

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