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Dharmendra Singh
Department of Soil Science, CSKHPKV, Palampur, H.P, India

RP Sharma
Department of Soil Science, CSKHPKV, Palampur, H.P, India

NK Sankhyan
Department of Soil Science, CSKHPKV, Palampur, H.P, India

SC Meena
Department of agriculture chemistry and soil science, MPUAT, Udaipur, Rajasthan, India

Correspondence
Dharmendra Singh
Department of Soil Science, CSKHPKV, Palampur, H.P, India

Influence of long-term application of chemical fertilizers and soil amendments on physico-chemical soil quality indicators and crop yield under maize-wheat cropping system in an acid alfisol

Dharmendra Singh, RP Sharma, NK Sankhyan and SC Meena

Abstract

The present investigation was undertaken in the ongoing long-term fertilizer experiment initiated during 1972 at experimental farm of Department of Soil Science, CSK HPKV, Palampur with eleven treatments replicated three times. The soil of the experimental site was silty loam and classified taxonomically as "Typic Hapludalf". Continuous application of balanced chemical fertilizers either alone or in combination with FYM or lime for forty two years significantly improved available N, P and K, total carbon (C_T) and labile carbon (C_L) as compared to control and unbalanced use of fertilizers at both the surface and sub surface layers. While, 100 per cent N and zero fertilization led to decline in C_T and C_L as compared to buffer plot. Application of 100 per cent NPK + FYM was more effective for increasing available N, P, K, C_T and C_L as compared to application of chemical fertilizers alone. Highest productivity of maize and wheat was recorded in the treatment comprising 100 per cent NPK + FYM. The productivity of both the crops recorded under 100 per cent NPK + lime was at par with 100 per cent NPK + FYM. Continuous use of urea alone had most deleterious effect on soil properties and productivity of both the crops. Total carbon, labile carbon available N, P, K and CEC were found to be positively and significantly correlated with total yields of both the crops and negatively and significantly correlated with bulk density.

Keywords: Farmyard manure, Labile carbon, Total organic carbon

Introduction

Soil health is a key factor for increasing agricultural production. Overdependence on high analysis fertilizers has encouraged the process of land degradation. Consequently, most of the productive soils are becoming unproductive. Contribution of chemical fertilizers towards an increase in agricultural production is well known. But their injudicious use exhibits a detrimental effect on soil health. Continuous cropping and long-term fertilization are liable to change soil properties and crop productivity, depending upon the type of management practices. Maize-wheat is the most important cropping system of Himachal Pradesh. The area under maize and wheat in the state was 292.14 and 371.06 thousand hectares, respectively (Anonymous 2013-14). A major share of the food grain production in the state comes from these two crops forming about 85 per cent of the total food production. Therefore, enhancing the performance of this important cropping sequence is needed for improving agricultural scenario in Himachal Pradesh. Productivity of both maize and wheat is low in the country owing to poor soil fertility and inadequate, imbalanced and inefficient use of fertilizers in these nutrient exhaustive crops (Yadav *et al*. 2005) [26].

Single or short-term fertilizer experiments, however, only give a partial picture of yield sustainability and crop responses to the use of various inputs. Therefore, the adoption of integrated nutrient management and continuous cropping system has become the need of hour for enhancing soil quality and crop productivity from food security point of view in Indian agriculture. The long-term field experiments (LTFE) on the other hand, provide means to evaluate sustainability and environmental impact of subsistence soil quality. Hence, in the present investigation, the study on the effect of chemical fertilizers and amendments on crop yields under maize-wheat cropping system was undertaken.

Materials and methods

The present investigation was carried out in the ongoing long-term fertilizer experiment initiated during at the experimental farm of Department of Soil Science, CSK HPKV, Palampur $31^0 6$/N, $76^0 3$/E, 1290 m above the mean sea level.

The climate of the study area was wet temperate zone with annual rainfall of 2500-3000 mm as received during the wet season (June-September). The mean maximum temperature remains about 31^0C during the hottest months of May to June. December to February are the coldest months with minimum temperature of about 5^0C. The soil of the experimental site was silty loam and classified taxonomically as “Typic Hapludalf.” At the initiation of the experiment, soil of the experimental field was having pH 5.8, organic carbon 7.9 g kg^{-1}, available N 736, available P 12, and available K 194 kg ha^{-1}, respectively. The 11 treatments with three replications in a randomized block design with $15m^2$ plot for each treatment 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. Due to marked buildup of available P, the original treatment structure was slightly modified from kharif 2011, optimal and superoptimal doses of P were reduced by 50%, and in case of 50% NPK, addition of FYM @ 5 t ha^{-1} on dry weight basis to maize crop only was also included. The 100% NPK dose is 120, 60, and 40 and 120, 60, and 30 kg/ha N, P, and K for maize and wheat, respectively. Half dose of N and full dose of P and K were applied at the time of sowing in both the crops. The remaining half nitrogen was top dressed in two equal splits at maximum tillering and flowering stage of wheat and knee high and pre-tasseling stages in maize crop, respectively. The sources of N, P, and K were urea, single superphosphate (SSP), and muriate of potash (MOP), respectively. In 100% NPK (-S), P was applied through diammonium phosphate (DAP) to assess the effect of “S” free high analysis P fertilizer in crop production. Zinc was applied in T_5 as zinc sulfate @ 25 kg ha^{-1} every year to both the crops till rabi 2010-2011. FYM application was made @ 10 t ha^{-1} on fresh weight basis to maize crop only, which corresponds to the practice being followed by the farmers of the region. The FYM applied contained 60% moisture; and its average nutrient content on dry weight basis was 1.01, 0.26, and 0.40% of N, P, and K, respectively. Lime was added in T_{10} @ 900 kg ha^{-1} as marketable lime calcium carbonate ($CaCO_3$) passed through 100 mesh sieve to maize crop only.

Soil samples collected from a depth of 0-0.15 m and 0.15-0.30 m after the harvest of maize (2013) and wheat (2013-14) were used for determination of various chemical parameters. Three composite soil samples from both the depths were also drawn from adjacent buffer plots. The processed soil samples were analyzed for total carbon (C_T) labile carbon (C_L), pH, CEC, available N, P, K, and bulk density was determined by core method taken from undisturbed soil after harvesting of maize and wheat. Total carbon was determined by loss on ignition method outlined by Ben-Dor and Banin (1989) [3]. Labile carbon was measured by the Alkaline $KMnO_4$ oxidation method given by Weil *et al*. (2003) [25], a modified method from Blair *et al*. (1995) [7]. The soil pH was determined by 1:2.5 (soil:water) suspension using glass electrode pH meter method given by Jackson (1967) [11]. The CEC of soil was determined by Neutral normal ammonium acetate extraction method given by Jackson (1967) [11]. Available N, P and K was determined by alkaline permanganate method outlined by Subbiah and Asija (1956) [23], 0.5M $NaHCO_3$ (pH 8.5) extraction method Olsen *et al*. (1954) [18] and neutral normal ammonium acetate extraction method Jackson (1967) [11], respectively. After the harvest of the crops at maturity, grain and straw yields were recorded separately. Grain yield of maize was standardized at twelve 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. Relationship of total carbon, labile carbon, Available N, P, K, pH and CEC with yield of maize and wheat crops was worked out by computing simple correlation coefficients by employing standard procedure as described by Gomez and Gomez (1984) [9].

Results and discussion

Bulk Density

Application of balanced fertilizers alone or in combination with organics decreased bulk density of soil significantly over control and the extent of reduction was more when FYM were applied along with chemical fertilizers in both maize and wheat crops which may be due to the addition of organic matter that resulted in increase in pore space and good soil aggregation (Singh *et al*. 2014) [21]. The highest value of bulk density (1.40 Mg m^{-3}) was recorded in T_7 treatment which was significantly higher compared to other treatments may be due to low organic matter content in soil and formation of compact layer. Comparison of different fertilizer treatments with control revealed that there was a general decrease in the bulk density of soil except 100% N. Bulk density of soil increased with increasing soil depth after harvest of both maize and wheat crops.

Soil pH

Continuous cropping and fertilizer use over the years reduced the soil pH, except the treatment involving use of lime (100% NPK + lime) compared to the initial soil pH value of 5.8. The effect of different treatments on soil pH was found to be significant. The continuous use of N alone (T_7) led to substantial decrease in pH (4.48) after forty two cropping cycles of maize (Table 1). Decline in soil pH with the application of N alone could also be attributed to acid producing nature of urea as nitrogenous fertilizer (Magdoff *et al*. 1997) [14] which upon nitrification releases H^+ ions which are potential sources of soil acidity. The use of lime in combination with NPK increased the soil pH to near neutrality by raising the pH from the initial value of 5.8 to 6.30 after harvest of maize. The ameliorating effect of lime on soil acidity has been recorded by Obiri-Nyarko (2012) [17]. Continuous addition of FYM along with NPK also increased the soil pH as compared to the use of NPK alone (Sharma *et al*. 2013) [19]. In both surface and sub-surface soil layers, the soil pH value after harvesting of wheat either increased slightly or maintained in all treatments as compared to soil pH after harvesting of maize.

Table 1: Effect of long-term use of chemical fertilizer and amendments on bulk density (Mg m^{-3}), pH and cation exchange capacity {c mol (p^+) kg^{-1}} after harvesting of maize (2013) and wheat (2013-14)

Treatments	After maize			After wheat		
	BD	pH	CEC	BD	pH	CEC
	Soil depth (0-0.15 m)					
T_1: 50% NPK	1.25	5.24	9.6	1.25	5.28	9.9
T_2: 100% NPK	1.23	5.17	10.5	1.22	5.20	10.8
T_3: 150% NPK	1.24	4.76	10.4	1.23	4.81	10.6

T_4: 100% NPK+ HW	1.20	5.21	11.2	1.20	5.23	11.3
T_5: 100% NPK+ Zn	1.23	5.11	10.2	1.23	5.13	10.3
T_6: 100% NP	1.26	5.09	10.0	1.27	5.08	9.5
T_7: 100% N	1.40	4.48	6.6	1.40	4.49	6.8
T_8: 100% NPK+ FYM	1.14	5.35	12.4	1.13	5.39	12.8
T_9: 100% NPK (-S)	1.25	5.04	9.6	1.24	5.10	10.0
T_{10}: 100% NPK+ lime	1.22	6.30	12.2	1.22	6.33	12.3
T_{11}: Control	1.34	5.69	8.6	1.33	5.72	8.4
Initial	1.31	5.8	12.1	-	-	-
CD (P= 0.05)	0.04	0.18	0.85	0.05	0.13	1.22
	Soil depth (0.15-0.30 m)					
T_1: 50% NPK	1.27	5.20	8.8	1.28	5.15	9.0
T_2: 100% NPK	1.26	5.10	9.7	1.25	4.97	9.5
T_3: 150% NPK	1.26	4.80	9.0	1.25	4.88	9.1
T_4: 100% NPK+ HW	1.23	5.20	9.6	1.24	5.18	9.7
T_5: 100% NPK+ Zn	1.25	5.00	9.4	1.26	5.14	8.2
T_6: 100% NP	1.28	5.13	7.3	1.28	5.07	7.7
T_7: 100% N	1.41	4.60	5.9	1.42	4.48	5.7
T_8: 100% NPK+ FYM	1.17	5.27	11.0	1.17	5.30	11.1
T_9: 100% NPK (-S)	1.27	5.13	8.6	1.26	5.04	8.5
T_{10}: 100% NPK+ lime	1.24	6.20	10.3	1.25	6.21	10.7
T_{11}: Control	1.36	5.53	7.1	1.36	5.64	6.8
Initial	-	-	-	-	-	-
CD (P= 0.05)	0.04	0.31	0.87	0.04	0.21	1.04

Cation Exchange Capacity

The results revealed that the values of CEC declined in all the treatments except 100 per cent NPK + FYM and 100 per cent NPK + lime as compared to initial value of 12.1 c mol (p^+) kg^{-1} (Table 1). Application of balanced chemical fertilizers either alone or in combination with FYM increased the CEC of the soil significantly over the control (T_{11}) after harvest of both maize and wheat. At both surface and sub-surface soil layers, the values of CEC after harvesting of wheat either increased marginally or maintained in all treatments as compared to the value after harvesting of maize. It is pertinent to mention here that there was a decrease in CEC with increase in depth in both the crops. The decrease in CEC value of soil of the present experiment therefore, may be attributed to the acidifying effect of fertilizers leading to reduction in pH values under almost all the treatments and markedly in 100 per cent N treated plots. The value of CEC was higher in 100 per cent NPK + FYM treated plots which might be attributed to higher organic colloids in these plots. Similar findings were reported by Jagdeshwari *et al*. (2001) [12].

Available nitrogen

The continuous manuring and cropping for forty two years showed noticeable decline in available N content of soils in all the treatments as compared to initial value (Table 2). Such losses of added fertilizer N over the years might be due to leaching under high rainfall conditions or the schedule of N application perhaps not coinciding with the crop demands (Kumar and Yadav 2005) [26]. It is evident from the data that the application of 100 per cent NPK + FYM recorded significantly higher available N content over treatments receiving optimal dose of fertilizer and super optimal dose of fertilizer. These results confirm the findings of Bhandari *et al*. (2002) [4]. There was a decrease in available N content with the increase in soil depth in both the crops. Lower content of available N in sub-surface layer might be due to less accumulation of organic matter in this layer.

Available phosphorus

The application of either balanced chemical fertilizer alone or in combination with FYM or lime recorded an increase in the available phosphorus content of soil over control. The continuous use of graded doses of NPK at the rate of 50,100 and 150 per cent of its recommended level increased the soil available phosphorus content significantly over untreated plots with the values of 46.3, 95.5 and 175.9 kg ha^{-1}, respectively after harvest of maize. Build-up of available P with continuous use of phosphatic fertilizers is in agreement with the findings of Subehia *et al*. (2005) [24]. Use of 100% NP over 100% N significantly increased the available P status of soil.

Table 2: Effect of long-term use of chemical fertilizers and amendments on available nitrogen (N), available phosphorus (P) and available K (kg ha^{-1}) after harvesting of maize (2013) and wheat (2013-14)

Treatments	After maize			After wheat		
	N	P	K	N	P	K
	Soil depth (0-0.15 m)					
T_1: 50% NPK	324.1	46.3	140.0	324.1	47.5	142.7
T_2: 100% NPK	335.3	95.5	158.7	339.7	98.7	157.4
T_3: 150% NPK	355.4	175.9	182.9	365.9	182.0	187.4
T_4: 100% NPK+ HW	339.7	99.3	149.3	345.0	100.8	150.2
T_5: 100% NPK+ Zn	339.7	105.0	158.7	350.2	106.6	154.2
T_6: 100% NP	329.3	118.6	126.6	334.5	120.6	125.1
T_7: 100% N	334.5	8.4	132.5	345.0	7.9	131.3
T_8: 100% NPK+ FYM	376.3	164.5	191.1	381.5	168.8	195.9
T_9: 100% NPK (-S)	345.0	118.9	169.9	355.4	119.8	173.8
T_{10}: 100% NPK+ lime	325.5	123.4	165.2	330.0	124.6	169.0

T_{11}: Control	266.6	7.8	112.2	261.3	7.3	111.6
Initial	736	12.0	194.2	-	-	-
CD (P= 0.05)	29.74	8.0	22.53	19.96	9.09	4.48
Soil depth (0.15-0.30 m)						
T_1: 50% NPK	235.6	34.5	129.3	236.6	35.1	131.4
T_2: 100% NPK	258.8	89.6	139.3	260.1	88.8	142.6
T_3: 150% NPK	283.4	159.1	170.3	286.0	160.1	173.1
T_4: 100% NPK+ HW	262.3	86.1	141.4	265.0	87.0	140.0
T_5: 100% NPK+ Zn	252.0	88.3	134.8	253.6	90.0	135.9
T_6: 100% NP	260.0	102.8	110.2	262.0	104.0	113.5
T_7: 100% N	258.2	6.4	102.1	261.7	6.0	105.2
T_8: 100% NPK+ FYM	305.1	143.5	172.2	309.2	147.3	173.2
T_9: 100% NPK (-S)	254.5	105.3	155.2	258.9	106.6	156.8
T_{10}: 100% NPK+ lime	257.4	107.3	148.2	262.5	108.5	150.8
T_{11}: Control	192.3	6.8	105.2	189.0	6.5	104.5
Initial	-	-	-	-	-	-
CD (P= 0.05)	7.76	3.05	7.0	4.79	4.75	11.95

Compared to initial status, the available P content decreased in the control (T_{11}) and 100 per cent N (T_7) treated plots where application of P was omitted. Available phosphorus content decreased with increase in soil depth. In sub-surface layer, the available phosphorus content of the soil followed almost similar trend as that found in the surface layer.

Available potassioum

A deep insight into the data revealed that the available K declined in almost all the treatments except 100 per cent NPK + FYM as compared to its initial status of 194.2 kg ha^{-1} (Table 2). The reduction in available K content was much higher in the plots where potassium was not added (T_6, T_7 and T_{11}) than the plots which received balanced fertilizer (i.e. 100% NPK). Continuous application of 100 per cent NPK + FYM and 150 per cent NPK was significantly higher over 100 per cent NPK. Application of FYM with 100 per cent NPK has resulted to higher available K content which might be ascribed to additional supply of potassium through FYM. The increase in soil pH due to the application of lime is also responsible for the increase in K content in soil (Chimdi *et al*. 2012) [8]. There was a decrease in available K content with the increase in soil depth in both the crops.

Total carbon

Application of 100 per cent NPK + FYM (T_8) recorded significantly higher total carbon as compared to other treatments. The higher total carbon under this treatment can be attributed to addition of carbon through FYM and root biomass/crop residues. The effect of fertilizers application (100% NPK) with or without organic manure (FYM) was significant over control in surface soil layer. This could be attributed to the increase in root biomass in the soil due to easy availability of nutrients (Bhardwaj *et al*. 1994) [5]. The total carbon content improved in almost all the treatments except 100 per cent N, 100 per cent NP and control plots as compared to its content in the buffer plot (Table 3). However, increase in total carbon was more in surface as compared to sub-surface soil, which indicated higher accumulation of carbon in surface soil.

Labile carbon

The results revealed that balanced application of fertilizers either alone or with amendments recorded higher labile carbon content than that in unbalanced fertilization (100% N and 100% NP) in surface and sub-surface soil layer after harvest of both the crops. The labile carbon ranged from 4.2 to 6.4 per cent of total carbon in surface soil layer after harvest of wheat. Highest labile carbon content in both the crops were recorded with the application of 100 per cent NPK + FYM (Table 3) and this treatment was significantly higher as compared to other treatments. This may be due to the addition of carbon through FYM as well as higher turn-over of root biomass because of better growth and yield of maize and wheat crop under combined application of NPK + FYM. Similar findings were reported by Bhattacharyya *et al*. (2011) [6]. The treatments of inorganic fertilizer application except 100 per cent N (T_7) also registered significant increase in labile carbon over control plot in both the crops. The higher labile carbon content was observed at surface layer in comparison to sub-surface layer which may be attributed to relatively more incorporation of crop residue and higher microbial activity in surface layer.

Table 3: Effect of long-term use of chemical fertilizers and amendments on total carbon (g kg^{-1}) and labile carbon (g kg^{-1}) after harvesting of maize (2013) and wheat (2013-14)

Treatments	After maize		After wheat	
	Total carbon	Labile carbon	Total carbon	Labile carbon
	Soil depth (0-0.15 m)			
T_1: 50% NPK	25.23	1.30	25.33	1.33
T_2: 100% NPK	27.03	1.43	27.30	1.45
T_3: 150% NPK	28.06	1.52	28.23	1.56
T_4: 100% NPK+ HW	27.55	1.47	27.70	1.49
T_5: 100% NPK+ Zn	27.00	1.43	27.20	1.45
T_6: 100% NP	20.31	1.10	20.31	1.12
T_7: 100% N	16.83	0.70	16.93	0.70
T_8: 100% NPK+ FYM	31.80	1.99	32.27	2.06
T_9: 100% NPK (-S)	27.20	1.45	27.30	1.47
T_{10}: 100% NPK+ lime	28.70	1.61	28.83	1.65
T_{11}: Control	18.78	0.85	18.83	0.85

Buffer plot	24.50	1.05	-	-
CD (P= 0.05)	2.02	0.13	2.06	0.09
Soil depth (0.15-0.30 m)				
T_1: 50% NPK	15.83	0.71	15.83	0.72
T_2: 100% NPK	17.00	0.87	17.10	0.81
T_3: 150% NPK	17.83	0.91	17.97	0.94
T_4: 100% NPK+ HW	17.50	0.89	17.65	0.91
T_5: 100% NPK+ Zn	17.37	0.87	17.47	0.89
T_6: 100% NP	15.17	0.67	15.17	0.67
T_7: 100% N	12.97	0.40	13.00	0.40
T_8: 100% NPK+ FYM	21.67	1.14	22.33	1.19
T_9: 100% NPK (-S)	16.90	0.87	16.90	0.88
T_{10}: 100% NPK+ lime	18.13	0.94	18.13	0.96
T_{11}: Control	14.63	0.49	14.70	0.49
Buffer plot	15.00	0.65	-	-
CD (P= 0.05)	1.04	0.11	1.31	0.09

Effect of chemical fertilizers and amendments on productivity of maize

The results revealed that the grain yield of maize (2013-14) was highest in 100% NPK + FYM (55.2 q ha^{-1}), which was significantly superior to rest of the treatments except 100% NPK + lime (54.5 q ha^{-1}) being at par. Compared to 100% NPK, the application of 100% NPK + FYM recorded 30.8 and 30.2% higher grain and stover yield of maize, respectively. Continuous application of N alone through urea for 42 years, the grain yield of maize in 100% N (T_2) had declined to 0.0 q ha^{-1} (Table 4). This might be due to increased soil acidity and deteriorated soil quality with the continuous use of N over a period of 42 years. Application of FYM along with recommended doses of fertilizers increased the maize productivity to the maximum level, which might be due to the improvement in soil health and release of organic acids that bind aluminum (Al) and iron (Fe), thereby reducing P fixation and increasing its availability (Manjhi *et al*. 2014) [16]. Application of 100% NPK + lime also increased the productivity of maize, which might be attributed to ameliorating effect of lime.

Table 4: Effect of long-term use of fertilizers and amendments on grain and straw/stover yield of maize and wheat crops.

Treatments	Maize (q ha^{-1})			Wheat (q ha^{-1})		
	Grain	Stover	Biological	Grain	Straw	Biological
T_1: 50% NPK	33.8	59.4	93.2	17.1	32.0	49.1
T_2: 100% NPK	42.2	75.1	117.3	21.2	38.1	59.3
T_3: 150% NPK	39.0	69.1	108.1	18.8	36.8	55.6
T_4: 100% NPK+ HW	44.0	78.1	122.1	22.1	40.1	62.2
T_5: 100% NPK+ Zn	37.4	68.4	105.8	20.3	37.4	57.8
T_6: 100% NP	21.2	37.3	58.6	13.0	23.5	36.5
T_7: 100% N	0.0	0.0	0.0	0.0	0.0	0.0
T_8: 100% NPK+ FYM	55.2	97.8	153.0	36.6	65.2	101.8
T_9: 100% NPK (-S)	17.9	34.0	51.9	12.3	23.9	36.2
T_{10}: 100% NPK+ lime	54.5	95.4	149.9	32.1	61.2	93.3
T_{11}: Control	8.4	17.0	25.4	4.6	9.2	13.8
Buffer plot	5.28	7.31	12.41	3.99	6.86	10.78
CD	33.8	59.4	93.2	17.1	32.0	49.1

Effect of chemical fertilizers and amendments on productivity of wheat

Continuous application of N alone through urea for 42 years, the grain yield of wheat in 100% N (T_2) had declined to 0.0 q ha^{-1} (Table 4). Among rest of the treatments, the grain and straw yield of wheat was highest in 100% NPK + FYM (36.6 q ha^{-1}), which was significantly superior to rest of the treatments except 100% NPK + lime (32.1 q ha^{-1}) being at par. Increase in grain and straw yields of wheat in 100% NPK (T_2) over 100% NPK without sulfur treatment (T_9) may be due to the supply of sulfur through SSP in T_2. Singh *et al*. (2014) [22] also reported increase in the yield of wheat crop due to addition of sulfur fertilizers. Increase in wheat grain and straw yields in 100% NPK + lime-treated plots might be ascribed to the higher nutrient availability due to ameliorating effect of lime. Singh *et al*. (2009) [20] have also recorded similar effect of lime application on productivity of wheat. Highest yield in T_8 may be due to addition of FYM which besides supplying all the essential nutrients might have also improved the physico-chemical properties of the soil.

Relationship between different physico-chemical properties of soil and productivity of maize and wheat

The entire data collected from each treatment, depth and replication were pooled together to compute the correlations among different physico-chemical properties and productivity of maize and wheat. Computing relationships with maize and wheat yield, as an independent variable showed positively and significantly correlated with pH, CEC, available N, P, K, total carbon and labile carbon in both surface and sub-surface soil layer. On the contrary, bulk density significantly and negatively correlated with maize and wheat yield in both the surface and sub-surface soil. A negative correlation between bulk density and yield has been reported earlier by Aragon *et al*. (2000) [2]. All the negative correlations were stronger in surface than in sub-surface soil depths. In the present study, maize and wheat yield was found highly correlated with labile carbon with respective values of coefficient of correlation ‘r’ 0.882, and 0.916 in surface layer and 0.869 and 0.880 in sub-surface layer, respectively. Mandal *et al*. (2013) [15] also observed significant and positive relationship of wheat yield with labile carbon and total carbon in surface soil.

Table 5: Correlation coefficients between bulk density (BD; Mg m^{-3}), pH, CEC {c mol (p$^+$) kg^{-1}}, available N, P, K (kg ha^{-1}), total carbon (C_T; g kg^{-1}) and labile carbon (C_L; g kg^{-1}) with yield of maize and wheat (q ha^{-1}) in both surface and sub-surface layer

Yield	BD	pH	CEC	N	P	K	C_T	C_L
Soil depth (0-0.15 m)								
Maize	-0.839	0.462	0.813	0.460	0.697	0.678	0.877	0.882
Wheat	-0.843	0.525	0.815	0.478	0.723	0.726	0.858	0.916
Soil depth (0.15-0.30 m)								
Maize	-0.825	0.399	0.834	0.541	0.682	0.736	0.837	0.869
Wheat	-0.804	0.497	0.814	0.591	0.709	0.726	0.864	0.880

Conclusion

Long-term application of chemical fertilizers alone or in combination with amendments decreased the bulk density of soil significantly over control and the extent of reduction was more when FYM was applied along with chemical fertilizers. Continuous application of urea as a source of N for a period of 42 years has resulted in acidification of soils while lime application increased the pH in the surface and subsurface soil. The highest available total carbon, labile carbon, available N and K content was recorded under 100 per cent NPK + FYM treatment (T_8) while available P content was recorded under 150 percent NPK (T_3) treatments in both surface and sub-surface layer after harvesting of maize and wheat crop. Balanced application of NPK showed higher available N, P and K, total carbon and labile carbon than the unbalanced use of fertilizers. Highest productivity of maize and wheat was recorded in the treatment comprising 100 per cent NPK + FYM. The yield of maize and wheat were significantly and positively correlated with soil pH, CEC, available N, P and K, total carbon and labile carbon and significantly and negatively correlated with bulk density of soil.

References

1. Anonymous. Statistical Outline of Himachal Pradesh, Directorate of Economics and Statistics, Shimla, Himachal Pradesh, 2013-14.
2. Aragon A, Garcia MG, Filgueira RR, Pachepsky YA. Maximum compactibility of Argentine soils from the Proctor test: the relationship with organic carbon and water content. Soil and Tillage Research. 2000; 56:197-204.
3. Ben-Dor E, Banin A. Determination of organic matter content in arid zone soils using a simple Loss on Ignition method. Communications in Soil Science and Plant Analysis. 1989; 20:1675-1695.
4. Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK. Yield and soil and nutrient changes in a long-term rice-wheat rotation in India. Soil Science Society of America Journal. 2002; 66:162-170.
5. Bharadwaj V, Bansal SK, Maheshwari SC, Omanwar PK. Long-term effect of continuous rotational cropping and fertilization on crop yield and soil properties changes in the fraction of N, P & K. Journal of the Indian Society of Soil Science. 1994; 42: 392-397.
6. Bhattacharyya R, Kundu S, Kumar A, Gupta HS, Prakash V, Bhatt JC. Long-term fertilization effects on soil organic carbon pools in a sandy loam soil of the Indian sub-Himalayas. Plant Soil. 2011; 341:109-124.
7. Blair GJ, Lefroy RDB, Lisle L. Soil carbon fractions based on their degree of oxidation and the development of CMI for agricultural systems. Australian Journal of Agricultural Research. 1995; 46:1459-1466.
8. Chimdi A, Gebrekidan V, Kibret K, Tadesse A. Effects of liming on acidity related chemical properties of soils of different land use systems in Western Oromia, Ethiopia. World Journal of Agricultural Sciences. 2012; 8:560-567.
9. Gomez GA, Gomez AA. Statistical procedures for agricultural research. John Wiley and Sons, New York, 1984, 680.
10. Islam MN, Hoque S, Islam A. Effect of P×S interactions on nutrient concentration and yield of wheat, rice and mungbean. Journal of the Indian Society of Soil Science. 2006; 54:86-91.
11. Jackson ML. Soil chemical analysis. Prentice Hall, India Pvt. Ltd, New Delhi, 1967.
12. Jagdeshwari PV, Kumar S, Kumaraswamy K. Sustenance of soil fertility status of an Alfisol under fifteen years of continuous fertilization and cropping of rice. Crop Research. 2001; 22:25-28.
13. Kumar A, Yadav DS. Influence of continuous cropping and fertilization on nutrient availability and productivity of an alluvial soil. Journal of the Indian Society of Soil Science. 2005; 53:194-198.
14. Magdoff F, Lanyon L, Liebhardt B. Nutrient cycling, transformations and flows: Implications for a more sustainable agriculture. Advances in Agronomy. 1997; 60:65-73.
15. Mandal N, Dwivedia BS, Meena MC, Singha D, Datta SP, Tomar RK *et al.* Effect of induced defoliation in pigeonpea, farmyard manure and sulphitation pressmud on soil organic carbon fractions, mineral nitrogen and crop yields in a pigeonpea-wheat cropping system. Field Crops Research. 2013; 154:178-187.
16. Manjhi RP, Yadav MS, Thakur R. Effect of integrated nutrient management on crop productivity and changes in soil fertility in maize (Zea mays)-wheat (*Triticum aestivum*) cropping sequence. Indian Journal of Agronomy. 2014; 59:371-76.
17. Obiri-Nyarko F. Ameliorating soil acidity in Ghana: A concise review of approaches. ARPN Journal of Science and Technology. 2012; 2:143-153.
18. Olsen SR, Cole CV, Watanave FS, Dean LA. Estimation of available phosphorus by extraction with sodium bicarbonate. US Department of Agriculture. 1954, 939.
19. Sharma GD, Thakur R, Raj S, Kauraw DL, Kulhare PS. Impact of integrated nutrient management on yield, nutrient uptake, protein content of wheat (*Triticum aestivum*) and soil fertility in a typic haplustert. The Biosacn. 2013; 8:1159-1164.
20. Singh AK, Sarkar AK, Kumar A, Singh BP. Effect of long-term use of mineral fertilizers, lime and farmyard manure on crop yield, available plant nutrient and heavy metal status in an acidic loam soil. Journal of the Indian Society of Soil Science. 2009; 57:362-65.
21. Singh S, Bhat ZA, Rehman HU. Influences of organic and integrated nutrient management on physico-chemical properties of soil under basmati-wheat cropping sequence. The Bioscan. 2014; 9:1471-1478
22. Singh SP, Singh R, Singh MP, Singh VP. Impact of

sulphur fertilization on different forms of and balance of soil sulphur and the nutrition of wheat in wheat-soybean cropping sequence in Tarai soil. Journal of Plant Nutrition 2014; 37:618-32. doi:10.1080/01904167.2013.867987

23. Subbiah BW, Asija GL. A rapid procedure for the estimation of available micronutrient in soils. Current Science. 1956; 25:259-260.
24. Subehia SK, Verma S, Sharma SP. Effect of long-term use of chemical fertilizers with and without organics on forms of soil acidity, phosphorus adsorption and crop yields in an acid soil. Journal of the Indian Society of Soil Science. 2005; 53:308-314.
25. Weil RR, Islam KR, Stine MA, Gruver JB, Samson-Liebig SE. Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. American Journal of Alternative Agriculture. 2003; 18:3-17.
26. Yadav MP, Aslam M, Kushwaha SP. Effect of integrated nutrient management on rice (*Oryza sativa*)-wheat (Triticum aestivum) cropping system in central plains of Uttar Pradesh. Indian Journal of Agronomy. 2005; 50:89-93.