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Assessment of soil fertility gradient experiment in the view of crop yield and soil fertility

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Abstract
A Field experiment was conducted on wheat crop at N.E. Borlaug Crop Research Centre, G.B.U.A.&T, Pantnagar during the year 2017-18 to asssess the effect of soil fertility gradient on crop yield and soil fertility. The experiment field was divided into three equal strips and three graded levels of nitrogen, phosphorus and potassium fertilizers were applied as N0P0K0, N100P100K100 and N200P200K200 in strip I, strip II and strip III, respectively. Urea, Single super phosphate and murate of potash were used as the source of nutrients. Exhaust crop wheat was cultivated and recommended agronomic practices were followed and harvested at maturity. Grain and straw yield were recorded after harvesting the crop. Soil samples were taken before and after the harvest of the crop from the surface layer and analyzed for available N, available P and available K. Wide variation in wheat yield and soil fertility was recorded among the strips which established the impact of graded levels of fertilizer application on these parameters and creation of soil fertility gradient.

Keywords: Soil fertility gradient, wheat, STCR, nitrogen, phosphorus, potassium, yield

Introduction

For sustaining soil health and increasing crop productivity nutrient management is of paramount importance. Nutrient application, good management practices and production systems are critical in enhancing overall farm productivity, resource use efficiency, food grain production and minimizing environmental risks. Most of the cost of production is incurred on fertilizers therefore the judicious use of fertilizer is the fundamental need for farm profitability and environmental protection (Kimetu *et al*., 2004) [7]. Fertilizer consumption in India has increased remarkably in last few decades. At the same time, Indian agriculture is running at a net negative nutrient balance of around 8-10 million tonnes per year (Tandon, 2004) [14] which is expected to reach around 15 million tonnes by 2025. Application of chemical fertilizers without considering the soil fertility status and nutrient requirement of the specific crop affects both soil and crop adversely (Ray *et al*., 2000) [10]. Intensive cropping and imbalanced fertilizer applications are the major causes of exhaustion of macronutrients like nitrogen, phosphorus and potassium. Soil test crop response (STCR) approach takes into account, the amount of the nutrient taken up by the crop, initial soil fertility levels and the efficiency of nutrient uptake from the soil and fertilizers. Hence, the fertilizer prescription based on STCR approach is designed to maintain soil fertility and reduce yield variations. Soil fertility gradient approach aims at minimizing the influence of other factors affecting yield like crop, climate and management by choosing one field over which elaborate treatments are superimposed to obtain crop responses for correlating with soil test values which are artificially created by differential fertilizer treatments before conducting the main experiment and provides a scientific basis for balanced fertilization between applied and soil available forms of nutrients. Wheat (*Triticum aestivum* L.) being one of the important staple crops is only next to rice both in area and production. Current wheat production in country is around 99 million tonnes from an area of 30.8 million hectares with productivity of 3.2 tonnes ha-1 (ASG, 2018) [2]. Wheat occupies about 3.5 lakh hectares in Uttarakhand having 8.8 lakh metric tonnes production and 25.83 q ha^{-1} productivity (ASG, 2018) [2]. Wheat is a nutrient exhaustive crop which is helpful in creating artificial soil fertility gradient due to its high nutrient responsive nature. Exhaust crop is usually grown in order to get fertilizers undergo transformations in the soil with plant and microbial activity. Keeping in view the above rationales the objective of this study was to evaluate the impact of soil fertility gradient on yield and soil fertility.

Materials and Methods

The materials and methods that are adopted in this investigation are such that they can bring about as maximum variation as possible in the soil fertility levels in a field in order to evaluate the real relationship between the yield and the level of soil fertility without interference from other factors affecting yield (Ramamoorthy *et al*., 1967) [9]. Operational range of variation in soil fertility was created artificially to generate data covering an appropriate range of values for each dependable variable (fertilizer dose) at different levels of an independent variable (soil fertility) which could not be expected at one place under natural conditions. Hence, in order to create soil fertility variation in the same field and to evaluate the impact of soil fertility gradient experiment on crop yield and soil fertility a field experiment was conducted during the year 2017-18 with exhaust crop wheat (var. UP 2526) at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (290 N latitude, 790 29' E longitude and 243.84 m above MSL), District U.S. Nagar, Uttarakhand. Experimental field was divided into three equal strips (59.0 m × 7.5 m) and initial soil sample was taken before the application of fertilizers. Graded doses of fertilizer nutrients N, P_2O_5 and K_2O were applied in strip I (N0P0K0), strip II (N100P100K100), and strip III (N200P200K200) (Table1). Nutrient sources used were Urea, SSP and MOP fertilizers. Exhaust crop wheat was grown by following recommended agronomic practices and crop was harvested at maturity and a sample sized of 4 m^2 (2 m × 2 m) area from randomly selected three spots from each strip were taken. Harvested crop was left in the field for sun drying; thereafter average biological yield (kg m^{-2}) was recorded. After threshing of produce strip wise average grain yield (kg m^{-2}) was recorded and substracted from the average biological yield to get an average straw yield (kg m^{-2}) and reported as quintal per hectare. Soil sample was collected from the surface layer before sowing of the exhaust crop, air dried in shade, processed and used in chemical analysis for EC (Bower and Wilcox, 1965) [4], pH (Jackson, 1958) [6], Soil organic carbon (Walkley and Black, 1934), available nitrogen by Alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [13], available phosphorus by Olsen's method (Olsen *et al*., 1954) [8] and available potassium by Neutral normal ammonium acetate method (Hanway and Hiedal, 1952) [5]. 24 soil samples were also collected from each strip (72 in total from all the strips) after the harvest of the exhaust crop and analyzed for available nitrogen, phosphorus and potassium by adopting the similar procedures as mentioned above.

Results and Discussion

The soil of the experimental field was sandy loam in texture, with 6.76 pH, 0.19 dS m^{-1} electrical conductivity and 0.62 percent soil organic carbon content. Initial soil test value of available nitrogen, phosphorus and potassium was 135.5 kg N ha^{-1}, 12.8 kg P ha^{-1} and 170.3 kg K ha^{-1}, respectively. Total biomass and grain yield of the exhaust crop (wheat) clearly depicted that the effect of application of graded level of nutrients (N, P_2O_5 and K_2O) on yield of exhaust crop was prominent (Table 2). The highest grain yield of exhaust crop was obtained in strip III (44 q ha^{-1}) followed by strip II (37 q ha^{-1}) and the least in strip I (16 q ha^{-1}). Similarly straw yield was 29.33, 83.00 and 96.00 q ha^{-1} in strip I, II and III, respectively. In strip III, where the fertilizer N, P_2O_5 and K_2O applied were twice as that of strip II, the grain yield recorded an increase of 175 and 18.9 percent over strip I and II respectively. Whereas, straw yield recorded an increase of 227.3 and 11.62 percent over strip I and II respectively. It might be due to the graded levels of nutrient application that had enhanced nutrient uptake and growth parameters. Verma *et al*., (2014) [17] also found that application of graded level of fertilizers to gradient crop of rice recorded higher grain and straw yield.

Soil fertility status after the harvest of exhaust crop

Average soil test values after the harvest of exhaust crop showed statistically significant effect of varied levels of nutrient applications on soil fertility (Table 3). Soil available nitrogen, phosphorus and potassium content increased from strip I to strip III. Average soil test value of available nitrogen (Alkaline-$KMnO_4$-N) was 93.55 kg N ha^{-1} in strip I, 109.76 kg N ha^{-1} in strip II and 124.39 kg N ha^{-1} in strip III. Mean value of available soil phosphorus was 14.45 kg P ha^{-1} in strip I, 15.26 kg P ha^{-1} in strip II and 17.70 kg P ha^{-1} in strip III. Average soil test value of available potassium was 135.94, 148.02 and 165.29 kg K ha^{-1} in strip I, II and III, respectively. Soil test values of alkaline KMnO4-N, Olsen's-P and NH4OAc-K was highest in strip III followed by strip II and the least in strip I. Significant increase in the fertility gradient build up with respect to available N, P and K was noted from strip I to strip III (strip I< strip II< strip III). Highest soil test values of available nutrients in strip III might be due to very high nutrient application with super-optimal doses of nutrients in strip III than no application of nutrients in strip I. Such type of marked fertility gradient build up by preliminary fertility gradient experiment have also been reported by Udayakumar and Santhi (2017) [16]. It is evident from the above data that wide variability existed in soil test values of available nutrients. In quantitative terms, soil fertility gradient build up was observed 32.96, 22.49 and 21.59 per cent for alkaline $KMnO_4$- N, Olsen's-P and NH4OAc-K in strip III over strip I, respectively. While it was 17.32, 5.60 and 8.88 per cent for alkaline $KMnO_4$-N, Olsen's-P and NH4OAc-K in strip II over strip I, respectively. Gradient build up for alkaline $KMnO_4$-N, Olsen's-P and NH4Oac K was 13.32, 15.98 and 11.66 per cent in strip III over strip II, respectively. This variation in the strips with regards to soil fertility was prerequisite for calculating the basic parameters and fertilizer prescription equations for calibrating fertilizer doses for desired target yield of different crops. The results were in accordance with the findings of Ahmed *et al.*, (2015) [1]. Yield and soil test values data indicated that fertility gradient has been created since crop yield of the exhaust crop followed the same trend as of the applied fertilizer nutrients, i.e. strip III > strip II > strip I. It may be due to the application of graded levels of N, P and K in strips which influenced the grain yield and nutrient availability and nutrient uptake by the crop. Similar observations were also reported by Srinivasan and Angayarkanni (2008) [12] and Singh *et al.*, (2015) [11] with rice. On the basis of soil fertility gradient crop experiment, it can be concluded that an application of graded levels of nutrients (NPK) application resulted in marked variation in wheat yield and soil fertility between strips which confirmed the significant impact of graded level of fertilizer nutrients on crop yield and soil fertility.

Table 1: Nutrient doses applied in soil fertility gradient experiment with wheat crop

Strip	Symbol	Nutrient level (kg ha^{-1})		
		N	P_2O_5	K_2O
I	$N_0P_0K_0$	0	0	0
II	$N_1P_1K_1$	100	100	100
III	$N_2P_2K_2$	200	200	200

Table 2: Strip wise grain yield and biomass yield of wheat crop

Strip	Symbol	Grain yield (q ha^{-1})	Biomass yield (Grain+ Straw) (q ha^{-1})	Straw yield (q ha^{-1})
I	$N_0P_0K_0$	15.67	45	29.33
II	$N_1P_1K_1$	34	120	86
III	$N_2P_2K_2$	44	140	96

Table 3: Range and mean* of the soil test values under different strips

S. No.	Particular	Strip I	Strip II	Strip III
		Range	Range	Range
1.	Alkaline $KMnO_4$-N (kg ha^{-1})	50.176-125.44 (93.55)	87.808-137.984 (109.76)	87.808-175.616 (124.39)
2.	Olsen's-P (kg ha^{-1})	10.46-18.43 (14.45)	11.21-18.93 (15.26)	25.67-21.67 (17.70)
3.	NH_4OAc-K (kg ha^{-1})	96.32-165.76 (135.94)	127.68-163.52 (148.02)	127.68-198.24 (165.29)

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