International Journal of Plant & Soil Science

Volume 35, Issue 23, Page 665-671, 20YY; Article no.IJPSS.76212
ISSN: 2320-7035

Impacts of Long-term Application of Fertilizer and Manures on Physico-chemical Properties, Phosphorus Uptake and Crop Yield at Different Growth Stages of Wheat

B. H. Sunil [a*], B. S. Dwivedi [b], S. P. Datta [c], M. C. Meena [d] and Immanuel C. Haokip [c]

[a] ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur 440033, India.
[b] ASRB, Department of Agricultural Research and Education, MoA&FW, New Delhi 110012, India.
[c] ICAR-Indian Institute of Soil Science, Bhopal-462038, India.
[d] Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i234286

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/76212

Original Research Article

Received: 20/08/2021
Accepted: 26/10/2021
Published: 24/12/2023

ABSTRACT

A field experiment was conducted on wheat in a sandy loam soil (*Typic Haplustept*) at IARI farm, New Delhi during 2018-19 in a long-term fertilizer experiment to study the physico-chemical properties of soil, crop yield, phosphorus uptake and phosphorus availability. The experiment was designed with seven different treatments, replicated thrice in a randomized complete block design. The treatments details were T_1: Control, T_2: 100%N, T_3: 100%NP, T_4: 100%NPK, T_5: 150% NPK, T_6:

**Corresponding author: E-mail: sunilbh62@gmail.com;*

100%NPK+5t FYM and T_7: 100% NPK+ Zn-5 kgha^{-1}. The results revealed that pH and electrical conductivity were highest under control and lowest recorded under 100% NPK+FYM. Available phosphorus content at all four stages was wheat significantly greater under NPK+FYM followed by 150% NPK treatment and lowest under nitrogen alone (100% N) and unfertilized treatment (control). Initially available phosphorus in soil ranged from 13.5 to 39.8 and 15.4 to 37.9 kg ha^{-1} at 0-15 cm and 15-30 cm depth, respectively. At the tillering stage, available P was 20.7 to 43.7 and 16.5 to 38.1 kg ha^{-1} at 0-15 cm and 15-30 cm depth, respectively. At panicle emergence, it was 24.1 to 48.4 kg ha^{-1} and 18.6 to 42.3 at 0-15 cm and 15-30 cm depth. At harvest of wheat crop, available P ranged from 20.5 to 41.8 and 16.5 to 39.1 kg ha^{-1} at 0-15 cm and 15-30 cm depth, respectively. Total phosphorus uptake and crop yield significantly increased under 150% NPK treatment followed by 100% NPK+FYM.

Keywords: Available phosphorus; farm yard manure; pH; electrical conductivity; total phosphorus uptake.

1. INTRODUCTION

“Wheat (*Triticum aestivum*) is the most extensively grown cereal crop, globally, covering about 237 million hectares annually, accounting for a total of 420 million tonnes” [1] which requires a huge quantity of chemical fertilizers for production. “It is observed that continuous use of inorganic fertilizers leads to deterioration in soil chemical, physical, and biological properties and soil health” [2]. “The negative impacts of chemical fertilizers, coupled with escalating prices, have led to growing interest in using of organic fertilizers as a source of nutrients” [3]. “Farm yard manure supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth and micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer” [4]. “FYM improves soil physical, chemical and biological properties. Improvement in the soil structure due to FYM application leads to a better environment for root development” [5]. “The use of FYM alone as a substitute for inorganic fertilizer is not enough to maintain the present crop productivity levels of high yielding varieties” [6]. “Long-term experiments allow monitoring change in crop yields and nutrient balances with time and studying the impact of different nutrient management scenarios on the sustainability of wheat-based systems” [7]. Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is the most effective method to maintain healthy and sustainably productive soil. Emerging evidence indicated that integrated soil fertility management involving the judicious use of combined organic and inorganic resources is feasible to overcome soil fertility constraints. With this background, the present study was conducted to study the effect of long-term application of fertilizers and manures on physico-chemical properties of soil, crop yield, phosphorus uptake and phosphorus availability.

2. MATERIALS AND METHODS

2.1 Experimental Site and Treatment Details

The present investigation was carried out during 2018-19 from an ongoing long-term fertilizer experiment which was initiated in 1971 with maize-wheat cropping sequence. The soil belongs to Mehrauli series, member of coarse loamy, non-acid, and mixed hyperthermic family of Typic Haplustept [8]. The experimental area falls under semi-arid sub-tropical agro-climatic zone of the Upper Gangetic Plain (28°30′ N, 77°10′ E; 250 m above the mean sea level) having hot summers and cold winters with a mean annual maximum and minimum air temperature of 40.5°C and 6.5°C, respectively. Annual rainfall is 651 mm, most of which remains confined to a three-month period from July to September (monsoon). The total precipitation during the course of this study was 189.9 mm and average temperature ranged from 9.9°C to 23.3°C.

The experiment was designed with seven different treatments, replicated thrice in a randomized complete block design. Three blocks were separated with a gap of 2.0 m, whereas individual plots (21 m x8 m) were separated with a distance of 1.0 m. The pooled soil sample was analysed for different soil characteristics of the surface and sub-surface soil (0-15 cm and 15-30 cm) of the experiment at different stages of wheat. The treatments consist of T_1: Control, T_2: 100%N, T_3: 100%NP, T_4: 100%NPK, T_5: 150% NPK, T_6: 100%NPK+5t FYM and T_7: 100% NPK+ Zn- 5 kgha^{-1}. The soil of the experimental field has 8.3 pH, 0.45 dSm^{-1} electrical conductivity, 10.6 cmol (p^+) kg^{-1} cation exchange capacity (CEC), 0.44 % organic carbon, 94 mg kg^{-1} available N, 7.14 mg kg^{-1} available P and 69 mg kg^{-1} available K. The recommended dose of fertilizers for wheat was 120:60:40 NPK kg ha^{-1}. In addition uniform dose of treatments, uniform Zn, was applied as zinc sulphate at 5 kg ha^{-1} just before sowing of *rabi* crop. In contrast FYM was applied as a source of organic manure at 5 t ha^{-1} just before *kharif* crop in the respective treatments.

2.2 Soil Sampling and Analyses

Using a tube auger, soil samples were collected from two different depths (0-15 cm and 15–30 cm) from each plot. All soil samples were air-dried under shade, ground to pass through 70-mesh (0.27 mm) sieve, processed, and stored for chemical analysis. Soil pH was determined using 1:2 soil/water suspension, electrical conductivity was determined by using a conductivity bridge meter [9].

Olsen P was determined by shaking the soil with 0.5 M sodium bicarbonate ($NaHCO_3$) (pH 8.5) for 30 min, followed by photometrical measurement using the molybdate– ascorbic acid method [10].

2.3 Statistical Analysis

Data were analyzed statistically using analysis of variance (ANOVA) for randomized complete block design using the SAS program. (SAS version 9.3; Cary NC) [11].

3. RESULTS AND DISCUSSION

3.1 Crop Yield

The data on grain yield of wheat presented in Table 1 revealed that the highest grain yield **(**5.74 t ha^{-1}) was obtained due to continuous application of 150% NPK, which was statistically on par with 100% NPK + FYM (5.46 t ha^{-1}), 100% NPK (5.12 t ha^{-1}) and NPK +Zn (5.06 t ha^{-1}). Lowest grain yield of 1.93 t ha^{-1} was recorded in the control. Continuous application of only 100% N every reduced yield compared to 100% NP (4.66 t ha^{-1}) and NPK (5.12 t ha^{-1}), emphasizing the need for balanced fertilization. Application of 150% NPK and 100% NPK +FYM treated plots recorded higher yields (grain and straw) as compared to all other treatments which could be due to higher nutrient uptake and improvement of soil environment [12] and FYM proved to be beneficial in enhancing crop productivity and soil fertility [13] due to the indirect effect resulting from reduced loss of organically supplied nutrients.

3.2 Total Phosphorus Uptake

It is evident from Table 4 that the continuous application of 150% NPK had a significant positive impact on the uptake of nutrients over other treatments. The highest P uptake by wheat was observed in T_5 treatment (24.3 $kgha^{-1}$). While, the lowest phosphorus uptake was found in treatment T_1 (15.5 kg ha^{-1}). Increasing P levels significantly increased total P uptake by wheat. An increase of 4.9 and 6.5 kg P ha^{-1} uptake was observed with 60 and 120 kg P_2O_5 ha^{-1} fertilizers, respectively, over control. These results conform with the results obtained by Setia and Sharma [14].

3.3 P Availability

Available P content in soil vary with cropping period, P availability in soil at initial stage (13.5 to 39.8 kg ha^{-1}) at 0-15cm depth, (15.4 to 37.9 kg ha^{-1}) at 15-30 cm depth, at tillering stage (20.7 to 43.7 kg ha^{-1}) at 0-15 cm and (16.5 to 38.1 kg ha^{-1}) at 15-30 cm depth, at panicle emergence stage (24.1 to 48.4 kg ha^{-1}) at 0-15 cm depth and (18.6 to 42.3 kg ha^{-1}) at 15-30 cm depth. At harvest stage of wheat crop available P ranged from (20.5 to 41.8 kg ha^{-1}) at 0-15 cm depth and (16.5 to 39.1 kg ha^{-1}) at 15-30 cm depth, respectively (Table 2). With maturity of crop, P availability increases in soil due to lesser fixation of P in soil (Hansen *et al.* 2004). At all four stages of wheat, a significant reduction of available P content observed under N alone (100% N) and unfertilized treatment (control). Available P was significantly greater under NPK+FYM followed by 150% NPK treatment at both depths, respectively. Khiari [15] also found that the available P varied widely from 5.85 kg ha^{-1} in control to 52.57 kg ha^{-1} in 100%NPK+Lime+FYM treated plot. The addition of FYM to 100%NPK measured the next best value for Olsen P. Garg and Aulukh [16] had also reported that the highest content was found when the integrated application of fertilizer was practised with FYM (39.83 kg ha^{-1}) followed by 150% NPK (39.55 kg ha^{-1}) treatments indicating the beneficial effect of FYM on mineralization of P to a greater extent in soil.

Thamaraiselvi et al. [17] reported that increases in available phosphorus due to FYM application.

Similarly, Aziz et al. [18] reported maximum soil N and P contents after a maize harvest for FYM. In contrast, the minimum N and P contents were found for the treatments with the application of inorganic NPK fertilizer. Available P content of the soil increased by applying of inorganic P fertilizer, green manure and FYM treatments. Increased available N and P by combined use of inorganic and organic fertilizers were also reported by Thind et al*.* [19].

The application of fertilizers and manures showed a positive response to soil physico-chemical properties. The perusal of the data on soil reaction of the experimental soil at different stages of wheat indicated that intensive cropping with continuous use of fertilizer alone or in combination resulted in slight change in soil pH (Table 3). In the present investigation pH of soil varied from 7.96 to 8.16 at 0-15 cm and 7.85 to 8.14 at 15-30 cm at the initial stage of wheat, at tillering stage pH of the soil was 7.64 to 7.85 at 0-15 cm and 7.51 to 7.80 at 15-30 cm, 8.01 to 8.20 at 0-15 cm and 7.79 to 8.06 at 15-30 cm in panicle emergence stage and harvest stage soil pH ranged from 8.02 to 8.24 at 0-15cm and 7.93 to 8.16 at 15-30cm. At all four stages of wheat pH under control treatment significantly greater than other treatment, lowest value observed in NPK+FYM treatment at both the depths, no appreciable change in soil pH concerning depth as a result of long term fertilization and manuring. After 48 years of cropping and fertilization, soil pH in all treatments had a trend of reduction compared with the initial value. In addition, soil pH values in the unfertilized treatments were higher than those of the balanced fertilization. Devi [20] reported that there was no significant effect on soil pH within 13 years of cropping on a Vertic Haplaquept. Dwivedi et al. [21] reported that continuous cropping and fertilizer use has no adverse effect on soil pH and might be due to the high buffering capacity of the soil. These results are also in agreement with Yaduvanshi et al. [22], Santhy et al. [23]; Singh et al. [24]. There was no appreciable change in pH of the soil with respect to depth due to continuous fertilizer additions and intensive cropping for over 48 years. The electrical conductivity also did not show any appreciable changes over the different stages of wheat due to continuous fertilizers application in almost all the treated plots presented in Table 4. Sharma [25] also reported that black soils that possessed inherent high buffering capacity affected the slight alterations in EC of soil due to fertilizer addition. There was no considerable changes in the soil's EC with depth due to continuous fertilizer addition over the 36 years. These results are also in agreement with the finding of Tomar [26].

Table 1. Effect of long- term nutrient management options on total phosphorus uptake and crop yield of wheat

Treatments	Crop Yield (t ha^{-1})			Total P Uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T1	1.93	3.26	5.19	13.2	2.23	15.5
T2	4.60	5.32	9.92	13.5	3.35	16.9
T3	4.66	6.54	11.2	13.9	3.49	17.3
T4	5.12	6.94	12.0	17.9	4.31	22.2
T5	5.74	7.95	13.6	19.1	5.16	24.3
T6	5.46	7.68	13.1	18.0	4.36	22.3
T7	5.06	7.41	12.4	16.2	4.20	20.4
CD (5%)	0.71	0.55	1.26	2.03	0.82	2.85

Table 2. Effect of long-term nutrient management options on available-P (kg ha^{-1}) at different stage of wheat at 0-15 cm and 15-30 cm depth

Treatments	Initial	Tillering	Panicle	Harvest
Surface soil (0-15cm)				
T1	13.5	20.7	24.1	20.5
T2	16.9	15.0	18.5	15.3
T3	33.3	36.2	36.7	34.7
T4	36.0	39.2	39.5	36.6
T5	38.4	43.4	45.9	41.0
T6	39.8	43.7	48.4	41.8
T7	32.8	33.8	36.2	33.0
CD (5 %)	0.90	0.47	1.09	0.77

Treatments	Initial	Tillering	Panicle	Harvest
Sub-surface soil (15-30cm)				
T1	15.4	16.5	18.6	16.5
T2	11.8	13.6	15.1	12.2
T3	32.2	32.6	32.4	34.9
T4	34.1	35.7	36.4	36.4
T5	37.7	37.7	41.5	38.4
T6	37.9	38.1	42.3	39.1
T7	30.4	30.9	30.8	32.1
CD (5 %)	0.87	0.60	1.19	0.83

Table 3. Effect of long -term nutrient management options on soil pH at different stages of wheat at 0-15 cm and 15-30 cm depth

Treatments	Initial	Tillering	Panicle	Harvest
Surface soil (0-15cm)				
T1	8.16	7.85	8.20	8.24
T2	8.09	7.83	8.16	8.19
T3	8.08	7.76	8.11	8.15
T4	8.06	7.75	8.09	8.12
T5	8.03	7.68	8.06	8.08
T6	7.96	7.64	8.01	8.02
T7	8.16	7.80	8.16	8.21
CD (5%)	NS	NS	NS	NS
Sub-surface soil (15-30cm)				
T1	8.14	7.80	8.06	8.16
T2	8.11	7.70	8.00	8.12
T3	8.01	7.72	7.96	8.07
T4	7.99	7.66	7.93	8.05
T5	7.91	7.59	7.81	8.03
T6	7.85	7.51	7.79	7.93
T7	8.11	7.72	8.00	8.12
CD (5%)	NS	NS	NS	NS

NS: Non-significant

Table 4. Effect of long- term nutrient management options on EC (dSm^{-1}) of the soil at different stages of wheat at 0-15 cm and 15-30 cm depth

	Initial	Tillering	Panicle	Harvest
Surface soil (0-15cm)				
T1	0.33	0.36	0.35	0.34
T2	0.31	0.33	0.33	0.32
T3	0.33	0.36	0.35	0.34
T4	0.30	0.32	0.29	0.30
T5	0.31	0.33	0.33	0.32
T6	0.30	0.33	0.30	0.31
T7	0.31	0.33	0.33	0.32
CD (5%)	NS	NS	NS	NS
Sub-surface soil (15-30cm)				
T1	0.31	0.34	0.31	0.33
T2	0.30	0.32	0.30	0.32
T3	0.29	0.34	0.31	0.31
T4	0.29	0.30	0.28	0.31
T5	0.30	0.33	0.30	0.32
T6	0.28	0.31	0.29	0.30
T7	0.30	0.33	0.30	0.32
CD (5%)	NS	NS	NS	NS

NS: Non-significant

4. CONCLUSIONS

The present study revealed the long-term application of fertilizers and manures on the physico-chemical properties of soil, crop yield, total phosphorus uptake and phosphorus availability. Over a period of time, depletion of the nutrients was observed in the control, whereas, the application of fertilizers and manure has recorded in sustainable higher crop yield, total phosphorus uptake in 150% NPK treatment followed by 100% NPK+FYM treatment. Similarly, available phosphorus content at initial, tillering, panicle emergence and harvest stage of wheat, highest under NPK+FYM followed by 150% NPK treatment, lowest under nitrogen alone (100% N) and unfertilized treatment at both depths. pH under control treatment greater than other treatment, lowest value observed in NPK+FYM treatment. Electrical conductivity did not show any appreciable changes over the different stages of wheat due to continuous fertilizers application.

ACKNOWLEDGEMENTS

The first author would like to thank the Director of the Indian Agricultural Research Institute (IARI), New Delhi, India for providing facilities for conducting the experiments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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