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EFFECT OF LONG-TERM APPLICATION OF FERTILIZERS AND MANURE ON SOIL PROPERTIES

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ABSTRACT

A field experiment was conducted under ICAR coordinated scheme on Long Term Fertilizer Experiment during 2016-17 at the Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur to study the soil properties after 44 years of cropping with continuous application of fertilizers and manure. The treatments involve were 50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+FYM, 100% NPK-S and Control. The experiment was laid out in a randomized block design with four replications. The soil samples were collected and analyzed for pH, electrical conductivity, organic carbon and soil available nutrients viz., N, P, K and S. The results revealed that soil pH and EC have not changed substantially even after repeated application of fertilizers for the last 44 years. The use of balanced fertilizers either alone or integrated with organic manure (FYM) have helped in improving the organic carbon content of the soil, which is an indicator of soil health improvement. A build up of available soil P and S was observed due to its continuous addition through fertilizer but depleting level of available K indicates inadequacy of applied dose of potassium under intensified cultivation of crop.

(Key words: Soil properties, chemical fertilizers, organic manure)

INTRODUCTION

The use of high analysis fertilizer for immediate boosting of production potentials of crop plants cast the shadow on use of organic manures. This reflects on degradation of soil quality and environments as well as sustainability of yield levels of crop plants (Virmani, *et al*. 1991). Soil quality is the major functional factor in alteration of production potential of crops. To over come this problem the integrated nutrient management system (INM) is adopted in cropping system. The basic concept of the INM is to maintain soil fertility for sustained crop productivity on longterm basis and also reduce fertilizer input cost. At present the quantity of inorganic fertilizers is reduced by substituting the various organic manures viz., FYM, vermi compost, green manuring and recycling of crop residues.

The protection of environment and sustainability in yield levels can be achieved by the integrated nutrient management. This will be the noble approach toward organic farming. Integrated nutrient management (INM) has shown its potential in increasing crop productivity may be due to the combined effect of nutrient supply, synergism and improvement in soil physical and biological properties and also in crop physiological processes. Therefore, it has realized that there is a need for an assessment on crop specific land quality so that the yield diminishing factors can be identified. The need for development of a land quality index with reference to type of land use was stressed by the Kerlen *et al*., (1997). Long-term monitoring allows both the identification of current changes in the soil and prediction of future changes (Antil and Singh, 2007). Although it is well established that inorganic fertilizers serve to maintain or improve crop yields, their application can induce changes

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in the physical, chemical and biological properties of soil (Dick *et a*l,1996). These changes in the long-term are believed to have significant influences on quality and productive capacity of the soil (Acton and Gregorich, 1995). Some studies claim diminishing soil quality and productive capacity (Doran *et al*., 1996; Gregorich *et al*., 1996; Manna and Swarup,2000); other studies imply both positive and negative effects (Hera and Mihaila 1981; Johnston 1994) or no noticeable changes (Aref and Wander, 1998). In this context, the information on long term effects of inorganic fertilizer application and manure on soil properties particularly in Central India is lacking.

MATERIALS AND METHODS

Experimental site, climate and soil characteristics

Present investigation was conducted in an ongoing scheme All India Coordinated Research Project (AICRP) on Long Term Fertilizers Experiment (LTFE) of Indian Council of Agricultural Research (ICAR). The LTFE is laid out on a permanent site at the Experimental field Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru krishi Vishwa Vidyalaya. Jabalpur (M.P.). The experimental site is situated in 'Kymore Plateau and Satpura Hills' agro climatic region of M.P. It falls on 23.9° N latitude and 79.6° E longitudes with an altitude of 411.8 m above the mean sea level. Jabalpur is situated in the semi-arid region having sub-tropical climate with hot dry summer, and cold winter. The average rainfall is about 1350 mm, which is mainly distributed from mid June to October. The maximum and minimum temperature ranges between 35.1°C and 5.3°C. The average annual relative humidity is 62%.

Table 1. Initial characteristics of experimental soil

Soil properties	Value
Sand (%)	25.5
Silt (%)	17.6
Clay (%)	56.9
Texture class	Clay
Bulk density (Mg m^{-3})	1.30
pH (1:2.5)	7.60
EC (1:2.5) (dS m^{-1})	0.18
OC (g kg^{-1})	5.70
Available nitrogen (kg ha^{-1})	193
Available phosphorus (kg ha^{-1})	7.60
Available potassium (kg ha^{-1})	370
Available sulphur (mg kg^{-1})	7.80

The experiment was started with maize fodder as the first crop in summer season of 1972; since then Soybean (*kharif*)-Wheat *(rabi)*-Maize fodder *(summer)* crop rotation was adopted till 1994. However, since 1994 the cultivation of maize fodder was left and presently the cropping sequence being followed is soybean *(kharif*) and wheat *(rabi).* The soil of the experimental field is medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert. At the beginning of this experiment in 1972, initial soil samples were collected before application of the treatments and analyzed for different soil properties (Table1).

Treatments detail

The experiment has been in continuance since 1972 with 10 different treatments, however in present experiment following 8 sets of treatments were selected. The selected treatments involve 50% NPK; 100% NPK; 150% NPK; 100% NP; 100% N; 100% NPK+FYM; 100% NPK-S and Control. The 100% optimal NPK doses based on initial (1972) soil test values were 120:80:40 and 20:80:20 ($N:P_2O_5:K_2O$) for wheat and soybean respectively. Nitrogen was applied through urea, phosphorus through single super phosphate and potassium was applied through murate of potash. The farm yard manure in FYM treatment was applied @ 5 ton ha^{-1} $year^{-1}$ to soybean crop only. Due to build of Zn content in soil. The application of Zn as $ZnSO_4$ @ 20 kg ha^{-1} in alternate year to wheat crop was discontinued since, 1987.

Soil sampling and analysis

The representative soil samples were collected from two depths viz.,0-15 and 15-30 cm from each plot with the help of soil auger after 44 year of continuous cropping. The composite soil samples were prepared by quartering technique. The composite soil samples were air dried, crushed by wooden pestle and mortar then passed through 2 mm sieve and finally the processed samples were used for analysis of different physical and chemical properties. The soil pH and electrical conductivity (EC) was measured by glass electrode pH meter and EC meter in 1:2.5 soil:water suspension (Piper, 1966). For determination of the soil organic carbon, a suitable quantity of the soil was digested with chromic acid and sulphuric acid. Excess of chromic acid left over unreduced by the organic matter of the soil was determined by a titration with ferrous ammonium sulphate solution using diphenylamine indicator. (Walkley and Black, 1934). Available nitrogen in soil sample was determined by using alkaline permanganate method (Subbiah and Asija, 1956) in which soil was mixed with excess of alkaline permanganate and distilled. Organic matter present in soils was oxidized by the nascent oxygen liberated by $KMnO_4$ in the presence of NaOH and thus ammonia was released. The released ammonia was absorbed in the boric acid (2%) containing mixed indicator and converted to ammonium borate. The formed ammonium borate was back titrated with standard sulphuric acid. The soil available phosphorus content was estimated by extracting the soil with 0.5 M $NaHCO_3$ (pH 8.5) and determination was done by ascorbic acid method on spectrophotometer (Olsen *et al*., 1954). The available potassium in soil was extracted by neutral 1N ammonium acetate and it was estimated using flame photometer (Muhr *et al*., 1963). Soil available sulphur was extracted with 0.15% solution of $CaCl_2$ and determined by turbidimetric method (Chesin and Yien, 1951).

Statistical analysis

The data obtained was compiled and analyzed for its significance (p=0.05) by statistical procedure appropriate for randomized block design as outlined by Gomez and Gomez (1985). Further, the data was subjected to computation of coefficient of determination (r^2) and correlation coefficient (r) as follows and the relationship between two parameters was studied (Snedecor and Cochran, 1994).

Coefficient of determination (r^2) $= \frac{[n(\Sigma xy)-(\Sigma x)(\Sigma y)]^2}{[n\Sigma x^2-(\Sigma x)^2][n\Sigma y^2-(\Sigma y)^2]}$

Correlation coefficient (r) = $\frac{n(\Sigma xy)-(\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2-(\Sigma x)^2][n\Sigma y^2-(\Sigma y)^2]}}$

RESULTS AND DISCUSSION

Soil pH and electrical conductivity (EC)

The initial pH and electrical conductivity of soil was 7.6 and 0.18 dS m^{-1}, respectively (Table 1). The continuous use of fertilizer either alone or in combination with manure over 44 years resulted in a slight change in soil pH however, the change was not found significant. The pH of the soil ranged from 7.49 to 7.62 in surface soil (Table 2) and 7.50 to 7.60 in sub-surface (Table 3), showing that continuous cropping used fertilizer and manure had no adverse effect on the pH of soil and might be due to high buffering capacity of soil (Suman *et al*., 2017). It appears that no substantial changes occurred due to various treatments as reported earlier by Swarup and Bhardwaj (2000), Dubey *et al*. (2015). Thus, there was no remarkable change in pH of the soil with respect to depth as a result of continuous fertilizer additions and intensive cropping over 44 years. Similarly, the EC of the soil (Table 2 and Table 3) also did not show any appreciable change over the years due to continuous fertilizers application in almost all the treated plots. The EC of the soil ranged from 0.15 to 0.19 dS m^{-1} in surface soil and 0.15 to 0.20 d Sm^{-1} in sub-surface soil. This could also be due to the peculiar characteristics of black soils that possessed inherent high buffering capacity (Dwivedi and Dwivedi, 2015) which affected the slight alterations in EC of soil due to fertilizer addition as stated earlier by Grewal *et al.* (1999). The EC in both soil depth was found non significant as a result of continuous fertilizer addition over the last 44 years. These results are in agreement with the findings of Singh *et al.* (2002) and Patidar (2014), who reported non significant effect of continuous cropping and fertilizer/manure application on soil electrical conductivity.

Soil organic carbon (SOC)

The soil organic carbon content was 5.70 g kg^{-1} when the experiment was started in the year 1972 (Table 1). The soil organic carbon was significantly increased with increase in the doses of fertilizers. The minimum value was noticed in control (5.60 g kg^{-1}) which was increased to 6.30, 7.23, and 7.45, g kg^{-1} with use of 50% NPK, 100% NPK and 150% NPK of fertilizer, respectively. The maximum content 8.85 g kg^{-1} was observed in 100% NPK+FYM over rest of the treatments (Table 2). Similarly, the soil organic carbon content in 15-30 cm soil depth was found lower as compared to surface soil (Table 3). However, it was noticed that with increasing level of fertilizer dose OC content of soil continued to increase and the values were found higher as compared to control (4.60 g kg^{-1}).Inclusion of FYM along with 100% NPK noticed improvement in the OC content (6.93 g kg^{-1}) followed by 150% NPK (6.87 g kg^{-1}) treatment. The data depicted that the lowest organic carbon content 5.60 g kg^{-1} in surface soil and 4.60 g kg^{-1} in sub surface soil was noted in control where no fertilizer was applied. However, the organic carbon values improved significantly with proportionate increment in fertilizer addition at sub optimal dose (6.30 g kg^{-1}) in surface soil and (4.78 g kg^{-1}) in sub surface soil, optimal dose 7.23 g kg^{-1} in surface soil and 5.80 g kg^{-1} in sub surface soil and super optimal dose 7.45 g kg^{-1} in surface soil and 6.87 g kg^{-1} in sub-surface soil. The various fertilizer and manure treatments registered 9-58% increment in soil organic carbon as compared to the control. Similarly, these treatments registered 9-58% higher organic carbon as compared to the initial SOC (Table 5). The highest increment was observed for the treatment involving the application of 100% NPK+FYM. This increase in organic carbon content could be due to enhanced root development of crop resulting in higher residues as a result of intensive farming with continuous fertilizer applications (Choudhary *et al*., 2016). Thus, FYM addition had a pronounced effect on organic carbon build up in the soil (Swarup and Yaduwanshi, 2000) thereby showing that chemical fertilizer along with organic manure would be beneficial for sustaining the soil health and crop productivity (Vasanthi and Kumarswamy, 2000). The higher organic carbon content was obtained at surface and declined progressively with depth. The magnitude of organic carbon was higher on surface and declined with depth could possibly due to the fact that cultivation enhanced and promoted the decomposition of plant organic residues at surface level (Tembhare *et al*., 1998).

Table 2. Soil properties under long term application of fertilizers and manure (0-15 cm)

Treatments	pH	EC	SOC	N	P	K	S
50% NPK	7.51	0.16	6.30	220	18.9	253	22.5
100% NPK	7.58	0.17	7.23	265	29.1	290	32.1
150% NPK	7.62	0.19	7.45	290	34.6	315	35.2
100%NP	7.54	0.16	6.65	250	25.8	220	30.2
100% N	7.49	0.15	6.10	210	8.83	215	13.8
100% NPK+FYM	7.53	0.18	8.85	325	36.7	317	38.5
100% NPK-S	7.56	0.17	7.10	258	27.8	286	13.2
Control	7.50	0.16	5.60	178	8.40	236	12.5
SEm±	0.10	0.01	0.30	11.2	1.04	7.52	0.68
CD (5%)			0.89	32.5	3.03	21.8	3.61

EC-Electrical conductivity (dS m^{-1}); SOC-Soil organic carbon (g kg^{-1}); N-Soil available nitrogen (kg ha^{-1}); P-Soil available phosphorus (kg ha^{-1}); K-Soil available potassium (kg ha^{-1}); S-Soil available sulphur (mg kg^{-1})

Soil available nitrogen (N)

The soil available N content was 193 kg ha^{-1} when the experiment was started (Table 1). The soil available N content in 0-15 cm soil depth was found increased successively from 220, 265 and 290 kg ha^{-1} as the doses of fertilizer increased from 50%, 100% and 150% NPK, respectively. Significantly the highest value of available N (325 kg ha^{-1}) was recorded with 100% NPK+FYM treatment whereas, the lowest value of available N was observed in control (178 kg ha^{-1}) (Table 2). Similarly in 15-30 cm soil depth, the highest available N content (240 kg ha^{-1}) was recorded in 150% NPK whereas the lowest value was noticed as 140 kg ha^{-1} in control followed by 100% N (164 kg ha^{-1}). Slightly higher value of available N content was obtained in 100% NPK+FYM (255 kg ha^{-1}) as compared to 100% NPK (210 kg ha^{-1}) (Table 3). The available N was found decreased with soil depth irrespective of the treatment. The various fertilizer and manure treatments registered 18-82% increment in soil available N as compared to the control. Similarly, these treatments registered 9-69% higher soil available N as compared to the initial level (Table 5). The highest increment was observed for the treatment involving the application of 100% NPK+FYM. However, 8% reduction in soil available N was noticed in control plot over the initial level. The higher values of N content in surface soil could be due to the presence of residues after the harvest of crop as suggested by Singh *et al*. (2002). Further, the lower content was found in control (178 kg ha^{-1}) without fertilizers application which directly or indirectly affected normal biological activity. The highest N content was registered in 100% NPK+FYM (325 kg ha^{-1}) treatments followed by 150% NPK (290 kg ha^{-1}) could be resulted due to better biological activities in the presence of FYM (Dwivedi *et al*. 2007). However, due to addition of fertilizer doses suboptimal, optimal and super optimal, N content was correspondingly improved indicating an impact of fertilizer application on enrichment of N pools (Thakur *et al*., 2011). It has also been noted that higher status of N was obtained on the surface while progressively declined with depth but the rate of depletion was more apparent from surface to subsurface (Singh *et al.,* 2002 and Suman *et al*., 2017).

Soil available phosphorus (P)

Initially the experimental soil contained was 7.6 kg ha^{-1} available P when the experiment was started (Table 1). The soil available P content in soil increased successively and significantly from 8.40 kg ha^{-1} (control) to 18.90, 29.10 and 34.60 kg ha^{-1} in 50%, 100% and 150% NPK treatments, respectively. The highest value 36.70 kg ha^{-1} was noticed with 100% NPK when applied along with FYM. However, the difference & in phosphorus content was almost equal and at par in 100% NP (25.83 kg ha^{-1}) and 100% NPK-S (27.80 kg ha^{-1}) while the lowest value (8.40 kg ha^{-1}) noticed in control followed by 100% N (8.83 kg ha^{-1}). Similarly, in 15-30 cm soil depth, the available P content increased significantly from 4.10 kg ha^{-1} (control) to 21.60 kg ha^{-1} (150% NPK). However, the buildup of available P 21.60 kg ha^{-1} in 150% NPK was significantly higher than 17.20 kg ha $^{-1}$ in 100% NPK. The various fertilizer and manure treatments registered 5-337% increment in soil available P as compared to the control. Similarly, these treatments registered 11-383% higher available P as compared to the initial level (Table 5). The highest increment was observed for the treatment involving the application of 100% NPK+FYM. The control plot also registered an increment of 11% over initial level.

The continuous cropping and manuring remarkably improved the available P in almost all treatments receiving P annually as compared to application of fertilizer without P. The large difference in P content monitored from various fertility treatments receiving sub optimal, optimal and super optimal doses of nutrient indicated higher P build up. Furthermore, the highest content was found when integrated application of fertilizer was practiced with FYM (36.70 kg ha^{-1}) followed by 150% NPK (34.60 kg ha^{-1}) treatments indicating the beneficial effect of FYM on mineralization of P to a greater extent in soil, (Parmar and Sharma, 2002 and Behera and Singh, 2009). The accumulation of P was higher at surface than the lower depth. Such a behavior was attributed to the fixation of applied P with the soil and its subsequent restricted movement (Dwivedi *et al*., 2007; Dubey *et al*., 2015).

Table 3. Soil properties under long term application of fertilizers and manure (15-30 cm)

Treatments	pH	EC	S O C	N	P	K	S
50% NPK	7.50	0.16	4.78	190	9.80	240	20.2
100% NPK	7.57	0.17	5.80	210	17.2	270	29.5
150% NPK	7.63	0.2	6.87	240	21.6	290	32.1
100%NP	7.60	0.17	5.20	205	15.7	212	28.2
100% N	7.52	0.15	4.24	170	4.70	209	12.5
100% NPK+FYM	7.52	0.18	6.93	255	20.8	300	36.3
100% NPK-S	7.55	0.16	5.30	200	16.5	269	12.4
Control	7.51	0.15	4.60	140	4.10	228	10.8
SEm±	0.06	0.01	0.32	8.19	1.10	5.16	0.72
CD (5%)	-	-	0.94	23.8	3.20	14.98	3.12

EC-Electrical conductivity (dS m^{-1}); SOC-Soil organic carbon (g kg^{-1}); N-Soil available nitrogen (kg ha^{-1}); P-Soil available phosphorous (kg ha^{-1}); K-Soil available potassium (kg ha^{-1}); S-Soil available sulphur (mg kg^{-1})

Soil available potassium (K)

The available K content was 370 kg ha^{-1} when the experiment was started (Table 1). The available K content was increased with successive addition of fertilizers from 50% (253 kg ha^{-1}), 100% (290 kg ha^{-1}) to 150% NPK (315 kg ha^{-1}) respectively, whereas the highest value 317 kg ha^{-1} was noted where 100% NPK applied along with FYM. However, the value 286 kg ha^{-1} was observed in 100% NPK-S lower than 100% NPK (290 kg ha^{-1}).The minimum content of available K was found in 100% N (215 kg ha^{-1}) (Table 2). In 15-30 cm soil depth, the highest value of available K (300 kg ha^{-1}) was recorded in 100% NPK+FYM followed by 150% NPK (290 kg ha^{-1}) whereas; the lowest value (209 kg ha^{-1}) was observed in N alone followed by 212 kg ha^{-1} with 100% NP as compared to 100% NPK (270 kg ha^{-1}) (Table 3). The data also implied that available K status declined from surface to lower depth. The application of optimal (290 kg ha^{-1} in surface soil and 270 kg ha^{-1}) to super optimal doses (315 kg ha^{-1} in surface soil and 290 kg ha^{-1} in sub surface soil) resulted in depletion of available K leading to a negative balance (Thakur *et al*. 2011) and ultimately it reflects on consequent loss of K fertility in further successive years (Bhattacharya *et al*. 2007). The soil available K reduced by 14-42% over initial K in soil (Table 5). Hence, the soil initially well supplied with K would decline medium to low level of available K (Swarup and Yadhuvanshi, 2000). The highest value of available K was found in 100% NPK+FYM, similar results were also reported by Singh *et al*. (2014).

Table 4. Change in soil properties after 44 year of continuous cropping

Treatments	pH	EC	S O C	N	P	K	S
50% NPK	-1.2	-11.1	13	14	149	-32	188
100% NPK	-0.3	-5.6	29	38	283	-22	312
150% NPK	0.3	5.6	33	50	355	-15	351
100%NP	-0.8	-11.1	19	30	240	-41	287
100% N	-1.4	-16.7	9	9	16	-42	77
100% NPK+FYM	-0.9	0.0	58	69	383	-14	394
100% NPK-S	-0.5	-5.6	27	34	266	-23	69
Control	-1.3	-11.1	0	-8	11	-36	60

EC-Electrical conductivity; SOC-Soil organic carbon; N-Soil available nitrogen; P-Soil available phosphorus; K-Soil available potassium; S-Soil available sulphur; Values in %

Soil available sulphur (S)

The initial value of available sulphur content was 15.60 kg ha^{-1} when the experiment was started (Table 1). The available sulphur content in soil was increased with the increasing levels of fertilizer from 50% NPK (22.50 kg ha^{-1}) to 100% NPK (32.13 kg ha^{-1}) and 150% NPK (35.20 kg ha^{-1}). The available sulphur content was found significantly higher in 100 % NPK (32.13 kg ha^{-1}) as compared to 100% NPK-S (13.20 kg ha^{-1}). The content of available sulphur was found higher in 100% NP (30.20 kg ha^{-1}) to that of 50% NPK (22.50 kg ha^{-1}). However, the lowest content was observed in control (12.50 kg ha^{-1}). Similarly, in 15-30 cm soil depth, the maximum buildup of available sulphur was observed in 100% NPK+FYM (36.30 kg ha^{-1}) as well as in 150% NPK (32.12 kg ha^{-1}). However, the lower content of available sulphur was observed in control (10.80 kg ha^{-1}) followed by 100% NPK-S (12.40 kg ha^{-1}), whereas the content of available sulphur was found significantly higher in 100% NPK (29.50 kg ha^{-1}) as compared to 100% NPK-S (12.40 kg ha^{-1}). It was also found that the available sulphur content was higher in 50% NPK (20.21 kg ha^{-1}) when compared with 100% N (12.50 kg ha^{-1}) and it decreased with increased soil depth. The various fertilizer and manure treatments registered 15-236% increment in soil available S as compared to the control. Similarly, these treatments registered 60-394% higher available S as compared to the initial level (Table 5). The highest increment was observed for the treatment involving the application of 100% NPK+FYM. The control plot also registered 60% increase in soil available S. The available sulphur content was increased with addition of S over control (12.50 kg ha^{-1}) in surface soil and (10.80 kg ha^{-1}) in sub surface soil) and 150% NPK (35.20 kg ha^{-1} in surface soil and 32.12 kg ha^{-1} in sub surface soil) which could be due to higher transformation of added fertilizer S to available S retention in soil. Singh *et al*. (2001) found that rice-wheat grown in a sequence and supplied P through single super phosphate since 1991 caused an increase in the available S content. This increase was further accentuated when FYM was included in the treatment. It has also been noted that a significantly higher content of available S was observed with successively higher addition of S from optimal to super optimal dose which might be due to the differential conversion of applied S in available S form as a result of varying transformation (Sharma and Choudhary, 2007). However, addition of FYM along with optimal dose resulted in maximum build up of available S this could be due to the release of organic acids during the decomposition of organic matter ultimately causing resolution of applied as well as native S into available S compounds thereby it increases the activity and concentration of available S in soil (Thakur and Sawarkar, 2009; Suman *et al*., 2017).

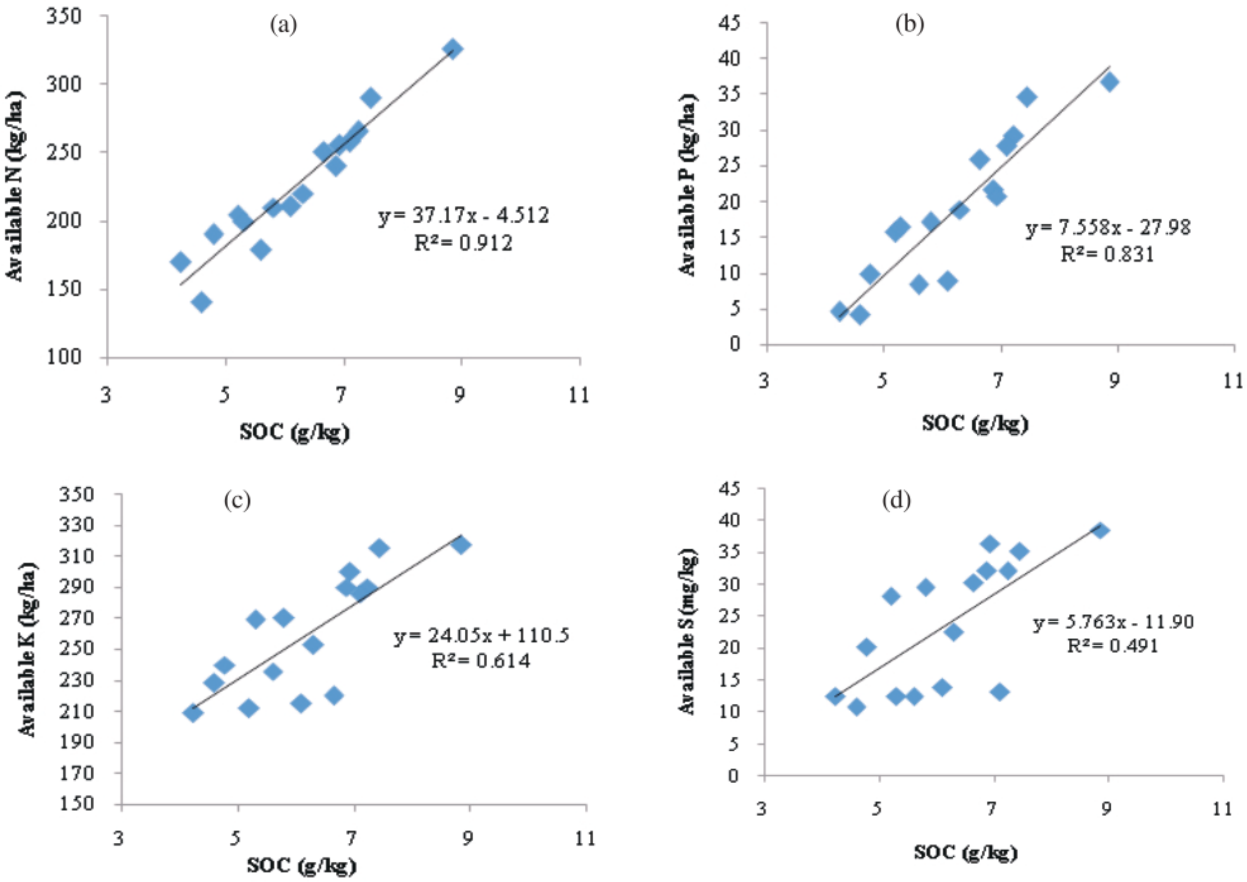

Figure 1. Correlation of soil organic carbon with available nutrients. (a) Soil available N Vs Soil organic carbon (b) Soil available P Vs Soil organic carbon (c) Soil available K Vs Soil organic carbon and (d) Soil available S Vs Soil organic carbon

Correlation between soil properties

The physical and chemical properties viz. pH, electrical conductivity, soil organic carbon and soil available nutrients viz. N, P, K and S were determined and the correlation between these properties was studied and its significance was interpreted using Student's T Test (Table 5 and Figure 1). The pH of the soil was found in significant positive correlation with electrical conductivity (*r=0.762*), soil available (*r=0.543*) and S (*r=0.522*). The electrical conductivity of soil found in significant positive correlation with all the parameters studied viz. soil organic carbon (*r=665*), soil available N (*r=0.687*), P (*r=0.696*), K (*r=0.782*) and S (r=0.759). The soil organic carbon was observed significantly and positively correlated with all the parameters except soil pH. A significant positive correlation was found between SOC and soil available N (r^2*=0.912*) (Figure 1-a), SOC and available P (r^2*=0.831*) (Figrue 1-b), SOC and available K (r^2*=0.614*) (Figure 1-c) and SOC and soil available S (r^2*=0.491*) (Figure 1-d). Similarly, the soil available nutrients were also found in significant positive correlation with each other (Table 5).

Table 5. Correlation between soil parameters

Parameter	pH	EC	S O C	N	P	K
EC	0.762*					
SOC	0.333	0.665*				
N	0.418	0.687*	0.955*			
P	0.543*	0.696*	0.912*	0.959*		
K	0.453	0.782*	0.784*	0.772*	0.789*	
S	0.522*	0.759*	0.701*	0.769*	0.740*	0.614*

EC-Electrical conductivity; SOC-Soil organic carbon; N-Soil available nitrogen; P-Soil available phosphorous; K-Soil available potassium; S-Soil available sulphur; *Significant at 5% level as per Students T test (T table value – 2.145)

The soil pH and EC have not changed substantially even after repeated application of fertilizers for the last 44 years. The use of balanced fertilizers either alone or integrated with organic manure (FYM) have helped in improving the organic carbon content of the soil, which is an indicator of soil health improvement. A build up of available soil P and S was observed due to its continuous addition through fertilizer but depleting level of available K indicates inadequacy of applied dose of potassium under intensified cultivation of crop.

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