International Journal of Bio-resource and Stress Management 2018, 9(2):197-202 Full Research

Doi: HTTPS://DOI.ORG/10.23910/IJBSM/2018.9.2.1854b

Effect of 36 Years of Continuous Cropping and Fertilization on Productivity, Micro and Secondary Nutrient Status and Uptake by Maize-wheat Cropping System in Western Himalayas

Shweta Shambhavi[1], Rakesh Kumar[1*], S. P. Sharma[2], Gayatri Verma[3], Sanjay K. Sharma[2] and R. P. Sharma[2]

[1]Dept. of Soil Science and Agricultural Chemistry, BAU, Sabour, Bihar (813210), India
[2]Dept of Soil Science, CSKHPKV, Palampur, H.P. (176 062), India
[3]Regional Research Station, Gurdaspur, PAU, Punjab (141 004), India

Corresponding Author

Rakesh Kumar
e-mail: rbinnu@gmail.com

Article History

Article ID: AR1854b
Received in 11th January, 2018
Received in revised form 17th February, 2018
Accepted in final form 29th March, 2018

Abstract

A study was conducted during 2008-09 to assess the changes in the soil status of secondary and micronutrients and micronutrients uptake by maize-wheat cropping system after 36 years of fertilizer use at CSKHPKV, Palampur, Himachal Pradesh, India. The exchangeable Ca and Mg and available S varied from 1.47-6.63, 0.17-0.52 c mol (p^+) kg^{-1}, 11.6-26.0 kg ha^{-1}, respectively. An overall decline in exchangeable Ca and Mg status was observed as compared to its initial value in all the treatments over the years except in lime treatment where a build-up in Ca content was noticed. The available S status increased in all the treatments except control and 100% N as compared to its initial value. DTPA-extractable micronutrients in general showed a decline from its initial level except for Cu where a noticeable build-up has been observed. All the DTPA-extractable micronutrients were higher in FYM treated plots except DTPA-Zn being highest in 100% NPK+Zn treatment. The highest grain and stover/straw yields of maize and wheat were obtained in 100% NPK+FYM treatment (13.9 and 9.7 t ha^{-1}, respectively) followed by 100% NPK+lime (mention yield 13.24 and 8.82 t ha^{-1}, respectively), both being at par. Total uptake of Fe, Mn, Zn and Cu ranged from 62.9-2223.1, 17.4-986.6, 11.5-701.5 and 20.1-715.8 g ha^{-1}, respectively by maize and from 197.4-1473.2, 112.2 -956.1, 44.1-395.0 and 69.4-586.0 g ha^{-1}, respectively by wheat under different treatments.

Keywords: Crop productivity, long-term fertilization, maize-wheat, micronutrients

1. Introduction

Micronutrient deficiencies in crop plants are widespread because of (i) increased removal of micronutrients by intensive cropping practices and adoption of high yielding cultivars (ii) Raising of crops on marginal soils that contain low levels of essential nutrients (iii) increased use of high analysis fertilizers with low micronutrients content (iv) decreased use of animal manures, composts, and crop residues and (v) use of soils that are inherently low in micronutrient reserves. Historical development in micronutrients use in India started from green revolution. Green revolution during late sixties remarkably boosted the agricultural production and made the country self sufficient to feed the millions population (Brar et al., 2015). But in the process it caused soil degradation especially the nutrient imbalances because of rapid depletion of soil fertility due to heavy withdrawal of essential plant nutrient by crops. In the initial years of cultivation of high yielding crop variation, the main fertilizer nutrient added was N. This caused the imbalance of P and thus phosphorus deficiency came into existence and this deficiency was made up with phosphatic fertilizers (Mortvedt, 2000). With the further advancement in agricultural technology and with continuous removal of micronutrients by bumper harvests, deficiency of micronutrients Zn cropped up. This paved the way for understanding the role of micronutrients also. Long-term mineral and organic fertilization can significantly modify soil properties such as pH, organic matter contents or else soil richness in available forms of macronutrients, which determine availability of micronutrients to plants (Rutkowska et al., 2014). Mineral fertilization especially nitrogen nutrition contributes to decrease of soil pH and it also enhances mobility of Cu, Fe, Mn and Zn (Fan et al., 2011). Application of manure and chemical fertilizers in combination helped to improve the micronutrient content of wheat grains (Dhaliwal et al., 2014). Long-term fertilizer experiments rather than single season trials are considered as vital tools to examine the sustainability of modern intensive cropping (Hetal and Jadav, 2016). These experiments provide valuable information regarding the impact of continuous application of fertilizers in varying combinations of nutrients on soil health and crop productivity. Keeping the above facts in view, the present investigation was conducted for assessing the soil status of secondary and micronutrients and uptake of micronutrients by maize-wheat system as influenced by 36 years of continuous cropping and fertilizer use.

2. Materials and Methods

The long-term fertilizer experiment was commenced in 1972 on a Typic Hapludalf soil of experimental farm of Department of Soil Science, CSKHPKV, Palampur (32°6′ N latitude and 76°3′ E longitude, 1290 m above MSL), Himachal Pradesh, India and is characterized as zone 2.2 under mid hill sub-humid zone of Himachal Pradesh. The climate of Palampur is characterized as wet temperate with mild summers (March to June) and cool winters (December-February). The average annual rainfall is about 2250 mm with June-September being the wettest months. The soil of the experimental site is illitic and silty clay loam in texture (24% clay, 47% silt and 29% sand). At the onset of the long-term fertilizer experiment in 1972, the soil (0-0.15 m depth) was acidic (pH 5.8), contained 7.9 g kg^{-1} organic carbon, 13.5 kg ha^{-1} available S, 5.3 and 1.3 c mol (p^+) kg^{-1} exchangeable Ca and Mg, respectively and 26.0, 24.3, 1.9 and 0.4 mg kg^{-1} of DTPA-extractable Fe, Mn, Zn and Cu, respectively.

The long-term fertilizer experiment is being carried out in fixed plots since 1972 with maize-wheat cropping system (earlier maize-potato-wheat cropping system till 1981……) under irrigated conditions. The experiment had eleven treatments with four replications conducted in a randomized block design The treatments are T_1: Control; T_2: 100% N; T_3: 100% NP; T_4: 100% NPK pl clarify whether it is NPK or N, P_2O_5, K_2O; T_5: 100% NPK+FYM; T_6: 100% NPK+lime; T_7: 100% NPK+Zn; T_8: 100% NPK+HW; T_9 100% NPK (-S); T_{10}: 150% NPK; T_{11}: 50% NPK.

The 11th treatment (100% NPK-S) was introduced in *kharif* 1981. The 100% NPK dose corresponds to the state level recommendations for the corresponding nutrients and is 120, 26 and 33; and 120, 26 and 25 kg ha^{-1} N, P and K for maize and wheat, respectively. The sources of N, P and K were urea, single super phosphate and muriate of potash, respectively. In 100% NPK (-S), P was applied through di-ammonium phosphate to assess the effect of 'S' free high analysis P fertilizer in crop production. Zn was applied in T_7 as zinc sulphate at the rate of 25 kg ha^{-1} every year to both the crops. Farmyard manure application was made at the rate of 10 t ha^{-1} on fresh weight basis to maize crop only, which corresponded to the practice being followed by the farmers of the region. The farmyard manure applied contained 60% moisture; and had 1.01, 0.26 and 0.40% of N, P and K, respectively on dry weight basis. Thus, 10 t ha^{-1} farmyard manure on fresh weight basis contained 40 kg N, 10 kg P and 16 kg K ha^{-1}. Lime was added in T_6 at the rate of 900 kg ha^{-1} only to maize crop as marketable lime ($CaCO_3$) passed through 100 mesh sieve. Lime application was continued till the soil pH was raised to 6.5 in 1979. Lime application in the subsequent years was restored only when the soil pH declined to 6.3. Chemical weed control measures (specify weedicide and herbicide as recommended) were followed in both the crops except in T_8 (100% NPK+hand weeding), where weeds were removed manually.

After the harvest of the crops at maturity grain and straw yields were recorded separately. Grain yield of maize was standardized at thirteen per cent moisture content and stover yield on oven dry basis, whereas in wheat, yields of both grain and straw were recorded on air-dry basis. The thoroughly washed plant samples were dried in oven at 70 ^{0}C for 48 hr, ground in a stainless steel Wiley mill, and digested in a di-acid mixture of HNO_3 and $HClO_4$ (Jackson, 1973). Micronutrient was determined in aqueous extracts of the digested plant material by atomic absorption spectrophotometer (AAS). Total micronutrient uptake was calculated as dry weight of stover/straw multiplied by the micronutrient concentration and added to the grain yield multiplied by micronutrient concentration in grain.

Soil samples were collected from each plot with a steel palta from 0 to 0.20 m and 0.20 to 0.40 m depths after the harvest of the maize crop and analysed for Available S (Chesnin and Yien, 1950), exchangeable Ca and Mg (Jackson, 1973) and DTPA extractable Fe, Mn, Zn and Cu (Lindsay and Norvell, 1978).

3. Results and Discussion

3.1. Status of secondary nutrients in soil

The available S content declined in control and 100%N treated plots as compared to the initial status of 13.5 kg ha^{-1}. The available S (14.0 kg ha^{-1}) in the plots where sulphur free phosphatic fertilizer was used was almost equal to the initial value. The rest of the treatments showed significant increase in the available S content of the soil. The graded doses at the rate of 50, 100 and 150% of its recommended level of NPK increased the soil available S content to 17.0, 22.8 and 26.0 kg ha^{-1} at the end of 36th cropping cycle, respectively. Application of FYM, lime or zinc in combination with the recommended dose of NPK showed an increase of 92.8, 90.1 and 79.8%, respectively over the initial status of 13.5 kg ha^{-1}. The available S content in the subsurface soils was less in comparison to the surface layers in all the treatments (Table 1). The increase in the available sulphur in 100% NPK+FYM (T_5) and 150% NPK (T_{10}) might be due to the addition of single super phosphate (SSP) and FYM which contained about 12 and 0.15% of S, respectively. The sulphur content of control, 100%N and sulphur excluded plots reduced to below critical level of 16 kg ha^{-1} in surface soils which could be due to low organic carbon content in control and 100% N plots as S is known to be an integral part of soil organic matter while exclusion of S, in 100% NPK (-S) plots. Similar results have also been reported by Singh et al. (1999); Sudhir et al. (2002).

The content of Ca as well as Mg drastically reduced in all the fertilizer treatments over a period of 36 years except that lime application showed increase in the exchangeable Ca content

(Table 1). The Ca content after the harvest of 36th maize crop ranged from 1.47 in the 100% N to as high as 6.63 c mol (p^+) kg^{-1} in the 100% NPK+lime treated plots compared to its content of 5.3 c mol (p^+) kg^{-1} before the start of the long term study (Table 1). Exchangeable Mg content declined consistently in all the fertilizer treatments after 36 years of manuring and cropping. The decline in exchangeable Mg content after 36th cropping cycle ranged from 86.9 (100% N)-60.0% (100% NPK+FYM). The exchangeable Ca and Mg content in the sub-surface layer followed decreasing trend compared to the surface layer (Table 1). Lime and FYM additions increased the exchangeable Ca^{2+} and Mg^{2+} status of the soils due to increase in biomass production and its incorporation in the soil. Also, lime provides additional amounts of Ca and Mg in soil. The consistently declining trend of Ca and Mg with the recommended levels of chemical fertilizers warrants the supplementation of NPK fertilizers with Ca as well as Mg for the maintenance of soil health and sustainable crop production.

3.2. Status of DTPA-extractable micronutrients in soil

There was general reduction in DTPA extractable Fe, Mn and Zn after the harvest of thirty-sixth maize crop in comparison to their initial values at the beginning of the experimentation

Table 1: Effect of 36 years cropping and fertilizer use on secondary and micronutrient status of soil under maize-wheat rotation

Treatment	Available S ($kg\ ha^{-1}$)	Exchangeable cations (c mol (p+) kg^{-1})		DTPA extractable micronutrients ($mg\ kg^{-1}$)			
		Ca	Mg	Fe	Mn	Zn	Cu
(0.0–0.20 m)							
Control (T_1)	11.6	3.47	0.39	19.88	21.76	1.37	1.70
100% N (T_2)	13.2	1.47	0.17	24.51	20.99	1.06	1.98
100% NP (T_3)	20.0	3.20	0.18	32.81	25.25	1.02	1.90
100% NPK (T_4)	22.8	3.10	0.37	25.02	23.08	1.29	1.59
100% NPK+FYM (T_5)	26.0	4.33	0.52	40.17	32.68	2.10	2.38
100% NPK+lime (T_6)	25.7	6.63	0.42	32.09	24.69	1.43	2.09
100% NPK+Zn (T_7)	24.3	2.93	0.34	24.73	30.11	5.68	1.93
100% NPK+HW (T_8)	23.2	3.63	0.43	24.70	22.20	0.92	1.98
100% NPK(-S) (T_9)	14.0	2.33	0.30	25.04	22.97	1.14	1.66
150% NPK (T_{10})	26.0	2.73	0.29	33.27	24.88	1.56	2.04
50% NPK (T_{11})	17.0	3.10	0.32	24.39	22.82	1.01	1.56
Initial status	13.5	5.3	1.3	26	24.3	1.9	0.4
SEm±	1.65	0.39	0.3	1.77	1.09	0.41	0.07
CD (p=0.05)	1.57	0.153	0.026	0.929	1.017	0.195	0.140
(0.20–0.40 m)							
Control (T_1)	6.2	2.70	0.33	11.26	10.99	0.65	0.95
100% N (T_2)	6.8	1.00	0.11	16.13	16.11	0.51	1.11
100% NP (T_3)	13.8	2.33	0.13	24.28	17.35	0.69	1.02
100% NPK (T_4)	19.4	2.40	0.32	17.84	17.39	0.61	0.90
100% NPK+FYM (T_5)	20.9	3.13	0.35	32.12	25.28	1.04	1.24
100% NPK+lime (T_6)	20.2	5.17	0.32	24.41	18.35	0.70	1.19
100% NPK+Zn (T_7)	18.8	1.57	0.25	17.80	19.39	4.41	1.08
100% NPK+HW (T_8)	17.4	2.60	0.36	17.73	15.91	0.63	1.12
100% NPK(-S) (T_9)	7.0	1.20	0.27	18.30	17.27	0.59	0.84
150% NPK (T_{10})	20.2	1.33	0.20	24.24	17.58	0.76	1.17
50% NPK (T_{11})	11.8	2.47	0.23	16.05	15.60	0.46	0.86
SEm±	1.78	0.35	0.3	1.72	1.02	0.34	0.04
CD (p=0.05)	1.41	0.126	0.020	0.849	0.671	0.094	0.071

i.e., 1972-73 (Table 1). DTPA extractable Cu, on the other hand showed marked increase in its content. The DTPA extractable Fe declined to 19.88 mg kg^{-1} in the plots receiving zero fertilization compared to its status of 26 mg kg^{-1} during 1972-73, the per cent decline over a period of 36years being 23.5 (Table 1). Combining FYM and lime with chemical fertilizers (T_5) and (T_6), the use of 100% NP (T_3), and 150% NPK (T_{10}), however, showed build up in the DTPA extractable Fe content, the per cent increase being 54.5, 23.4, 26.2 and 28.0, respectively after the harvest of thirty-sixth maize crop compared to its content in 1972-73 (Table 1).

The DTPA extractable Mn, like Fe, also showed declining trend in most of the treatments except for 150 per cent NPK, 100%NPK+Zn, 100% NP and 100% NPK+FYM, where increase in the DTPA extractable Mn was observed (Table 1). Unlike Fe and Mn, decline in Zn content with continuous manuring and cropping over a period of 36 years was more consistent in all the treatments except in the plots receiving Zn and FYM in combination with NPK. The continuous use of Zn for 36 years in the presence of NPK increased the DTPA extractable Zn to 5.68 mg kg^{-1} compared to its initial status of 1.9 mg kg^{-1} in 1972. The decline in Zn on the other hand was highest in the plots where manual weeding was practiced being at par with the plots receiving 50% NPK. Consistent increase as a result of continuous manuring and fertilization for thirty-six years was observed in the DTPA extractable Cu. The initial content of DTPA extractable Cu was 0.4 mg kg^{-1} at the inception of this long-term experiment. The increase in its content in the plots treated with different levels and combinations and amendments ranged from 1.93 (100% NPK+Zn) to as high as 2.38 mg kg^{-1} (100% NPK+FYM) after thirty-six years of cropping (Table 1). There was consistent declining trend in DTPA extractable Fe, Mn, Zn and Cu in the sub-surface soils in comparison to their status in the surface layers.

Change in soil pH appears to be primarily responsible for such observed variation in the content of available soil micronutrients. Results suggest that liming acid soils with balanced chemical fertilizer use can sustain high crop productivity with favourable soil environment and regular use of lime with balanced NPK use in acidic soils has a favourable effect on availability of secondary and micronutrients in acid soil (Singh et al., 2009). Higher availability in FYM treated plots may be due to formation of organic chelates, which decreased their susceptibility to adsorption, fixation and precipitation resulting in their enhanced availability in soil. Hodgson (1963) found that the addition of organic matter to soil encouraged microorganisms, which under certain conditions aided in the liberation of trace elements.

Marginally higher DTPA-Fe under treatments with low pH was due to solubilsation of soil Fe under such condition. However, situation was not same in case of Mn as it requires a little higher pH than Fe. The increase in DTPA-Zn in Zn and FYM treated plots may be due to application of Zn in former while in latter due to mineralization of organically bound forms of Zn in the FYM and also possible addition of zinc as impurity through superphosphate as it might result in the formation of organic chelates of higher stability, because Zn is known to form relatively stable chelates with organic ligands which decrease their susceptibility to adsorption, fixation and/or precipitation. FYM also contains zinc which might have also contributed to its enhanced availability in soil. Build-up of available Cu was observed with the application of FYM which may be due to the fact that Cu forms Cu-humus complex of relatively high stability with humus that decrease its susceptibility to fixation or precipitation in soil. Less removal of micronutrients in graded doses of fertilizers is due to its presence in superphosphate as one of the other constituents/impurities. Lower contents of DTPA-extractable micronutrients in lime treated plots may be due to their conversion to insoluble forms as pH increased. The results are in confirmation to the findings of Kher (1993); Sudhir et al. (2002); Behera and Singh (2009).

The levels of DTPA extractable Fe, Mn, Zn and Cu were much higher than their critical levels even after 36 years of cropping in all the treatments. The availability of these micronutrient cations is thus not going to be the limiting factor despite their fairly high removal by the crops under different set of fertilizer treatments. The steady supply of micronutrients in the soils is due to acidic soil environment favouring solublisation of these nutrients.

3.3. Uptake of micronutrients by crops

The yields of maize and wheat crops during 36^{th} cropping cycle are given in Table 2. Continuous application of 100% N alone (T_2) through urea for the last 36 years reduced the yield to 0.0 t ha^{-1} in both the crops. A number of workers working in AICRP LTFE reported complete degradation of soils in plots treated with nitrogen alone over a period of time and thereby resulting in zero yields. It is ascribed to sharp decline in pH that triggered the process of land degradation by increasing the concentration of Al and Fe ions to toxic levels as reported by Dutta et al. (2015) under same set of management practices rendering the soil completely unsuitable for crop growth. Among rest of the treatments the grain and stover/straw yield of maize and wheat was lowest in control (T_1) while highest in 100% NPK+FYM (T_5). These two treatments differed significantly from rest of the treatments except 100% NPK+lime (T_6) being at par with T_5. The plots where Zn was applied along with 100% NPK (T_7) and in plots where HW (T_8) was practiced, yields were found to be at par with 100% NPK alone. The addition of P in combination with N showed marked increase in maize and wheat productivity over N alone and control treatment. However, the continued absence of K and S in crop nutrition led to drastic decline in the crop yield. The yield of maize and wheat in NP and NPK(-S) treated plots was significantly lower than the plots receiving 100% NPK during the last 36 years. The MEY was also highest in the plots treated with FYM followed by lime treated plots. This highlights the importance of integrated nutrient management and balanced

Table 2: Effect of 36 years cropping and fertilizer use on yield (t ha^{-1}) and micronutrient uptake (g ha^{-1}) by the annual cropping cycle of maize-wheat rotation

Treat-ment	MGY	WGY	Maize yield		Wheat yield		MEY	Maize				Wheat			
			G	S	G	S		Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1	0.35	1.01	0.49	1.29	0.39	1.07	0.99	62.9	17.4	11.5	20.1	197.4	112.2	44.1	69.4
T_2	2.98	2.27	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_3	4.33	3.81	1.09	2.56	1.10	2.67	2.51	208.0	127.5	66.2	75.9	513.8	318.6	125.1	197.2
T_4	4.16	3.93	2.73	5.78	1.93	4.36	5.21	1457.2	446.0	335.1	406.2	1146.9	704.4	281.9	358.6
T_5	5.57	4.30	4.34	9.56	3.12	6.58	8.35	2223.1	986.6	674.5	715.8	1473.2	956.1	395.0	586.0
T_6	4.92	4.19	4.00	9.24	2.86	6.02	7.67	2106.6	558.3	701.5	634.9	1335.0	789.6	273.8	503.5
T_7	4.52	4.10	2.46	5.82	1.85	4.27	4.83	860.7	510.5	469.1	437.9	872.4	576.2	253.7	378.9
T_8	4.18	5.12	2.81	6.42	2.05	4.87	5.44	1225.6	660.4	440.5	424.9	1000.4	782.0	274.7	382.0
T_9	0.0	0.0	0.91	2.18	1.33	2.73	2.62	254.7	53.3	58.1	65.1	528.5	316.7	159.6	190.7
T_{10}	6.32	4.77	2.56	5.67	1.73	4.09	4.79	1321.1	330.7	348.6	405.0	983.3	494.8	220.2	341.6
T_{11}	1.98	2.66	1.60	3.80	1.52	3.38	3.56	980.2	217.7	166.9	228.2	947.4	392.9	171.2	249.8
SEm±	0.62	0.53	0.42	0.93	0.28	0.59	0.72	236.57	93.82	77.31	75.06	138.68	90.31	34.57	53.03
CD	0.86	0.74	0.35	0.82	0.29	0.80	0.92	153.38	84.55	56.77	56.55	187.16	106.32	48.43	64.42

MGY: Maize grain yield 1972; WGY: Wheat grain yield 1972; G: Grain; S: Stover; MEY: Maize equiv. yield (MEY); T_1: Control; T_2: 100% N; T_3: 100% NP; T_4: 100% NPK; T_5: 100% NPK+FYM; T_6: 100% NPK+lime; T_7: 100% NPK+Zn; T_8: 100% NPK+HW; T_9: 100% NPK(-S); T_{10}: 150% NPK; T_{11}: 50% NPK; CD: CD (p=0.05)

fertilization as well as proper amendment of soil for better crop production. The total uptake of Fe by maize (2223.1 g ha^{-1}) and wheat (1473.2 g ha^{-1}) was highest under 100% NPK+FYM treatment and it was at par with that under 100% NPK+lime treatment. As compared to control, total uptake of Fe by both the crops was significantly higher in plots receiving fertilizers (Table 2). Continuous removal of nutrients from the soil in the form of crop yield in control plots and the absence of nutrients' addition from any external source resulted in lowest yield as well as Fe uptake by the crops The significant increase in Fe uptake with the application of recommended dose of NPK may be attributed to the better availability of these nutrients due to direct supply and because of proliferous root system developed under balanced nutrient application resulting in better absorption of water and nutrients. Also that Fe is present in P fertilizers as impurities. Higher uptake values in manual weeding, Zn and lime amended plots might be due to the high crop growth. The increased uptake in FYM plots may be ascribed to improvement in soil environment which encourages proliferation of roots which, in turn, draw more water and nutrients from larger area and greater depth. Moreover, organic manures after decomposition release micronutrients which after becoming available are easily taken up by the plants.

Uptake of Mn varied from 17.4-986.6 g ha^{-1} in maize and from 112.2-956.1 g ha^{-1} in wheat crop. The highest uptake being in FYM treated plots (T_5) and the lowest being in the control plots (Table 2). Similarly the uptake of Zn by crops varied from 11.5-701.5 g ha^{-1} in maize crop and from 44.1-395.0 g ha^{-1} in wheat crop. The highest uptake of Zn in maize crop was under 100% NPK+lime treatment followed by 100% NPK+FYM, both being at par and significantly higher than rest of the treatments. However, the highest Zn uptake in case of wheat crop was observed under 100% NPK+FYM treated plots. In both the crops the uptake of Zn was lowest in control plots. Uptake of Cu increased with the application of balanced doses of NPK. Cu uptake was significantly higher in 100% NPK+FYM treated plots in both the crops as compared to rest of the treatments. Control plots showed lowest Cu uptake. Results are in conformity with the findings of Behera and Singh (2009). Complete degradation of soil due to continuous use of 100% N alone has led to decline in productivity of both the crops. Therefore, nutrients' uptake in both the crops was zero in 100% N treated plots. The increased uptake in rest of the treatments over control was due to increased level of nutrition resulting in increased productivity level of both the crops. Low N uptake in control plots is due to lower yields because of poor inherent fertility status of these plots. In 100% NPK (-S) plots, the yield was low due to S deficiency, so the uptake was also low. Among graded doses of fertilizers, application of NPK at higher level registered higher uptake by the crop due to more addition of nutrients and high mineralization potential which makes nutrient readily available for plant growth as the uptake followed the yield pattern. The increase in the uptake in FYM amended plots could be attributed to the fact that organic manures after decomposition release micronutrient cations, which after becoming available for plant use increase their uptake. Further, the higher total uptake in crops has been mainly due to increased biomass produced rather than per cent content in grain and stover/straw, the latter being generally unaffected by the fertilizer treatments in this study.

4. Conclusion

Continuous use of imbalanced inorganic fertilizers resulted in reduced crop yields and nutrient uptakes. Application of 100% N alone caused complete crop failure and loss of productivity, while omission of K also reduced the yields significantly. Balanced application of NPK fertilizers with FYM and lime improved soil quality, sustained crop productivity and availability of micro and secondary nutrients. Application of N alone for 36 years had the most deleterious effect on soil properties and the crop productivity leading to complete failure of crops. Further, after 36 years of continuous cropping and fertilization the levels of DTPA extractable Fe, Mn, Zn and Cu were much higher than their critical levels.

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