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Long-term effect of inorganic fertilizers and amendments on macronutrients uptake and relationship with soil organic carbon under maize-wheat rotation system in an acid Alfisol

Anjali*, Narender Kumar Sankhyan and Raj Paul Sharma
Department of Soil Science, College of Agriculture,
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, India.

*Corresponding author: dr.anjali.21.1993@gmail.com
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Abstract

A study was conducted during winter (*rabi*) season 2018-19 in the ongoing long-term fertilizer experiment, initiated since 1972 in an acid Alfisol, at the experimental farm of the Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur to find the effect of chemical fertilizers, farmyard manure and lime application on yield and nutrient uptake by wheat and its relationship with soil organic carbon. The experiment consisted of eleven treatments with three replications in a randomized block design. The results revealed that the continuous use of NPK fertilizers along with FYM or lime resulted in higher wheat yield and nutrient uptake as compared to the other treatments. Soil organic carbon recorded a positive and significant relation with NPK uptake by wheat.

Key words: Alfisol, Manure, Nutrient uptake, Soil organic carbon, Wheat, Yield

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops at global scenario and about two-thirds of the world's population thrives on wheat grains. In India, it is the second most important food crop next to rice contributing about 35 per cent of the food grain production. The area under wheat in India is 31.45 million hectares and production is 107.59 million tonnes (Anonymous 2020). However, India is now one of the major world's importers of wheat. Besides its tremendous significance, average yield is far below than developed countries (FAO 2010). Further, the global food demand is continuously increasing, and by 2050 it is projected that global food demand may escalate to approximately 25–70 per cent (Hunter *et al.* 2017). The demand for food as a basic necessity has been a challenge to every farmer in terms of increasing productivity. Food security can be achieved by constantly improving grain yield per unit area. However, it is also important to note that continual crop production without replenishing the nutrients removed by crops during its entire life cycle would drain the inherent fertility level of soil (Tan *et al.* 2005).

Managing agricultural nutrients to provide a safe food supply and secure the environment remains one of the enormous challenges of the 21st century. Crop yields and crop nutrient uptake are the principal factors that determine optimal fertilization practices. Therefore, it is of immense importance to apply fertilizers in an efficient way to minimize loss and to improve the nutrient use efficiency. The nutrient uptake and transport within the plant system primarily depends upon the plant growth stage, soil fertility, amount of fertilizers applied, etc. Chemical fertilizers are applied to the soil in order to supplement the nutrient supply and increase crop yields. However, inadequate and imbalanced use of fertilizers adversely affects soil health and declines crop productivity (Kalhapure *et al.* 2014). Integration of organic and inorganic sources of plant nutrients may help to supply adequate nutrients in an optimum proportion.

Soil organic matter is a well-known reservoir of carbon as well as other nutrients in the soil, contains almost all the plant growth essential nutrients, therefore, is an important factor affecting the nutrient uptake by the crop (Wang *et al.* 2015). High exchangeable Al, Fe and Mn and deficiency of P, Ca, Mo, etc. are the most limiting factors for plant growth in acid soils (Rajneesh *et al.* 2018). Application of lime is done for ameliorating the soil acidity but it affects the availability as well as uptake of the nutrients. Thus, it is important to identify the effect of nutrient management practices involving fertilizers and amendments on crop productivity and nutrient availability to the crop over a long period. Long-term fertilizer experiments are very helpful tools in monitoring the effect of the use of fertilizers and manures on crop productivity and nutrient availability over a long period.

Materials and Methods

The present investigation was carried out during *rabi* 2018-19 in an on-going long-term fertilizer experiment, initiated during 1972 at the experimental farm of Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The site is situated at 31°62 N latitude and 76°32 E longitude with an altitude of 1290 meters above mean sea level. The mean weekly maximum and minimum temperature during the study period varied from 14 to 31°C and 1 to 18°C, respectively. The total rainfall received was 496 mm during crop season. The soil of the study site is illitic with silt loam texture and classified as subgroup Typic Hapludalf. At the start of the experiment (1972), soil pH was 5.9, soil organic carbon (SOC) was 7.9 g kg^{-1}, and available N, P and K were 736, 12 and 194 kg ha^{-1}, respectively. In the present investigation, the SOC after the harvest of the wheat crop ranged between 8.19 and 13.52 g kg^{-1}.

The experiment consisted of eleven treatments *viz.,* 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, with three replications in an RBD with a plot size of 15 m^2 (5m × 3m). Since 2011, optimal and super-optimal P doses have been reduced by 50 per cent due to marked P build-up and farm yard manure (FYM) application at the rate of 5 t ha^{-1} (dry weight basis) has been initiated in 50% NPK (T_1) to maize crop only. The optimal dose of NPK for wheat corresponds to 120, 26 and 25 kg ha^{-1} N, P_2O_5 and K_2O, respectively. Half dose of N and full dose of P and K were applied at the time of sowing. The remaining half of N was top dressed in two equal splits at maximum tillering and the flowering stage of wheat. Urea, single super phosphate (SSP) and muriate of potash (MOP) were the sources of N, P and K in all treatments, except in 100% NPK(-S), where, diammonium phosphate (DAP) was applied as a source of P. Zinc was applied in T_5 as zinc sulfate @ 25 kg ha^{-1} every year to both the crops till *rabi* 2010 – 11. FYM application was made @ 10 t ha^{-1} on a fresh weight basis to maize crop only, which corresponds to the practice being followed by the farmers of the region. Lime was applied continuously in T_{10} till the soil pH was raised to 6.5 but in successive years, the lime application was only done when the soil pH declined to about 6.3. The wheat crop (variety HPW-368) was sown on 17th November, 2018 and harvested on 10th May, 2019. Irrigations were given at critical growth stages of wheat. Chemical weed control 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.

After the harvest of wheat, data on grain and straw yields were recorded. The grain and straw samples of wheat were collected from each plot after the harvest of the crop and dried in an electric oven at 60 °C to a constant weight. The dried grain samples were finely ground in a mixer grinder in stainless steel jar and stored in plastic bags under moisture-free conditions. The straw samples were also ground and stored in paper bags. The grain and straw samples of wheat were digested in conc. H_2SO_4, followed by distillation with micro-Kjeldahl method (Jackson 1973) for determination of N content. Wheat grain and straw samples were also digested in the di-acid mixture (HNO_3:$HClO_4$ in 9:4 ratio) and the aqueous extract was used to determine P content using the vanado-molybdo-phosphoric acid method (Jackson 1973) and K content by flame photometer method (Black 1965). The SOC carbon was determined by Walkley and Black's titration method (Walkley and Black 1934).

Nutrient uptake was calculated by multiplying the grain and straw yield (kg ha^{-1}) with the nutrient concentration (%) of each treatment as follows:

a) Nutrient (N, P or K) uptake by grain or straw (kg ha^{-1}) = Yield of grain or straw (q ha^{-1}) × Nutrient (N, P or K) concentration of grain or straw (%)

b) Total uptake (kg ha^{-1}) = Nutrient uptake grain + Nutrient uptake straw

The data collected in the study were subjected to statistical analysis using Web Agri Stat Package 2.0. The differences between the means were tested using Duncan Multiple Range Test (DMRT) ($P \leq 0.05$).

Results and Discussion

Grain and straw yield of wheat

Significant variation was observed in the grain and straw yield of wheat amongst fertility treatments (Fig. 1). The highest grain (30.06 q ha^{-1}) and straw yield (50.06 q ha^{-1}) was recorded with the application of 100 per cent NPK + FYM. This increase in yield may be ascribed to the balanced supply of all essential nutrients due to improved physico-chemical properties of soil and additional nutrients added from FYM (Bhattacharyya *et al.* 2016). Higher yield owing to the application of lime along with NPK (T_{10}) could be attributed to higher nutrient availability due to the ameliorating effect of lime on soil acidity (Singh *et al.* 2017). Barring 100 per cent N alone (T_7), the lowest grain and straw yields of wheat were recorded in control, where nothing was added for the last 46 cropping cycles. Zero grain and straw yield in T_7 might be due to increased soil acidity and deteriorated soil quality with the continuous use of urea over a period of forty six years. Further, the role of P, K and S in crop production cannot be over-looked also. The application of P with N (T_6) increased the grain and straw yield significantly over N alone (T_7) and unfertilized control (T_{11}) while there was further increase in yield when K was included i.e.100 per cent NPK (T_2). It is pertinent to mention that continued absence of K and S in crop nutrition led to the decline in grain and straw yield of wheat. These results are in agreement with the findings of Chauhan *et al.* (2018) and Dhiman *et al.* (2019).

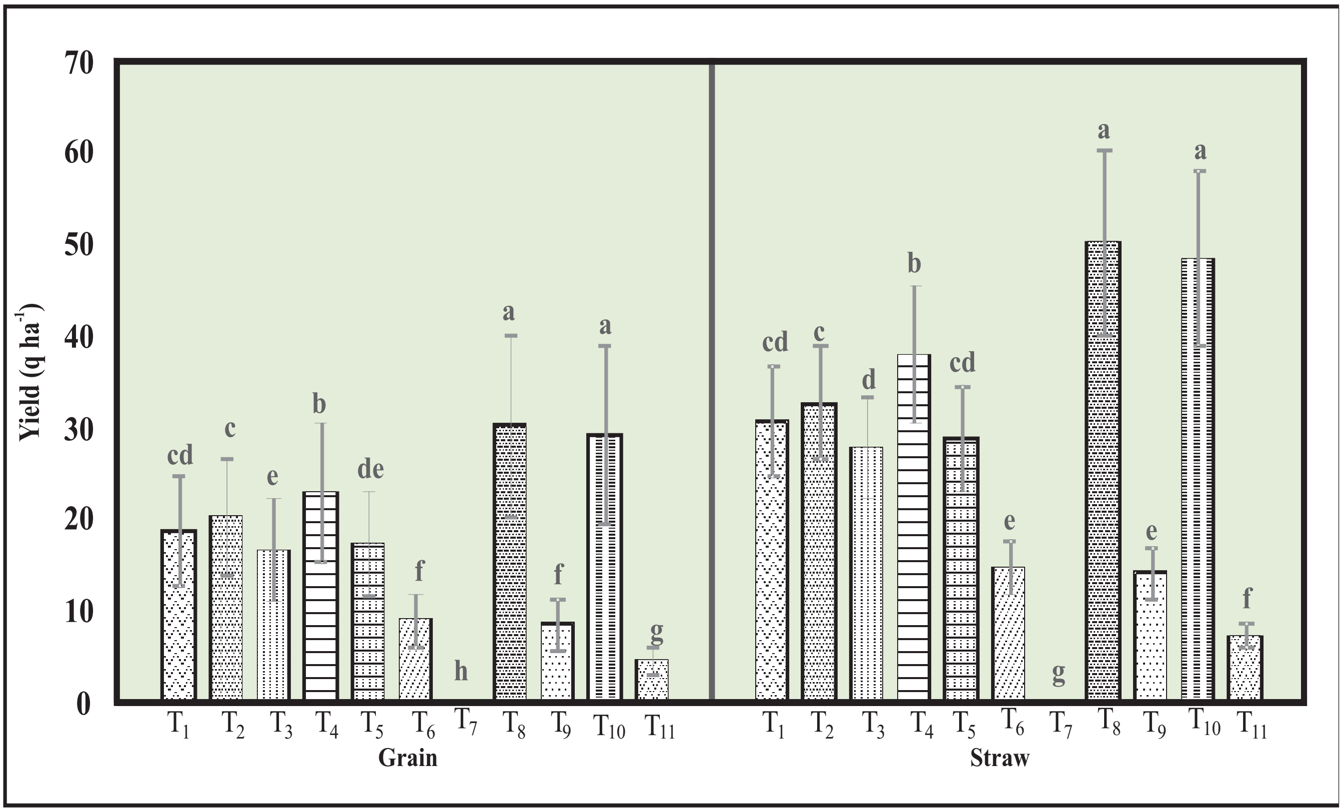


Fig. 1 Effect of long-term use of fertilizers and amendments on grain and straw yield of wheat
(Vertical bars indicate standard error; bars with different letters are significantly different at P < 0.05

Nitrogen uptake

The total N uptake varied from 9.45 kg ha^{-1} in control to 84.79 kg ha^{-1} in 100 per cent NPK + FYM barring T_7 (Table 1). Continuous application of FYM (T_8) or lime (T_{10}) in combination with optimal dose of NPK increased the nitrogen uptake by wheat crop significantly over rest of the treatments. These treatments recorded 76 and 58 per cent higher total N uptake over 100 per cent NPK, respectively. Chesti *et al.* (2013) also reported higher uptake of N by wheat with the application of organic manures and attributed this to higher nutrient availability, improved metabolic functions in plants which might have resulted in higher nutrient uptake and crop yield. The total N uptake in plots receiving super-optimal dose of NPK (T_3) was less than optimal NPK (T_2).

Phosphorus uptake

Total P uptake by wheat varied from 1.54 kg ha^{-1} in control to 20.45 kg ha^{-1} in 100 per cent NPK + FYM treated plots (Table 1). Treatment receiving FYM along with balanced dose of fertilizers was significantly superior over other treatments. Higher P uptake with addition of FYM (T_8) might be attributed to the solubilization of native P and release of P by mineralization of organic P (Sharma *et al.* 2016). The higher P uptake under 100 per cent NPK + lime might be ascribed to the increased soil pH, precipitation of Al ions, reduced P fixation and hence, increased availability of P to the crop (Rajneesh *et al.* 2017). Significantly higher P uptake under hand weeding treatment (T_4) might be due to higher organic carbon which encouraged better root and crop growth. Continuous cropping without addition of nutrients in control plots led to decline in P reserves in soil and poor crop growth which ultimately reduced the P uptake.

Potassium uptake

The highest total K uptake (54.58 kg ha^{-1}) was recorded under 100 per cent NPK + FYM which was significantly superior over rest of the treatments and least was recorded in control (5.27 kg ha^{-1}) (Table 1). Application of lime as an amendment also recorded significantly higher total K uptake than rest of the treatments except 100 per cent NPK + FYM. Improvement in soil properties resulting in better crop growth in response to FYM and lime addition might have resulted in higher uptake of K in these treatments. Exclusion of K (T_6) and S (T_9) from fertilization schedule resulted in low yield because of K and S deficiency and hence, less total K uptake was recorded in these treatments. Moreover, mining of native K reserves since last forty-six years in the absence of K in 100 per cent NP treatment reduced the availability of K in soil and thereby low uptake was recorded.

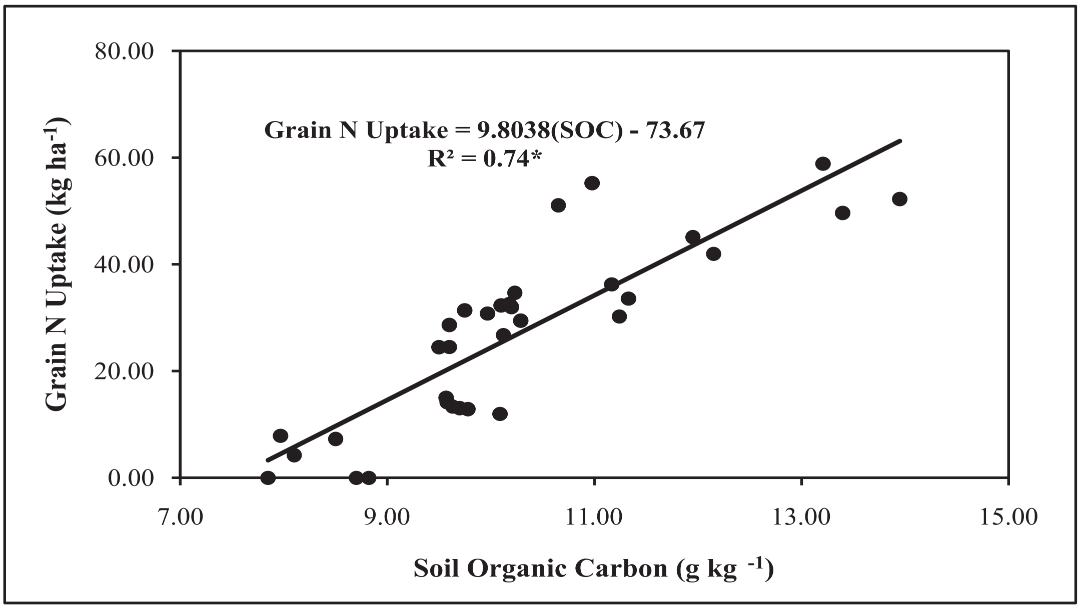
Table 1. Effect of long-term use of fertilizers and amendments on NPK uptake by wheat

Treatment	Uptake (kg ha^{-1})								
	N			P			K		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1: 50% NPK	30.65^{cd}	14.75^{d}	45.40^{de}	6.40^{de}	2.21^{de}	8.60^{ef}	7.33^{d}	20.93^{d}	28.25^{d}
T_2: 100% NPK	33.05^{c}	15.03^{d}	48.08^{d}	7.25^{cd}	2.59^{d}	9.84^{de}	7.98^{cd}	22.22^{d}	30.21^{d}
T_3: 150% NPK	27.35^{d}	14.37^{d}	41.72^{e}	7.02^{cde}	3.22^{c}	10.24^{cd}	6.87^{d}	19.56^{d}	26.43^{d}
T_4: 100% NPK + HW	37.29^{b}	18.25^{c}	55.55^{c}	8.05^{c}	3.29^{c}	11.33^{c}	9.11^{c}	27.13^{c}	36.25^{c}
T_5: 100% NPK + Zn	28.17^{d}	14.34^{d}	42.51^{de}	5.86^{e}	1.97^{e}	7.83^{f}	6.74^{d}	20.05^{d}	26.79^{d}
T_6: 100% NP	13.74^{e}	6.42^{e}	20.16^{f}	3.07^{f}	0.71^{fg}	3.78^{g}	2.74^{ef}	7.23^{ef}	9.97^{e}
T_7: 100% N	0.00^{g}	0.00^{g}	0.00^{h}	0.00^{g}	0.00^{h}	0.00^{i}	0.00^{g}	0.00^{g}	0.00^{g}
T_8: 100% NPK + FYM	53.56^{a}	31.23^{a}	84.79^{a}	14.96^{a}	5.49^{a}	20.45^{a}	14.09^{a}	40.49^{a}	54.58^{a}
T_9: 100% NPK (-S)	13.04^{e}	6.26^{e}	19.31^{f}	3.26^{f}	0.95^{f}	4.21^{g}	3.06^{e}	9.30^{e}	12.37^{e}
T_{10}: 100% NPK + lime	50.43^{a}	25.35^{b}	75.78^{b}	11.13^{b}	4.22^{b}	15.34^{b}	12.27^{b}	35.17^{b}	47.44^{b}
T_{11}: Control	6.45^{f}	3.00^{f}	9.45^{g}	1.25^{g}	0.29^{gh}	1.54^{h}	1.45^{fg}	3.82^{f}	5.27^{f}

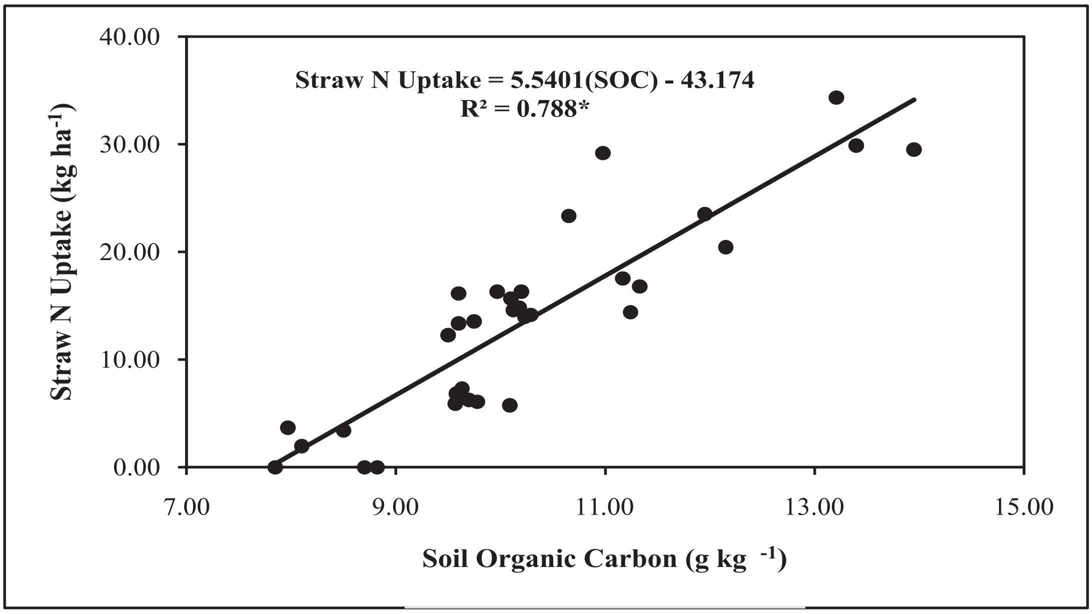
*Values with the same letters are not significantly different at $P < 0.05$

Relationship between nutrient uptake and soil organic carbon

Soil organic carbon is one of the important soil properties which influences the productivity of the soil and provides an account of the availability of plant nutrients. The relationship between nutrient uptake by wheat grain and straw, and SOC was determined with nutrient uptake as the dependent variable and SOC as the independent variable (Fig. 2, 3 & 4). It was observed that the nutrient uptake by grain and straw exhibited a strong and positive relationship with SOC for NPK. This might be due to the addition of organic carbon from FYM and plant biomass, which enhanced the microbial activity in the soil, increase the nutrient cycling and subsequently the availability of nutrients to the crop (Jadhao *et al.* 2019). Therefore, uptake of nutrients was highest in 100 per cent NPK + FYM treatment, in which organic carbon was added through FYM.

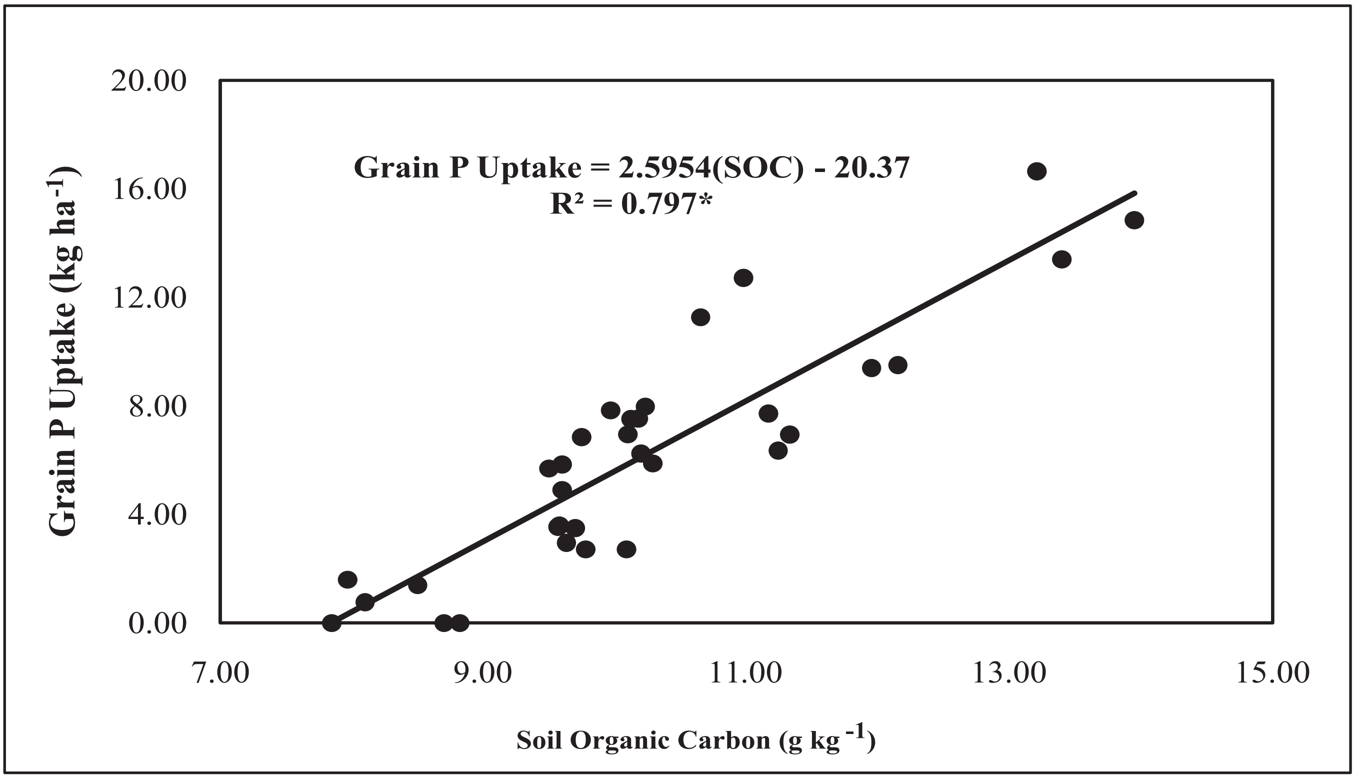


(a)



(b)

Fig. 2 Linear regression relationship of soil organic carbon with (a) grain N uptake, (b) straw N uptake



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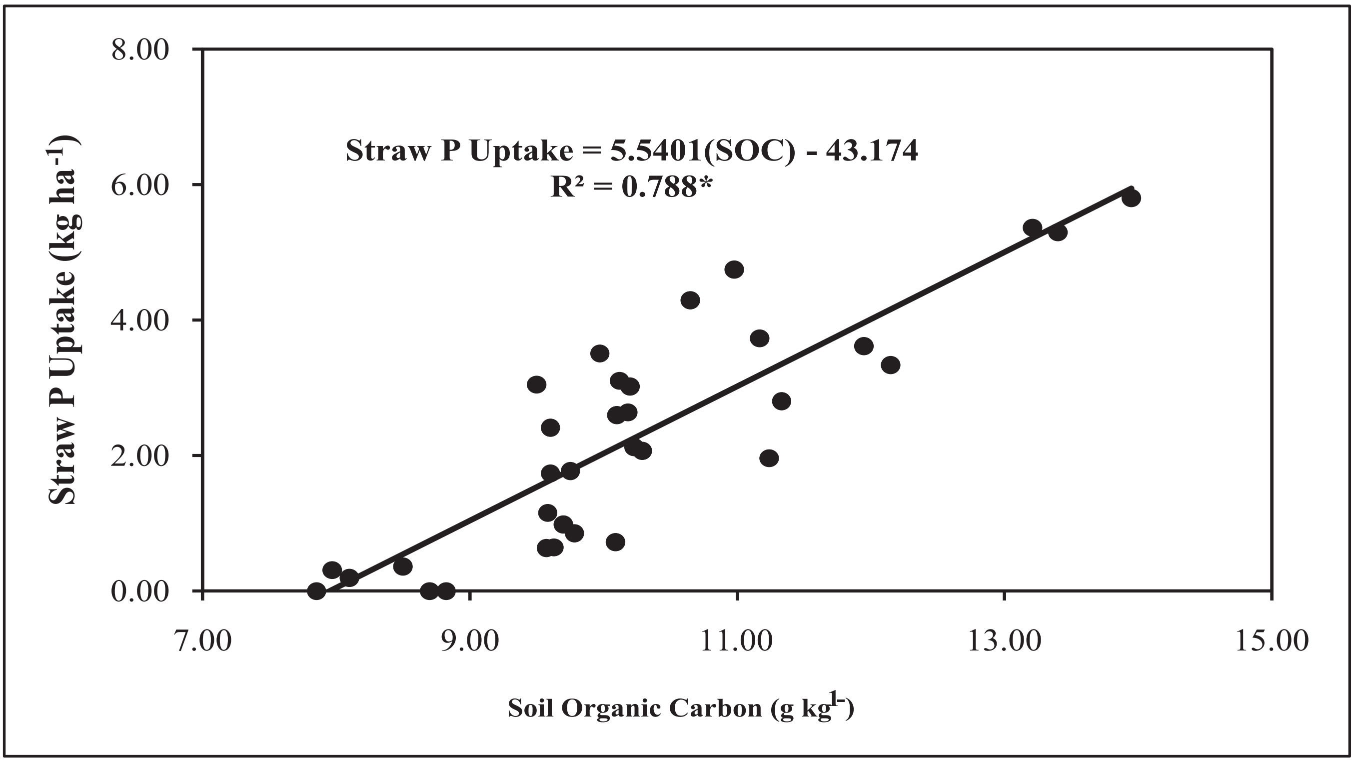
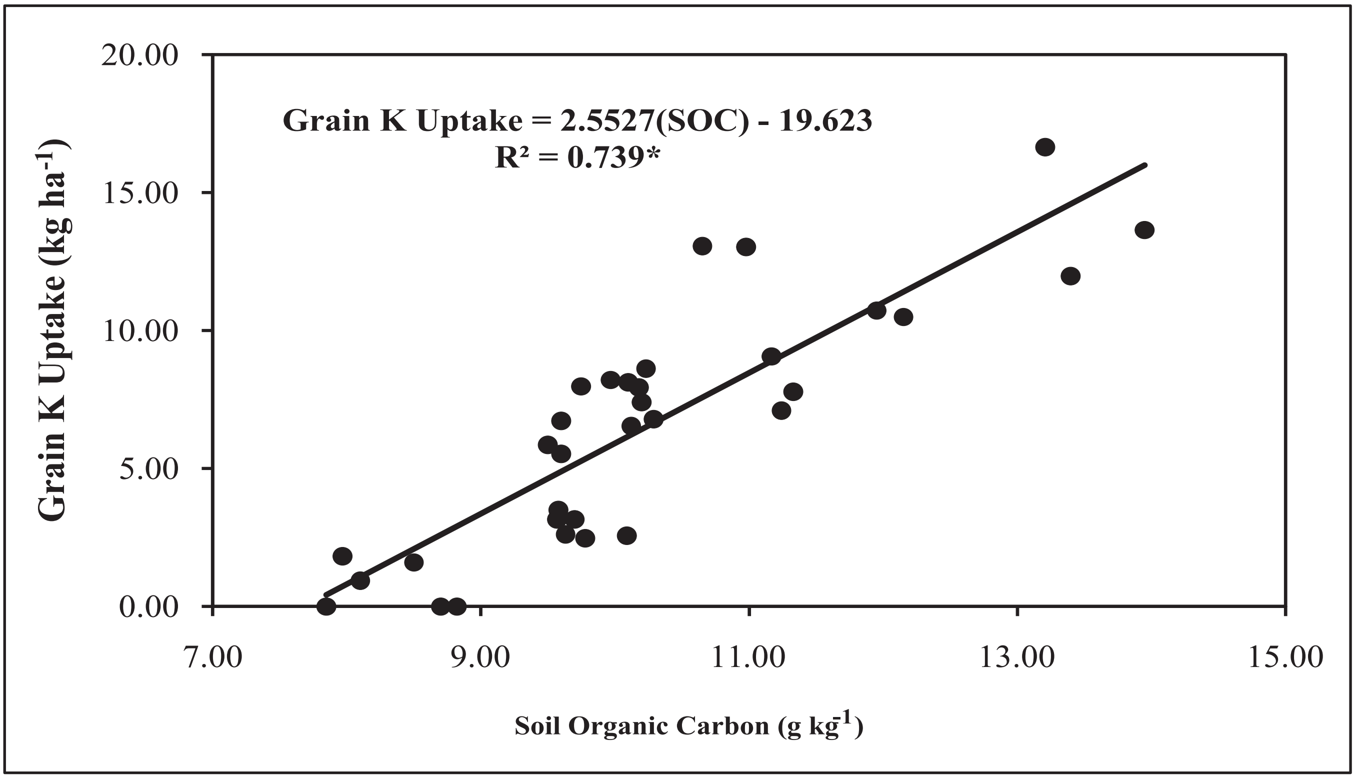
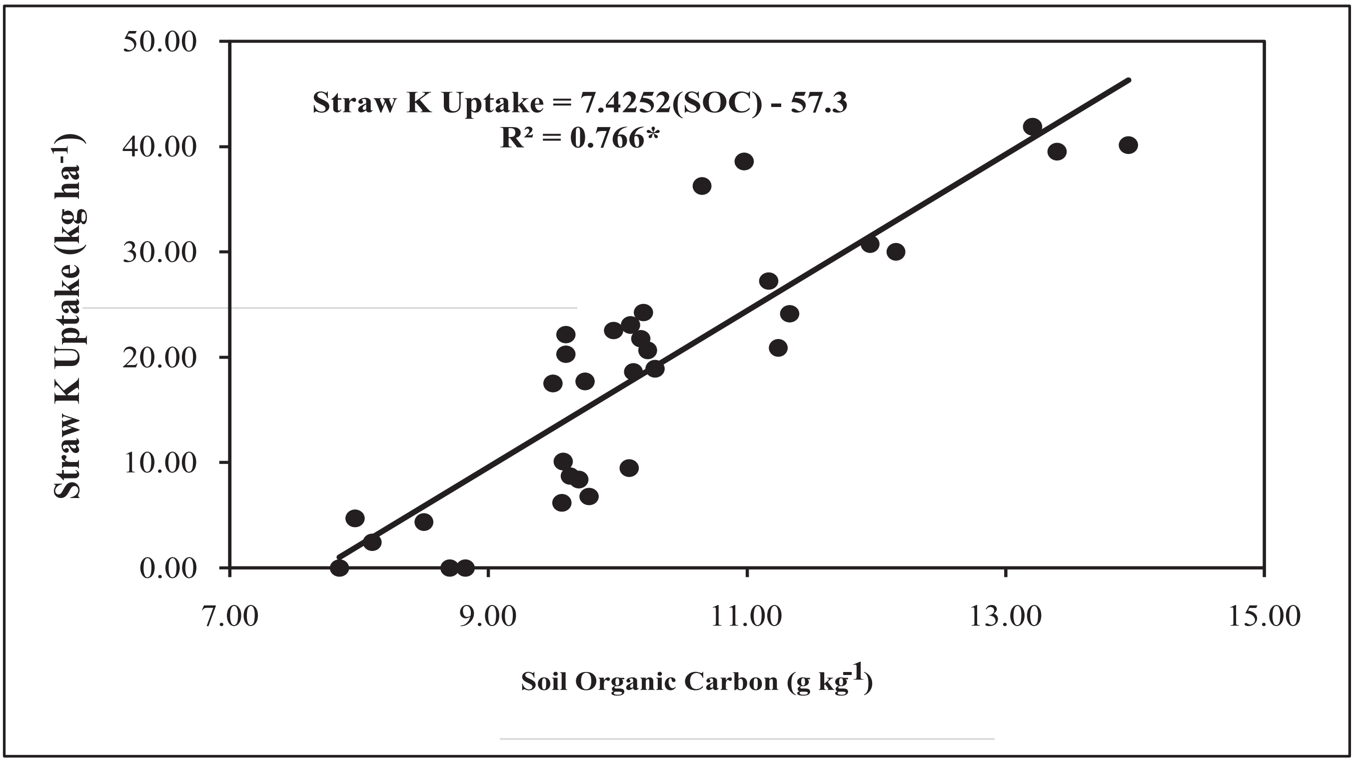


(b)

Fig. 3 Linear regression relationship of soil organic carbon with (a) grain P uptake, (b) straw P uptake



(a)



(b)

Fig. 4 Linear regression relationship of soil organic carbon with (a) grain K uptake, (b) straw K uptake

Conclusions

Balanced application of chemical fertilizers along with FYM or lime increased the wheat grain and straw yield significantly over sole use of NPK fertilizers. Nutrient uptake was also highest when NPK fertilizers were applied in integration with FYM and lowest in unfertilized control. Soil organic carbon exhibited a strong and positive relationship with NPK uptake by grain and straw of wheat crop, thus, indicating the importance of maintaining optimum levels of organic carbon in soil.

Conflict of interest: The authors declare that they have no conflict of interest.

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References

Anonymous. 2020. Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, India.

Bhattacharyya R, Pandey AK, Gopinath KA, Mina BL, Bisht JK and Bhatt JC. 2016. Fertilization and crop residue addition impacts on yield sustainability under rainfed maize-wheat system in the Himalayas. Proceedings of National Academy of Sciences India Section B Biological Sciences **86**: 21-32.

Black CA. 1965. Methods of Soil Analysis. Part II. American Society of Agronomy, Madison, Wisconsin, USA.

Chauhan N, Sankhyan NK, Sharma RP and Singh J. 2018. Effect of long-term application of fertilizers and amendments on wheat productivity and DTPA extractable micronutrients in an acid Alfisol. Himachal Journal of Agricultural Research **44 (1&2)**: 36-42.

Chesti MH, Kohli A and Sharma AK. 2013. Effect of integrated nutrient management on yield of and nutrient uptake by wheat (*Triticum aestivum*) and soil properties under intermediate zone of Jammu and Kashmir. Journal of the Indian Society of Soil Science **61 (1)**: 1-6.

Dhiman D, Sharma RP, Sankhyan NK, Sepehya S, Sharma SK and Kumar R. 2019. Effect of regular application of fertilizers, manure and lime on soil health and productivity of wheat in an acid Alfisol. Journal of Plant Nutrition **42 (19)**: 2507-2521.

FAO. 2010. Scaling soil nutrient balances: Enabling meso-level applications for African realities fertilizer and plant nutrition bulletin 15 Rome.

Hunter MC, Smith RG, Schipanski ME, Atwood LW and Mortensen DA. 2017. Agriculture in 2050: recalibrating targets for sustainable intensification. Bioscience **67 (4)**: 386–391.

Jackson ML. 1973. Soil Chemical Analysis. Prentice Hall Inc. Englewood Cliffs, New Jersey, USA.

Jadhao SD, Mali DV, Kharche VK, Singh M, Bhoyar SM, Kadu PR, Wanjari RH and Sonune BA. 2019. Impact of continuous manuring and fertilization on changes in soil quality under sorghum-wheat sequence on a Vertisols. Journal of the Indian Society of Soil Science **67(1)**: 55-64.

Kalhapure A, Shete B, Dhonde M and Bodake P. 2014. Influence of different organic and inorganic sources of nutrients on maize (*Zea mays*). Indian Journal of Agronomy **59 (2)**: 295-300.

Rajneesh, Sharma RP, Sankhyan NK and Kumar R. 2017. Long-term effect of fertilizers and amendments on depth-wise distribution of available NPK, micronutrient cations, productivity, and NPK uptake by maize-wheat system in an acid Alfisol of north-western Himalayas. Communications in Soil Science and Plant Analysis **48 (18)**: 2193-2209.

Rajneesh, Sharma RP, Sankhyan NK, Kumar R and Sepehya S. 2018. Effect of a four-decade long application of fertilizers, farmyard manure and lime, on forms of soil acidity and their relationship with yield of wheat and maize in an acid Alfisol. Journal of Plant Nutrition **41 (11)**: 1444-1455.

Sharma SK, Singh VP, Chouhan N and Sikarwar R. 2016. Effect of long-term fertility management practices on soil, crop quality and productivity of soybean grown in Vertisols of western Madhya Pradesh. International Journal of Agricultural Science **8 (60)**: 3371- 3377.

Singh D, Sharma RP, Sankhyan NK and Meena SC. 2017.

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. Journal of Pharmacognosy and Phytochemistry **6**: 198-204.

Tan ZX, Lal R and Wiebe KD. 2005. Global soil nutrient depletion and yield reduction. Journal of Sustainable Agriculture **26**: 123–146.

Walkley A and Black CA. 1934. An examination of wet acid method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science **37**: 29-38.

Wang JY, Yan XY and Gong W 2015. Effect of long-term fertilization on soil productivity on the north China plain. Pedosphere **25 (3)**: 450-458.