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Effect of long-term application of fertilizers and amendments on wheat productivity and DTPA extractable micronutrients in an acid Alfisol

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Abstract

The effect of continuous application of fertilizers and amendments on wheat yield and DTPA extractable micronutrients in an acid Alfisol during *rabi* (2016-17) was evaluated in field experiment at the research farm of the Department of Soil Science, CSKHPKV Palampur. This experiment was initiated during 1972 in randomized block design with eleven treatments which were replicated three times. The soil of the experimental area was silt loam and classified taxonomically as "*Typic Hapludalf*". The highest productivity of wheat was recorded in the treatment comprising 100 per cent NPK + FYM and was statistically comparable with 100 per cent NPK + lime. Continuous application of N alone resulted in zero yield and omission of K and S from the fertilization schedule also resulted in drastic reduction in the yield. In surface soil (0-0.15m), application of Zn along with 100 per cent NPK (T_5) recorded the highest value (3.75 mg kg^{-1}) of DTPA extractable Zn and combined use of FYM with optimal dose of NPK (T_8) recorded the highest value of DTPA extractable Fe, Cu and Mn (38.0, 2.25 and 37.25 mg kg^{-1}, respectively). The lowest value (1.08, 18.8, 1.32 and 17.90 mg kg^{-1}) of DTPA extractable Zn, Fe, Cu and Mn, respectively, was recorded in control plot.

Key words: wheat yield, micronutrients, fertilizers, amendments, Alfisol.

The continuously growing population and increase demand for food call for greater reliance on agriculture than had ever been witnessed. The mining of nutrients from soil if allowed to continue would severely limit crop production in the coming years. The present day agriculture all over the world has therefore become much dependent upon chemical fertilizer to produce more and more from the shrinking land area (Reddy *et al.* 2017).

Continuous use of micronutrient free high analysis N, P and K fertilizers with low use of organic manures under intensive cropping results in quick depletion of organic matter and micronutrients in soil (Singh and Ram, 2007). However, contribution of chemical fertilizers towards an increase in agricultural production is well known. But, their injudicious use exhibits a detrimental effect on soil health. Long-term use of FYM with inorganic fertilizers is a good management system in accumulating soil organic carbon, sustaining yield and enhancing soil quality for increasing crop production.

The importance of long-term fertilizer experiments in studying the effects of continuous cropping and fertilizers application on sustenance of crop production is widely recognized. Long-term fertilizer experiments play an important role in understanding the complex interactions involving soils, plants, climate and management practices and their effects on crop productivity. It is well recognized that long-term fertilizer experiments are repositories of valuable information regarding the sustainability of intensive agriculture. Thus, long-term fertilizer experiments serve as an important tool to understand the changes in soil properties due to intensive cropping and continuous fertilization. In the present investigation, an attempt was undertaken to study the long-term effect of application of fertilizers and amendments on wheat productivity and micronutrient status in an acid Alfisol.

Materials and Methods

The present investigation was carried out in an ongoing long-term fertilizer experiment started during 1972-73 (*rabi*) at the Research Farm of the Department of Soil Science, College of Agriculture, CSKHPKV Palampur. The experimental farm is situated at $32^0 6^/$ N latitude and $76^0 3^/$ E longitude at an altitude of about 1290 meters above mean sea level. The site is situated in the Palam valley of Kangra district under mid hills sub humid zone of Himachal Pradesh. Soil of the study area was silt loam in texture and was classified as "*Typic Hapludalf*". The 11 treatments were as follows: T_1 - 50% NPK; T_2 - 100% NPK; T_3 - 150% NPK; T_4 - 100% NPK + Hand Weeding (HW); T_5 - 100% NPK + Zinc (Zn); T_6 - 100% NP; T_7 - 100% N; T_8 - 100% NPK + FYM; T_9 - 100% NPK (-S); T_{10} - 100% NPK + lime; T_{11} – control. The experiment was conducted in randomized block design (RBD) with three replications and the plot size was 15 m^2 (5m × 3m). Due to the marked build-up of available P, the original treatment structure was slightly modified from *kharif* 2011, optimal and super optimal doses of P were reduced by 50 per cent and in case of 50 per cent NPK, the addition of farmyard manure (FYM) @ 5 t ha^{-1} on dry weight basis to maize crop only was also included. The wheat crop (variety HPW-155) was sown on 15th November, 2016 and harvested on 16th May, 2017. Irrigations were given at critical growth stages of wheat. Chemical weed control measures with Isoproturon @ 1.125 kg ha^{-1} (as post-emergence) was adopted except in T_4 (100 % NPK + hand weeding), where weeds were removed manually and incorporated in the plot itself. Surface and sub surface soil samples collected from individual plots after harvest of wheat (*rabi* 2016-17) were analyzed for DTPA extractable Zn, Fe, Cu and Mn (Lindsay and Norvell, 1978).

Results and Discussion

Productivity of wheat

The data pertaining to productivity of wheat as affected by the continuous use of fertilizers and amendments have been presented in Table 1. Results of the present study revealed that the mean grain yield of wheat after 45 years of continuous cropping and fertilization was the highest (28.22 q ha^{-1}) in 100 per cent NPK + FYM (T_8), which was at par with 100 per cent NPK + lime (25.89 q ha^{-1}). The lowest grain yield (0 q ha^{-1}) was recorded with sole application of nitrogen (T_7), followed by control (3.56 q ha^{-1}). Adding phosphorus in the fertilization schedule along with nitrogen i.e. 100 per cent NP (T_6), resulted in grain yield of 9.22 q ha^{-1}, while there was further improvement when potassium was included i.e. 100 per cent NPK (T_2) which resulted in 18.33 q ha^{-1} grain yield, which accounted for about 98.8 per cent increase in grain yield over imbalanced NP application (T_6). On the other hand, there was a significant decline in wheat grain yield (7.78 q ha^{-1}) when sulphur was excluded from the fertilization schedule i.e. in 100 per cent NPK(-S) (T_9) and this decline was about 57.6 per cent over 100 per cent NPK fertilization. The data also revealed that grain yield increased with increasing fertilizer dose from 50 per cent NPK (T_1) to 100 per cent NPK (T_2) by 8.5 per cent, but super optimal dose of 150 per cent NPK (T_3) reduced the grain yield by 12.7 per cent as compared to 100 per cent NPK (T_2).

Straw and biological yield of wheat varied from 7.11 to 46.66 q ha^{-1} and from 10.67 to 74.89 q ha^{-1} in control (T_{11}) and in 100 per cent NPK + FYM (T_8), respectively. Like grain yield, straw yield of wheat in 100 per cent NPK + FYM (T_8) was the highest and at par with 100 per cent NPK + lime (T_{10}). Continuous use of FYM along with 100 per cent NPK (T_8) increased the straw yield of wheat by 49.5 per cent over 100 per cent NPK (T_2). Application of 100 per cent NPK (T_2) was at par with 100 per cent NPK + HW (T_4) and 100 per cent NPK + Zn (T_5). The treatment wise trend of wheat straw and biological yield was similar to grain yield.

The highest wheat grain yield obtained in 100 per cent NPK + FYM (T_8), may be due to the addition of organic manure along with inorganic fertilizers, which might have improved the soil organic matter content and supplied not only the additional quantities of NPK directly, but also secondary and micro nutrients which were limiting in the soil (Bhattacharyya *et al*. 2016). It can also be due to the improvement in soil physical

Table 1. Effect of long-term use of fertilizers and amendments on productivity of wheat (q ha^{-1})

Treatment	Productivity		
	Grain	Straw	Biological
T_1: 50% NPK	16.89	26.89	43.78
T_2: 100% NPK	18.33	31.22	49.56
T_3: 150% NPK	16.00	28.45	44.45
T_4: 100% NPK + HW	20.67	33.78	54.44
T_5: 100% NPK + Zn	17.11	30.33	47.45
T_6: 100% NP	9.22	16.34	25.56
T_7: 100% N	0.00	0.00	0.00
T_8: 100% NPK + FYM	28.22	46.66	74.89
T_9: 100% NPK (-S)	7.78	14.67	22.44
T_{10}: 100% NPK + lime	25.89	43.22	69.11
T_{11}: Control	3.56	7.11	10.67
CD (P=0.05)	2.97	3.91	6.6

conditions as a result of continuous FYM application which provided congenial environment for plant growth and nutrient uptake (Mishra *et al.* 2008). Increase in wheat grain and straw yield in 100 per cent NPK + lime (T_{10}) treated plots as compared to other treatments might be ascribed to the higher nutrient availability due to ameliorating effect of lime on soil pH (Singh *et al.* 2017). Lime alleviates soil pH and protects plants from Al toxicity, reduces P fixation and increases Ca and P availabilities, leading to higher grain production. Application of N alone (T_7) declined the soil pH which might be due to the acidic nature of urea and continuous mining of nutrients for the last 45 years thus resulted in zero yield of wheat. Brar *et al.* (2015) have also reported complete degradation of soil in plots treated with nitrogen alone over a period of time and thereby resulting in zero yields. The low yield in control plot might be due to poor inherent capacity of the soils under study which was not able to meet the requirement of crops in respect of the essential nutrients and may also be due to decrease in soil organic carbon content (Shambhavi *et al.* 2017). Use of recommended dose of NPK through sulphur free fertilizer (T_9) decreased the grain and straw yield of wheat significantly over recommended dose of NPK through sulphur containing fertilizer (T_2). The lower yield obtained with sulphur free fertilizer treatment as compared to S bearing fertilizer treatments could be due to the depletion of S reserve in the soil under intensive cropping.

Effect of continuous application of fertilizers and amendments on the available micronutrient status of soil

The data on the effect of continuous manuring and cropping on the available (DTPA extractable) micronutrient status of soil have been presented in Table 2.

DTPA extractable zinc

In surface soil (0 - 0.15 m), the DTPA extractable Zn content ranged from 1.08 to 3.75 mg kg^{-1} in control (T_{11}) and 100 per cent NPK + Zn (T_5), respectively. A perusal of data indicated that after forty five years of experimentation, DTPA extractable Zn was considerably higher than the critical limits for the crop. Zinc content in surface soil varied from 1.08 mg kg^{-1} under control (T_{11}) to 3.75 mg kg^{-1} under 100 per cent NPK + Zn (T_5). Zinc content under 100 per cent NPK + HW treatment was at par with 100 per cent NPK alone. Graded doses of fertilizers from 50 to 150 per cent NPK resulted in increased zinc content, although, the increase was insignificant. Zinc content (DTPA extractable) in 0.15 - 0.30 m soil depth varied from 0.92 to 2.27 mg kg^{-1} in control and 100 per cent NPK + Zn, respectively. A general reduction in DTPA extractable Zn content was recorded with the increase in soil depth and treatment wise trend was almost similar to the surface layer.

The inclusion of FYM along with 100 per cent NPK resulted in the build-up of Zn content in soil. This could be attributed to the direct contribution of Zn by FYM to the nutrient pool in soil and its beneficial effects either through complexation or mobilization of native Zn in soil. The build-up of available zinc due to organic matter application has also been reported by Prasad *et al.* (2010). Relatively higher values of DTPA extractable Zn in FYM amended plots could also be ascribed to the better supply of Zn by conversion of less soluble fractions of Zn to plant available fractions, addition of micronutrients through FYM and release of chelating agents from organic matter decomposition which might have prevented micronutrients from precipitation, oxidation and leaching (Sharma *et al.* 2001). Addition of zinc along with 100 per cent NPK (T_5) raised the level of available Zn content to its highest value in the soil. There were no marked differences within the graded levels of fertilizers from 50 to 150 per cent NPK on available Zn content in soil. Similar results were reported by Thakur *et al.* (2011). The combined application of FYM, lime and zinc along with recommended dose of fertilizer increased the availability of zinc in the soil as compared to 100 per cent NPK.

DTPA extractable iron

A perusal of data (Table 2) revealed a significant effect of nutrient management practices on DTPA extractable Fe. The content of DTPA extractable Fe was higher than the critical limits in all the treatments. Among various treatments, significantly higher amounts of DTPA extractable iron (38.0 mg kg^{-1}) was recorded in FYM amended plot (T_8), while the lowest (18.8 mg kg^{-1}) was recorded in control (T_{11}). Continuous cropping and zero fertilization (T_{11}) for the last forty five years resulted in 42 per cent reduction in DTPA extractable Fe content as compared to optimal fertilization (T_2). Comparison of different fertilizer treatments with control revealed that there was a significant increase in available Fe content in all the treatments except lime amended treatment (T_{10}). Regarding the content of DTPA extractable Fe at 0.15 - 0.30 m soil depth, the Fe content varied from 16.4 to 30.7 mg kg^{-1} in control and 100 per cent NPK + FYM treated plot, respectively. There was a consistent declining trend in DTPA extractable Fe in the sub surface soil in comparison to the surface layer and treatment wise trend was similar down the soil profile.

Application of FYM along with 100 per cent NPK (T_8) recorded the highest DTPA extractable Fe content. Increase in available iron in FYM amended plot may be due to the direct addition and solubilization of native iron by organic acids produced from decomposition of added organic sources and could also be due to the production of chelating agents which have the ability to reduce their adsorption, fixation and precipitation resulting in their enhanced availability in soil (Kher 1993). Verma *et al.* (2012) also reported higher DTPA extractable Fe in treatment receiving combined application of organic and inorganic fertilizers. Increase in DTPA extractable Fe with the addition of chemical fertilizers as compared to control might due to the fact that fertilizers like SSP contains considerable Fe as contaminant and incorporation of the same in the field might have helped in checking the diminishing trend of Fe in NPK treated plots (Kundu *et al.* 2016). Increased available iron content in soil with super optimal dose of fertilizers could be ascribed to higher amount of crop residue and better microenvironment with efficient mobilization of mineral nutrients.

DTPA extractable copper

The result of present study reveals that the content of DTPA extractable copper was much higher than their critical levels. In surface soil (0 - 0.15 m), DTPA extractable Cu content varied from the its lowest value of 1.32 mg kg^{-1} in control (T_{11}) to the highest value of 2.25 mg kg^{-1} in 100 per cent NPK + FYM (T_8). The treatments 100 per cent NPK + HW (T_4) and 100 per cent NPK + Zn (T_5) were statistically at par with 100 per cent NPK (T_2) with Cu content of 1.69, 1.73 and 1.73 mg kg^{-1}, respectively. Application of FYM along with 100 per cent NPK (T_8) increased available Cu content to the extent of 30.1 per cent as compared to 100 per cent NPK (T_2). In sub surface soil (0.15 - 0.30 m), DTPA extractable Cu varied from 1.02 mg kg^{-1} in control (T_{11}) to 1.81 mg kg^{-1} in 100 per cent NPK + FYM (T_8). Copper content in the sub surface soil was less as compared to surface soil and the treatment wise effect was similar to surface layer.

Application of 100 per cent NPK + FYM showed significantly higher DTPA extractable micronutrients content than other treatments. The increase in available micronutrients status of soils in FYM treated plots might be the due to addition of micronutrients through FYM and release of chelating agents from organic matter decomposition which might have prevented micronutrients from precipitation, oxidation and leaching (Sharma *et al*. 2001). Higher contents of DTPA extractable Cu due to combined application of organic and inorganic fertilizers were also reported by Verma *et al*. (2012). Together with increasing soil acidification, an increase in available Cu content in soil was also recorded by Rutkowska *et al.* (2009).

DTPA extractable manganese

The results indicated that after forty five years of continuous cropping and fertilization, the level of DTPA extractable Mn was much higher than the critical level. A close look at the data indicated that DTPA extractable Mn varied from a minimum value of 17.90 mg kg^{-1} in control (T_{11}) to 37.25 mg kg^{-1} under 100 per cent NPK + FYM (T_8) in the surface layer. Application of FYM along with 100 per cent NPK recorded 61.2 per cent higher available Mn content as compared to 100 per cent NPK (T_2).

Graded doses of NPK i.e. 50, 100 and 150 per cent of its recommended level, increased the soil manganese content to the extent of 17.6, 29.1 and 42.3 per cent, respectively, over control (T_{11}), however, the treatments were statistically at par with each other. The DTPA extractable Mn under 100 per cent NPK + HW (T_4) and 100 per cent NPK + Zn (T_5) was also statistically at par with 100 per cent NPK (T_2). In sub surface soil layer (0.15 - 0.30 m), the lowest value of Mn (10.31 mg kg^{-1}) was recorded in control (T_{11}) and the highest value (25.46 mg kg^{-1}) was recorded under 100 per cent NPK + FYM (T_8). It was further observed that the contents of DTPA extractable manganese were lower in sub surface soil as compared to surface soil. However, the treatment wise effect was similar in trend as in case of surface layer.

The treatment which received organic matter through FYM recorded higher values of DTPA extractable manganese than rest of the treatments. The increase in micronutrients concentration in soils with addition of organics might be due to the enhanced microbial activity and consequent release of complex organic substances (chelating agents) besides direct addition of these nutrients to the available pool on decomposition of organics (Bellakki and Badanur 1997). Gupta *et al.* (2000) reported that the addition of organic manures to soil increased the availability of micronutrients in soil due to its complexing property with micronutrients and hence its retention in the soil against precipitation, fixation and leaching processes. Such an increase in the micronutrient content with the use of organics along with chemical fertilizers has also been reported by Sharma and Subehia (2003). The decrease in Mn status of soil over its initial status could be due to repetition of same cropping system year after year, which might have created favourable condition for Mn^{2+} oxidizing bacteria or fungi leading to quick depletion of Mn in the rhizosphere (Nambiar 1994).

Conclusion

Integrated use of optimal dose of NPK along with amendments (FYM/Lime) enhanced the productivity of wheat. The content of DTPA extractable micronutrients was higher than their critical limits in all the treatments in an acid Alfisol.

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