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Vishal Tyagi
Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University,
Varanasi, Uttar Pradesh, India

RK Singh
Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University,
Varanasi, Uttar Pradesh, India

M Nagargade
Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University,
Varanasi, Uttar Pradesh, India

Correspondence
Vishal Tyagi
Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University,
Varanasi, Uttar Pradesh, India

Chemical and biological properties of soil as affected by nitrogen scheduling in different varieties of wheat

Vishal Tyagi, RK Singh and M Nagargade

Abstract
The field experiment was carried out in wheat for two years during *rabi* (winter) seasons of 2015-16 and 2016-17 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) to find out the effect of nitrogen scheduling on chemical and biological properties of soil in wheat. Variety K 0307 recorded significantly higher available NPK in soil after wheat harvest as compared to HUW 234 and HD 2967. Amongst nitrogen scheduling, application of 25 kg N ha^{-1} at LCC ≤4 recorded highest available N, whereas, control treatment (no nitrogen) recorded highest available P and K in soil after wheat harvest. Different varieties din not differed significantly in respect of SMBC and SMBN, whereas, among nitrogen scheduling, application of 150 kg N ha^{-1} in three equal splits recorded highest SMBC and SMBN.

Keywords: Nitrogen scheduling, precision nitrogen management, soil microbial biomass carbon and soil microbial biomass nitrogen

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of the world as well as India. India rank second in both area and production of wheat in world producing 92.29 million tones and covering 30.93 million hectare area in 2015-16 (Anonymous, 2017) [1]. However, country needs still higher production to feed the ever increasing population. Nitrogen is one of the most important factors for growth and development of plants and most limiting nutrient in crop production particularly in irrigated cereal based cropping systems. Consumption of nitrogen has increased substantially in the past decades (Varinderpal-Singh *et al*., 2010) [17]. But, the quantity of wheat grain produced per unit of applied fertilizer N (partial factor productivity) has continuously decreased to very low values (Dobermann *et al.* 2002) [5] and N use efficiency following blanket fertilizer N application has been reported as low as 30% in rice-wheat cropping system (Krupnik *et al.* 2004) [8]. The main reason for low N use efficiency is blanket application of nitrogen, which do not take into account the high field to field variability and within-season dynamic changes in indigenous N supply. Moreover, farmers have a tendency to apply N in excess of the requirement of crop to avoid risk of N deficiency. When managed inefficiently, a large portion of the applied N can escape soil–plant system to reach water bodies and the atmosphere thus creating pollution problems. In many field situations, up to 50% of applied N is lost due to lack of synchrony of plant N demand and N supply. This lack of synchrony reduces the physiological use of the N available to the crop.
Sound N management practices need to be established and followed to improve N use efficiency leading to high grain yield levels and minimal fertilizer N loss to the environment. During last decades, many efforts have been taken on N management in wheat to improve NUE. The site-specific N management method has been used in wheat and it has been proved to superior in terms of cost, higher grain yield, more profitability (Khurana *et al*., 2008) [7] and higher fertilizer use efficiency (Nath *et al*, 2013) [10]. Traditional diagnostic tools such as soil testing, plant tissue analysis and long-term field trials have limited use due to time delay between sampling and obtaining results. Thus, instant and reliable methods having greater temporal and spatial precision for assessing N status and requirements of field crops are needed. Farmers generally use the leaf color as a visual and subjective indicator of the wheat crop's need for N fertilizer. Leaf color intensity is directly related to leaf chlorophyll content, which in turn is related to leaf N status.

For this, leaf and canopy characteristics are being increasingly used with the help of different tools/devices such as leaf colour chart (LCC), chlorophyll meter (SPAD), optical sensors etc.

LCC is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a wheat leaf as an indicator of the plant N status. It can even help farmers who are not highly trained in making nitrogen applications. It offers substantial opportunities to farmers for timely application of nitrogen for efficient N with optimum yield. Thus LCC becomes useful in avoiding under or above fertilization. GreenSeeker hand held optical sensor is another tool of precision N management. It is on-the go remote sensing tool which measures the reflectance of a given crop area. Green Seeker sensor embedded software calculates the reflectance in the red or green and near infrared, and then computes the NDVI, and then calculate the precise amount of nitrogen.

Nitrogen management in wheat can be substantially improved by using LCC and greenseeker, but the methodology needs to be perfected before it can be given to farmers. More research is needed to define the conditions under which LCC or optical sensor can be used to guide N applications at a given growth stage of wheat. Keeping this in view, the available tools like LCC and green seeker were tested in different varieties of wheat for precision nutrient management.

Material and Methods

The field experiment was carried out in wheat for two years during *rabi* (winter) season of 2015-16 and 2016-17 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) situated at 25º18′ N latitude, 83º30′ longitudes and at altitude of 128.93 m above the mean sea level. To find out physico-chemical properties of soil, soil samples were taken randomly before the commencement of experiment from different spots in the field to a depth of 0-30 cm. The composite sample was prepared and analyzed for physical and chemical properties of the soil. It is evident from data that the soil was sandy loam in texture, non-saline with a pH of 7.4 and 7.3 in the year 2015-2016 and 2016-2017, respectively. It was moderately fertile, being low in organic carbon (0.36% in the year 2015-2016 and 0.35% in the year 2016-2017), available nitrogen (210.68 kg ha^{-1} in the year 2015-2016 and 205.98 kg ha^{-1} in the year 2016-2017) and medium in available phosphorus (17.32 kg ha^{-1} in the year 2015-2016 and 16.26 kg ha^{-1} in the year 2016-2017) and potassium (238.45 kg ha^{-1} in the year 2015-2016 and 237.74 kg ha^{-1} in the year 2016-2017) (Table 1). pH was determined in a 1:2.5 soil-water suspension (Jackson, 1973) [6], organic carbon following (Walkley and Black, 1934) [18] available N by the alkaline potassium permanganate method (Subbiah and Asija, 1956) [15], available P by the 0.5 M $NaHCO_3$ extractable Olsen colorimetric method (Olsen, 1954) [11] and available K by flame photometer (Jackson, 1973) [6]. The experiment was laid out in split plot design consisting of 18 treatments. Three varieties *viz.* V_1-HUW 234, V_2-K 0307 and V_3-HD 2967 were assigned to main plot and six nitrogen scheduling practices *viz.* N_0-No nitrogen, N_1-150 kg N ha^{-1} (in three equal splits at basal, first irrigation and at second irrigation), N_2-50 kg N ha^{-1} as basal, 50 kg N at first irrigation and 25 kg N ha^{-1} at LCC ≤4, N_3-50 kg N ha^{-1} as basal, 50 kg N at first irrigation and 35 kg N ha^{-1} at LCC ≤4, N_4-50 kg N ha^{-1} as basal, 50 kg N at first irrigation and 45 kg N ha^{-1} at LCC ≤4 and N_5-50 kg N ha^{-1} was applied as basal, 50 kg N ha^{-1} at first irrigation and at second irrigation N was applied based on greenseeker reading (18.49 kg N ha^{-1} during 2015-2016 and 18.40 kg N ha^{-1} during 2016-2017) were assigned in sub plots. Treatments were allocated to each plot randomly and replicated thrice. For nitrogen application through greeneeeker the readings were collected by holding the unit at a height of about 80 cm above the plant canopy. The trigger of greenseeker optical sensor was pressed continuously while moving in plot and trigger was released after completing one plot. A N-rich strip was established by applying 200 kg N ha^{-1} in split doses to ensure that nitrogen was not limiting. The data from the sensor was exported to a desktop computer for analysis. Data was put in GreenSeeker calculator for calculating nitrogen requirement on per plot basis. The doses of nitrogen, phosphorus and potassium were applied as per treatment through urea, single super phosphate and muriate of potash. The levels of nitrogen were applied in split doses as per the treatment specifications and 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} were applied as basal in all the plots. Crop response to treatments was measured in terms of various qualitative and quantitative indices. Soil microbial biomass carbon (SMBC) was determined by Fumigation-extraction method as per the procedure given by Vance *et al*. (1987) [16]. The SMBC estimation was done after harvest of wheat during both the years of experimentation. 20 g soil (air dried) was fumigated with 50 ml of ethanol free chloroform in a desiccator. Ethanol free chloroform was prepared by passing 100 ml chloroform where a clear distinct zone was visible in a separating funnel. After 24 hrs of fumigation at 25ºC, chloroform was removed by repeated evacuations. The fumigated soil samples were extracted with 80 ml of 0.5 M K_2SO_4 for 30 min. on a rotary shaker at 160 rpm and filtered. 8 ml of filtrate was refluxed with 2 ml of $K_2Cr_2O_7$ and 15 ml of diacid mixture (H_2SO_4:H_3PO_4::2:1) for half an hour on hot plate at 150ºC with three drops of phenanthroline indicator solution. After cooling the mixture was titrated with FAS solution. Similar procedure was followed for non- fumigated soil samples also.

SMBC (µg C g^{-1} soil) = Extractable C in fumigated soil - Extractable C in non-fumigated soil

For soil microbial biomass nitrogen (SMBN), total N in the K_2SO_4 (extracted in estimation of SMBC) extract was measured after Kajeldahl digestion. The soil microbial biomass N was calculated using following formula given by (Brookes *et al*., 1985) [4].

SMBN (µg C g^{-1} soil) = (Nt_1- Nt_0) x 1.85

Where,

Nt_1 = extracted nitrogen (mg kg^{-1}) in fumigated samples

Nt_0 = extracted nitrogen (mg kg^{-1}) in un-fumigated samples

and 1.85 is a factor which is obtained via 0.54 (i.e. 100/54=1.85) which is extractable part of microbial N after fumigation.

Table 1: Initial Physico–chemical properties of the experimental plot

S. No.	Particulars	Values	
	Soil properties	**2015**	**2016**
	a. Physical properties		
1.	Texture class	Sandy loam	
2.	Bulk density (Mg m^{-3})	1.41	1.42
	b. Chemical properties		
1.	Organic carbon (%)	0.36	0.35
2.	pH (1:2.5 soil : water suspension)	7.4	7.3
3.	Electric conductivity (dsm^{-1} at 25°C)	0.15	0.14
4.	Available nitrogen (kg ha^{-1})	210.68	205.98
5.	Available phosphorus (kg ha^{-1})	17.32	16.26
6.	Available potassium (kg ha^{-1})	238.45	237.74

Table 2: Effect of varieties and nitrogen scheduling on available NPK in soil after harvest of wheat

Treatments	Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Varieties						
V_1 : HUW 234	175.90	170.77	19.91	18.14	150.08	143.28
V_2 : K 0307	179.89	172.64	21.97	19.48	165.64	156.53
V_3 : HD 2967	160.51	156.12	18.42	16.29	146.80	140.89
SEm ±	3.68	3.24	0.36	0.30	2.55	2.07
CD (P=0.05)	14.44	12.73	1.40	1.18	9.99	8.14
Nitrogen scheduling						
N_0: Control (0 kg N ha^{-1})	106.52	94.53	24.49	23.23	167.47	160.71
N_1: 150 kg N ha^{-1} (Three equal splits)	184.12	181.52	17.31	15.20	137.89	132.44
N_2: (25 kg N ha^{-1} at LCC≤4)	192.12	188.13	21.62	19.43	158.81	151.90
N_3: (35 kg N ha^{-1} at LCC≤4)	183.43	178.50	18.83	16.86	152.67	146.52
N_4: (45 kg N ha^{-1} at LCC≤4)	186.06	180.05	18.26	15.87	151.24	140.82
N_5: GreenSeeker	180.36	176.33	20.08	17.22	156.98	149.00
SEm ±	3.60	3.45	0.42	0.32	2.98	2.74
CD (P=0.05)	10.41	9.97	1.21	0.93	8.62	7.92
Interaction	NS	NS	NS	NS	NS	NS

Table 3: Effect of varieties and nitrogen scheduling on microbial biomass carbon and nitrogen of wheat

Treatments	Microbial biomass carbon (µg C g^{-1} soil)		Microbial biomass nitrogen (µg N g^{-1} soil)	
	2015-16	2016-17	2015-16	2016-17
Varieties				
V_1 : HUW 234	190.83	181.7	27.28	25.16
V_2 : K 0307	183.28	174.1	26.66	24.70
V_3 : HD 2967	191.50	184.3	28.27	26.15
SEm ±	2.99	2.4	0.45	0.39
CD (P=0.05)	NS	NS	NS	NS
Nitrogen scheduling				
N_0: Control (0 kg N ha^{-1})	112.22	109.8	10.99	10.42
N_1: 150 kg N ha^{-1} (Three equal splits)	218.11	204.7	32.96	30.48
N_2: (25 kg N ha^{-1} at LCC≤4)	195.67	186.6	27.91	26.34
N_3: (35 kg N ha^{-1} at LCC≤4)	201.33	194.6	30.40	28.96
N_4: (45 kg N ha^{-1} at LCC≤4)	217.00	205.0	33.57	29.53
N_5: GreenSeeker	186.89	179.6	28.59	26.30
SEm ±	3.15	2.9	0.49	0.40
CD (P=0.05)	9.09	8.5	1.41	1.16
Interaction	NS	NS	NS	NS

Result and Discussion

Available NPK in soil after harvest of crop

Variety K 0307 recorded significantly maximum NPK content in soil after harvest and showed marked superiority over rest of the varieties. This might be due to the less uptake of NPK in this varietyt as compared to others. HD 2967 produced highest grain and straw yield which ultimately contributed to higher total NPK uptake thus recorded minimum available NPK after harvest of wheat. Beek *et al*. (2016) [3] also reported that depletion of nutrients increased with yield levels due to more uptake of nutrients from available pool. Nutrient ions present in soil solution are absorbed by growing plants. Through harvesting the NPK is removed from soil. The magnitude of such removal increases if the crop is high yielding and the crop is capable of absorbing high amount of nutrients (Basak, 2012) [2]. As plant roots find their way through the soil with which plant roots come in contact with the soil solution. Nutrients are absorbed by the roots at a faster rate and the soil solution in the direct vicinity of root is depleted of nutrients (Mengel *et al*., 2001) [9].

Among nitrogen scheduling treatment N_2 recorded significantly maximum nitrogen content in soil after harvest and showed superiority over N_0, but remained on par with rest of the treatments. Significantly higher N uptake was attributed to crop response of producing higher grain yield and biomass in response to treatments which ultimately contributed to higher total N uptake by wheat plant (Rahman *et al*., 2011) [13]. Decrease in available N due to higher uptake may be attributed to the depletion of this nutrient to the available pool of soil.

As regard the available P and K, treatment N_0 (control) recorded significantly highest amount and remained superior to rest of the treatments. This might be due to the less uptake of nitrogen in this treatment as compared to others. This might be due to the less uptake of phosphorus and potassium in control plot. Less uptake in control plot was due to the significantly lower grain and straw yield. In present experiment phosphorus and potassium were applied uniformly in all the treatments including control. As plants take up phosphate and potassium, the concentration of these nutrients in the soil solution is decreases.

Soil microbial biomass carbon and nitrogen

Different varieties did not differ significantly in respect of SMBC and SMBN. However, numerically maximum SMBC and SMBN found with HD 2967 followed by HUW 234 during both the years of experimentation. This might be due to the release of equal amount of root exudates and similar amounts of root residue left in the soil in all the three varieties.

Nitrogen scheduling had a significant effect on both these parameters. Blanket application of 150 kg N ha^{-1} in three

equal splits (N_1) recorded highest microbial biomass carbon and nitrogen which were significantly superior to the rest of the treatments except N_4 during both the years, whereas, control treatment gave the lowest level of microbial biomass carbon and nitrogen. Zhao *et al*. (2013) [20] and Salehi *et al*. (2017) [14] also reported that SMBC content was higher in fertilized than in unfertilized soil.

Application of sufficient nitrogen provided the N required for microorganisms, which increased root growth. The increase of SMBC and SMBN due to application of 150 kg N ha^{-1} fertilization could be a result of better crop growth, higher release of root exudates and larger amounts of root residue left in the soil, which positively influence microbial processes and development. Significant effects of N applications on microbial parameters were mainly due to enhanced growth of wheat crops, resulting in accumulation of soil organic carbon through increased root turnover and exudates in soils. The results of the present study showed that total N and mineral N increased in plots that received more nitrogen. Natural fertility of experimental soil was relatively low, and the application of chemical fertilizers resulted in significant change in microbial substrates (*e.g*., soil microbial carbon and nitrogen). Influenced by all these factors, bacteria multiply faster in population in soil under N fertilizer application and may contribute to increasing soil microbial N and C in the rhizosphere due to their lower C/N ratio as compared to plots without N treatment. Similar findings were reported by Zhong and Cai (2007) [21], Wei-Dong *et al*. (2008) [19] and Omeke *et al*. (2016) [12].

Conclusions

It can be concluded from the study that variety K 0307 recorded maximum available NPK in soil after wheat harvest. Amongst nitrogen scheduling application of 25 kg N ha^{-1} at LCC ≤4 recorded highest available N, whereas, control treatment (no nitrogen) recorded highest available P and K after harvesting. Different varieties did not affected significantly in respect of SMBC and SMBN, whereas, among N scheduling, application of 150 kg N ha^{-1} in three equal splits recorded highest SMBC and SMBN.

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