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Yield and soil nutrient status as influenced by continuous sorghum: Wheat cropping sequence in vertisols

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Abstract
The present investigation was conducted on long term sorghum-wheat under cropping sequence to know the soil nutrient status and crop productivity during 2019-20 and 2020-21. Experiment was carried out at research farm department of soil science and agricultural chemistry Dr. PDKV, Akola. Results of experiment revealed that conjoint used of NPK along with FYM accounted the highest grain and fodder yield of sorghum crop under long term cropping sequence of 33rd cycle. Whereas, decline in yield potential of cropping system was observed over the initial crop productivity as result of 100% N alone and 100% NP imbalanced and continuous use of inorganic fertilizers. Balanced fertilization with macro and micronutrients it showed getting 15-25 higher yield over the omission of K, S and Zn from nutrient management practices leads it reflecting into sustainability of crop yields. There was significant effect on soil pH and EC was observed. Whereas, the lowest pH was observed with sole FYM in as result of continuous used as a source of nutrients. Moreover, with respect to other treatment there was no drastic effect as a result of buffering effect of soil colloid. Significantly highest OC was noted with application of FYM @ 10 t ha^{-1} and it was statistically at par with NPK+FYM and 150% NPK and lowest was observed under control. The availability of N,P,K, were significantly higher with the application of NPK along with FYM @ 5 t ha^{-1} which was on par with the used of 150% NPK and lowest available nutrient status was noticed under control treatment. Similarly in terms of DTPA-extractable micronutrients status were recorded with continuous application of FYM as source of nutrients which was significantly higher over the rest of treatments. The soil fertility status is significantly influenced by the balanced fertilization with NPK along with FYM followed by super optimal dose of NPK fertilization over the optimal and sub-optimal fertilization of nutrients. Whereas, the degradation in soil fertility and crop productivity were observed under continuous inorganics, imbalanced fertilization, exclusion of FYM and control cultivation.

Key words: Sorghum, wheat, yield, sequence, organic carbon, fertility and productivity

Introduction
Sorghum-wheat system is the most important system in southern and central part of India. It is being increasingly realized that when crops are grown in system, the fertilizer requirements of the cropping system as a whole is important than that of the individual crop. The soil fertility status and nutrients availability to plants are strongly affected by nutrient management practices and cropping systems. The loss of soil fertility due to continuous nutrient depletion by crops without adequate replenishment poses an immediate threat to food and environmental securities. There is a need to revive the age old practice of application of farmyard manure FYM) to maintain soil fertility and also to supplement many essential plant nutrients for crop productivity. Soil organic matter SOM) serves as soil conditioner, nutrient source, substrate for microbial activity, preserver of environment, and major determinant to sustain agricultural productivity, hence there is need to develop, refine, and document the management practices that help in addition and enhancement of SOM levels. This is particularly important in tropical and subtropical regions where soils are low in soil organic carbon SOC) contents and inherently low in fertility status. Increasing or even maintaining SOC levels in tropical.

Intensive farm management practices have led to depletion of plant nutrients in soil and exacerbated soil degradation. In most regions of countries, degradation of soil organic matter SOM), soil structure and the associated nutrient supply are major factors for yield decline in intensive cereal based cropping systems Ladha *et al.*, 2003 [12].

Cereal production, sustaining a world population of more than 6.5 billion, has tripled during the past 40 years concurrently with an increase from 12 to 104 Tg yr^{-1} of synthetic nitrogen N) applied largely as ammoniacal fertilizers Mulvaney *et al*., 2009) [17].

The chemical fertilizer-based cropping system has caused a decline in soil productivity, with a net loss of soil organic carbon SOC) and N. Soils of the world's agro ecosystems are depleted of their soil organic carbon SOC) stocks by 25–75% depending on climate, soil type, and historic management, and the magnitude of this loss may be 10-50 Mg C ha^{-1} Lal, 2011) [14, 29]. Soils with severe depletion of their SOC stocks have their low agronomic yield and low use efficiency of added input Srinivasarao *et al*., 2012) [27]. It involves a wide variety of soils, geographic regions and tillage practices in Asia. Thus, long-term sustainability may require agricultural diversification involving a gradual transition from intensive synthetic N inputs to legume-based crop rotation Mulvaney *et al*., 2009) [17]. The information in legume based cropping systems is sparse under subtropical climate.

The underlying reasons for decline or stagnation of crop yields are not precisely known, though it has been attributed to changes in quantity and quality of soil organic matter, and a gradual decline in the supply of soil nutrients, causing macro and micronutrient imbalances Ladha *et al*., 2000) [32]. Studies by Bhandari *et al*., 2002) [2] and Regmi *et al*., 2002) [34] attributed the reduced productivity of the rice-wheat system, inter alia, to declining soil organic matter SOM) content and decreased soil fertility. However, the concerns about declining SOM and soil fertility are either hypothesized or extrapolated from limited data sets.

Many researchers have reported negative yield trends in long term experiments because of factors such as the continuous use of imbalanced fertilizers, soil types and crop management practices Dawe *et al.*, 2003) [12]. Climate change may also be one of the factors that affect yield trends Horie *et al*., 1995) [35]. Thus, it is essential to restore degraded soils through enhancing the soil organic pool and improving the below-ground environment for food security. In this situation, the maintenance of soil organic pools is a major challenge in tropical climates Lal, 2009) [13]. Researchers have identified specific pools of SOC with functional significance in the turnover of organic matter in the soil Fortuna *et al*., 2003) [36].

Soil formed by many complex soil forming factors, *viz* parent material, relief, climate, organisms and time. Since different climatic zones have different soils and also differ in nutrient status and consequently fertility status. The knowledge of nutrient status of soil and their interrelationship with physical and chemical properties is helpful in understanding the inherent capacity of soil to supply essential plant nutrients for utilization by crops. Availability of nutrients is affected by their distribution in soil and other physicochemical properties of soils.

Thus, long-term experiments are the primary source of information to determine the effect of cropping systems and other fertilizer management practices on soil sustainability and crop productivity of sorghum and wheat in Vertisols of central India.

Materials and Methods

The experiment was laid out in randomized block design RBD) with twelve treatments were replicated in to four replication. The details of treatment are presented below. 50 NPK T_1),100 NPK(T_2), 150 NPK(T_3), 100 NPK S free) T_4), 100 NPK + Zn@2.5 kg ha^{-1}(T_5)' 100 NP(T_6),100 N(T_7), 100 NPK+FYM@ 5 t ha^{-1} T_8),100 NPK + S @ 37.5 kg ha^{-1} T_9),FYM @ 10 t ha^{-1} T_{10}),75 NPK + 25 N through FYM T_{11}) and control No manures and fertilizer) T_{12}). FYM were applied on oven dry basis before sowing. Half N, full P and K at the time of sowing. Remaining N was applied at 30 days after sowing to sorghum and at 21 days after sowing to wheat. Recommended dose of fertilizer: Sorghum - 100: 50: 40 Kg N, P_2O_5 and K_2O ha^{-1} and Wheat - 120: 60: 60 Kg N, P_2O_5 and K_2O ha^{-1}.N, P_2O_5 and K_2O was applied through Urea, SSP and MOP in all treatments except T_4 and T_9, where P was applied through DAP. Sulphur was applied through gypsum. Zinc application based on soil test value. Sowing of sorghum was done by drilling. All field operation were carried out as and when required. After the crop maturity the crop was harvested and spikelet were cut and bundled separately and kept for sun drying. After threshing, yield were recorded. Based on moisture content. Sowing of wheat was done by drilling. All field operation were carried out as and when required.

Experimental Site

The long term fertilizer experiment initiated during 1988-89 to study the changes in soil quality, crop productivity and sustainability. The present study entitled, "Appraisal of carbon dynamics and its sequestration under long term sorghum- wheat cropping sequence in Vertisols" was carried out at Research Farm AICRP on Long Term Fertilizer Experiment, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was superimposed on existing long term fertilizer experiment on sorghum-wheat sequence 32^{nd} and 33^{rd}) cycle during 2019-20 and 2020-21 at Research Farm, Dept. of Soil Science and Agricultural Chemistry Dr. PDKV, Akola. Akola is situated in the subtropical region at $22^0$42' North latitude and $77^0$02' East longitude and at an altitude of 307.42 m Agromet observatory) above mean sea level. Experimental field is situated at the latitude of $22^0$42' 19.2" North and 77^0 03' 43.2" East at the altitude of 30.78 m) above mean sea level MSL).

Soil of experimental area

In order to study the chemical properties of soil, the treatment wise soil samples were collected from surface soil 0-20 cm) at harvest of sorghum and wheat crop. The properties were determined in laboratory and the results are presented along with method adopted for each. Organic carbon determined by using the walkely and black method. The available nitrogen determined by alkaline permanganate method, available Phosphorus determined my Olsen method and available potassium determined by ammonium acetate method and micronutrient status determined by using the DTPA-extractable method. The result of the chemical analysis indicated that, the soils have pH 8.1 with organic carbon content was 4.6 g kg^{-1}. The available nitrogen and phosphorus content of soil was low 150 kg ha^{-1} and medium 18.4 kg ha^{-1}, respectively. However, soils were sufficiently higher in available potassium content 368 kg ha^{-1}) respectively.

Result and Discussion

Data in relation to productivity of grain yield of sorghum decline over the initial and control as result of continuous imbalanced fertilization compared to balanced fertilization.

Significantly highest grain (32.64 q ha^{-1}) yield of sorghum was recorded with the used of 100% NPK along with FYM @ 5 t ha^{-1}, which was followed by the 150% NPK. Similar findings were reported by Meena *et al*., 2016) [15]. Whereas, the lowest was noticed under absolute control plot. With the magnitude of fertilization from 50% NPK to 150% NPK recorded extend of yield potential. Optimal dose of fertilization with NPK recorded the higher yield over the omission of P and K sub optimal dose of fertilizer. These results corroborate with the findings of Prasad *et al*, 2010) [19] and Jadhao *et al*., 2019) [8]. The application of S @ 37.5 kg ha^{-1} with NPK getting 16.18% and 19.78% yield over the without S fertilization. Similar results were supported by Singh *et al*., 2014) [37] also reported that, increase in the yield of wheat crop due to addition of sulphur fertilizers. Similarly, application of Zn @ 2.5 kg ha^{-1} recorded the 4.1 and 10% maximum yield compared to with RDF. Similar order of 100% NPK+FYM+ 150% NPK>100%NPK+S>100%NPK+ZN>100%NPK>100%NPK-S>NP=N for the fodder and straw yield of sorghum and wheat was observed. As result of continuous used of alone 100% N resulting in depleting soil fertility and crop productivity in comparison with control.

Significantly highest fodder yield 87.71 q ha^{-1}) was obtained with 100% NPK+FYM @ 5 t ha^{-1} Yields of fodder showed almost similar trend to that of grain yields. The conjunctive use of optimal NPK fertilizers with FYM resulted in the highest organic carbon 7.83%) and improved physic-chemical properties of soil, which resulted in maintaining the continuous supply of macro- and micronutrients and increased productivity. The yield response for the different nutrients and manure was estimated by considering the yield difference in the 33rd cycle between particular nutrient added and omitted treatments.

Physiochemical properties of soil

Data in relation to Phycio-chemical properties of soil were presented in Table 2. The soil pH is important soil reaction which indirectly influenced the availability of plant nutrients and mobility of nutrients forms in soil.

Among the different fertilized treatments the lowest soil pH 7.95) was recorded with continuous use of FYM as source of nutrients resulted in dropped in pH compared to use of FYM along with NPK and 100% N alone. Which may be attributed to production of organic acids during decomposition of manures. Similar findings were reported by Walia *et al*. 2010) [32]; Gupta *et al*. 2000) [38] reported that, reduction in soil pH, which may be ascribed to microbial decomposition of organic manures. Significantly highest soil pH and EC was acquired where plot receiving 150% NPK. Highest pH was registered with continuous inorganic fertilization which is ascribed to basic nature and continuous uptake of monovalent nutrients from soil by cereal as result of luxury consumption. In terms of electrical conductivity of soil is electrolyte reaction of soil. The highest EC 0.38 ds m^{-1}) was measured under treatment with extra dose of NPK fertilization and application of FYM as result of addition and solubilisation effect of soluble complex. Lowest EC was noticed under the optimization of nutrients compared to imbalanced fertilization and control plot.

It is revealed from results that, significantly highest organic carbon was recorded (7.88 g kg^{-1}) with application of sole FYM @ 10 t ha^{-1}, which was significantly superior to all other treatment and on par with 100% NPK+ along with FYM @ 5 t ha^{-1} and 150% NPK. Whereas, lowest was noticed under control. It might be due to the continuous addition of FYM as direct source of carbon and partly to the fact that FYM addition along with fertilizers resulted in better crop growth which, in turn, led to addition of organic materials in the form of decaying roots, litter, and crop residues in these plots. These results corroborate with the findings of Mishra *et al*., 2008); Sharma *et al*., (2014) [25].

Continuous use of inorganic and organics FYM) fertilizers for 33 years resulted in increased of organic carbon compared to control plot and its over a initial value. Perusal of data further indicated that increase in NPK fertilizer dose from 50% to 150% NPK progressively increased the organic carbon. This increased in organic carbon continuous in soil possibly due to increase in crop productivity which is results in additions of large amount of residual biomass through root, leaves, stubble and rhizodeposition similar findings were reported by Singh *et al*.,(2012) [26, 27]. The highest build-up of OC carbon occur as result of continuous deposition of FYM and accumulation of crop residues which act as carbon source and increased crop productivity. Results were in line with Thakur *et al*., (2011) [29] and Sawarkar *et al*., (2015) [38] reported that, conjoint used of NPK and FYM resulted in enhanced soil organic carbon. The maximum percentage of OC in surface soil occur due to leaf fall, accumulation of crop residues greater percentage of root biomass is present in surface soil.

Macronutrients

All the fertilized treatments showed remarkable increased in soil available nitrogen (Table.2) as compared to control. Significantly highest available N observed 315.9 kg ha^{-1}) in 100% NPK + FYM @ 5 t ha^{-1} treated plot, which was at par with 150% NPK as similar findings earlier reported by Sawarkar *et al*., (2015) [38]. Whereas, the lowest value noted in control plot. The increase in available nitrogen content in soil due to application of FYM may be attributed to the mineralization of nitrogen and greater multiplication of soil microbes which converts organically bound N into inorganic form. The lowest value of available N in control may be due to mining of nutrients with continuous cropping without fertilization over the years. Application of fertilizers either alone NPK or in conjunction with organics were significantly superior to control. These results were corroborate with Jadhao *et al*. 2019) [8].Views consistent with results of Kushwaha *et al*., 2017) [11], higher status of available N was recorded in surface layer. The greater increase in available N contents in soil under different treatment might be due to direct addition, accumulation of crop residue and stimulation of bio inoculants for N-fixation.

The (Table.2) significantly highest available phosphorus 22.05 kg ha^{-1}) was recorded with conjoint application of 100% NPK along with FYM @ 5 t ha^{-1} followed by, 21.82 kg ha^{-1}) with 150% NPK in soil after harvest of sorghum, respectively. Whereas, lowest available phosphorus was noticed in absolute control. Enhancement in available phosphorus with the application of NPK fertilizers alone or in combination with FYM might be due to the release of organic acids during decomposition, which in turn helped in releasing phosphorus through solubilizing action of native phosphorus in the soil. The results were in conformity with Sharma and Sepehya, 2014) [42]. The soil organic matter SOM) also forms a protective cover on sesquioxides and makes them inactive, and thus reduces the phosphate fixing capacity of the soil, which ultimately, helps in release of abundant quantity of phosphorus as reported by Urkurkar *et al.,* 2010) [30].The addition of P at higher rates 150% NPK) treatment recorded the marked increase in available P. Application of 100% N alone had no significant effect on available phosphorus, but when applied along with P i.e 100% NP, resulted into significantly higher available phosphorus over 100% N alone treatment. Limited use of the P as compared to N through imbalanced fertilization that might be one of the reason for lower P availability in the soil. Low P availability in these may also be due to its fixation be Fe and Al oxides and hydroxides, similar results were reported by Sarkar *et al*., 2018) [39].

The available potassium in soil were ranged from 153.4 to 461.8 kg ha^{-1} after harvest of sorghum (Table.2). Significantly highest available K was 461.8 kg ha^{-1}) recorded under treatment with 100% NPK+FYM @ 5 t ha^{-1} and statistically at par with 150% NPK in soil after sorghum-wheat sequence. The available potassium content of soil showed an increase with continuous application of potassic fertilizer and FYM over the initial value. Increased in availability of K with 100% NPK+FYM application might be due to the direct addition of K to the available pool of the soil, mineralization of organic sources and solubilization from native sources during the decomposition Subehia and Sepehya, 2012) [22, 28] and Kharche *et al*., (2013) [10]. Further, data suggest that with increasing NPK dose from sub-optimal to super optimal levels, the magnitude of soil available K showed an increasing trend. The depletion of available K in N, NP and absolute control treatment may be attributed to exclusion of K in these treatments. Results were in agreement with Jadhao *et al*., (2018) [9]. Sharma *et al*., (2017) [40] reported higher contents of available K in 150% NPK treatment were obvious. Comparatively higher content of available K in the plots receiving 100% NPK-S) might be due to its lower removal emanating from lower yields caused by sulphur deficiency.

Micronutrients

The micronutrients status of soil were strongly influenced with the optimization of doses and balanced fertilization. The data presented in Table 3 indicated that DTPA-extractable micronutrients in soil was significantly influenced due to the various treatments. Significantly highest Zn (0.69 mg kg^{-1}) availability of Zn was obtained under treatment which consist of sole FYM @ 10 t ha^{-1} as organic source of nutrients which was superior over the rest of treatments and on par with the 100% NPK+FYM and 150% NPK balanced fertilization.

Similarly, the super optimal dose of 150% NPK recorded the highest availability of micronutrients compared with RDF of NPK and 100% N alone and 100% NP as result of reduction or omission of P, K and S impacting towards less production of above and below ground biomass of due to shortage of nutrient supply. Whereas, the lowest availability of Zn was noted under control plot and sub optimal dose of fertilizer. Organic manure or FYM dictates the chemical, physical and biological activities of soil but they have comparatively low nutrient content, so larger quantity is required for plant growth Akhtar *et al*., 2009) [41]. The increase in the content of DTPA extractable Zn in organically amended plots may be due to mineralization of organically bound forms of Zn in the FYM and also possible addition of zinc as impurity through single superphosphate. Addition of FYM might result in the formation of organic chelates of higher stability. Zinc is known to form relatively stable chelates with organic ligands, which decrease their susceptibility to adsorption, fixation, and/or precipitation. Similar results were also reported by Sharma *et al*., (2017) [40]. Pant *et al*. (2020) [18] reported that, when intensive systems of two or more than two crops are followed with high input use, the secondary and micro-nutrients are also removed in large quantities from the soil along with primary nutrients NPK) due to higher biomass yield. Since NPK are commonly replenished through high analysis fertilizers, the secondary and micro-nutrients, especially sulphur, zinc, iron, copper and manganese, remain uncared and have started showing up deficiencies in many areas.

Therefore, in recent years, the crops have started responding to these nutrients Kharche *et al*. 2013) [10]. Also considerable depletion in available Zn status of soil have been observed as compared to their initial status, before 32 years, under only chemical fertilizers. However, integration of organics maintained the level of micro-nutrient cations above the critical level in soil. The continuous use of only chemical fertilizers caused considerable depletion of all the four micro-nutrient cations, which indicates mining of these nutrients due to long-term intensive cultivation of cereal-cereal cropping sequence without addition of any organic manure or crop residues, which further suggests the necessity of regular use of organics for maintaining micro-nutrient status of soils.

The significantly highest DTPA-extractable-Fe (9.77 mg kg^{-1}) was recorded with application of FYM @ 10 t ha^{-1}. The increased in availability of Fe with combined application of organic manures and inorganic fertilizers compared to imbalanced fertilized treatments. This ascribed to consistent use of FYM as source of nutrients to crop growth which enhances the crop growth and development of excess biomass yield as source of organic matter. Similar findings were reported by Setia and Sharma 2004) [23] observed that increasing application of alone chemical fertilizers accelerated depletion of DTPA-Fe from soils. Moreover, the treatments receiving NPK+FYM had the highest concentration of DTPA-Fe. The lowest availability of Fe noticed under control treatments as impact of no manures and fertilizer application. This decline in DTPA-extractable Fe with continuous cropping has occurred because of Fe removal by successive crops from the native reserve of this micronutrient cation. The results were in accordance with those reported earlier by Singh *et al*., 1995) [41] and Behera *et al*., 2009) [1]. Behera *et al*., 2009) [1] reported that available Fe content declined in all the treatments from the initial level of 10.6 mg kg^{-1}, as a result of continuous cropping and fertilization for 33 years.

The content of DTPA-extractable Cu were varied from 2.91 to 3.52 mg kg^{-1} after harvest of kharif sorghum. Significantly highest DTPA-extractable-Cu (3.52 mg kg^{-1}) was recorded under plot receiving 100% NPK+FYM @ 5 t ha^{-1} and it was significantly superior over the all other treatments. Whereas, lowest (2.91 mg kg^{-1}) available Cu was recorded in the control. Results revealed that DTPA-extractable Cu content in soil increased with the combined application of chemical fertilizer and FYM as compared to chemical fertilizer alone and control. The increase in DTPA-extractable Cu may be attributed to the chelating action of organic compounds released during decomposition of FYM which increased availability of micronutrients by preventing fixation, oxidation, precipitation and leaching. Similar findings were reported by Shahid *et al*., 2015) [24]. Increment of DTPA-extractable Cu may be associated with the chelating action of organic sources (FYM, GM and WS) that are liberated due to decomposition of organic source that advantages in availability of micronutrients through the prevention of some particular processes like fixation, oxidation, precipitation and leaching Dhaliwal *et al*., 2019 [4] and Walia *et al*., 2010) [32].

The significantly highest (13.68 mg kg^{-1}) DTPA-extractable Mn was noted with application of FYM @ 10 t ha^{-1} it was on par with 100% NPK+FYM @ 5 t ha^{-1} and 75% NPK + 25% N through FYM. Whereas, the lowest Mn content 11.06 mg kg^{-1}) in soil was seen in control. This could be attributed to the addition of FYM which releases Mn^{2+} bound to organic legends and accelerates the reduction of Mn^{4+} to Mn^{2+}. Escalated the availability of Mn may also be due to the extended period of mineralization of organic manure which readily liberated the Mn in to labile pool over an extended period. Similar findings were reported by Saha *et al*., 2007) [20]. Apart from that, organic acids and humic substances released from FYM decomposition encourage the Mn mobilization from solid phase to soil solution by Dhaliwal *et al*., 2013) [5]. Organic manuring is another way to increase the Mn availability in soils.

Table 1. Effect of long term manuring and fertilization on grain and fodder yield under sorghum-wheat cropping sequence

Sr. No	Treatments	Pooled Yield q ha^{-1}) Sorghum	
		Grain	Fodder
T_1	50 NPK	16.53	44.12
T_2	100 NPK	24.41	65.37
T_3	150 NPK	29.80	79.01
T_4	100 NPK S free	22.74	59.95
T_5	100 NPK + Zn @ 2.5 kg ha^{-1}	25.48	67.85
T_6	100 NP	19.69	51.26
T_7	100 N	10.85	29.72
T_8	100 NPK+FYM@ 5 t ha^{-1}	32.64	87.71
T_9	100 NPK +S @ 37.5 kg ha^{-1}	27.13	72.18
T_{10}	FYM @10 t ha^{-1}	18.68	49.82
T_{11}	75 NPK + 25 N through FYM	27.10	74.04
T_{12}	Control(No manures and fertilizer)	3.14	8.46
	SE m(±)	0.82	2.22
	CD at 5%	2.36	6.42

Table 2. Effect of long term manuring and fertilization on physico-chemical properties and available N, P and K status under of soil under sorghum-wheat cropping sequence

Sr. No	Treatments	After harvest of Sorghum					
		pH	EC	OC	N	P	K
T_1	50 NPK	8.02	0.30	4.43	162.8	11.00	241.4
T_2	100 NPK	8.05	0.34	5.41	240.3	18.04	383.2
T_3	150 NPK	8.12	0.38	6.97	289.9	21.82	443.9
T_4	100 NPK S free	8.11	0.34	5.32	219.9	17.83	372.0
T_5	100 NPK + Zn @ 2.5 kg ha^{-1}	8.08	0.36	6.50	221.9	18.44	389.4
T_6	100 NP	8.14	0.32	4.78	210.5	18.06	223.8
T_7	100 N	8.08	0.31	4.05	200.5	10.60	187.2
T_8	100 NPK+FYM@ 5 t ha^{-1}	8.07	0.35	7.83	315.9	22.05	461.8
T_9	100 NPK +S @ 37.5 kg ha^{-1}	8.11	0.36	6.57	224.0	18.63	364.9
T_{10}	FYM @10 t ha^{-1}	7.95	0.38	7.88	221.4	15.80	289.3
T_{11}	75 NPK + 25 N through FYM	8.09	0.34	6.47	227.4	18.48	332.3
T_{12}	Control(No manures and fertilizer)	8.10	0.25	3.08	113.8	5.85	153.4
	SE m) ±	0.075	0.015	0.28	8.41	0.88	17.8
	CD at 5	0.225	0.055	0.82	24.26	2.53	51.17

Table 3. Effect of long term manuring and fertilization on DTPA-extractable micronutrient status under sorghum-wheat cropping sequence

Sr. No	Treatments	After harvest of Sorghum			
		Zn	Cu	Fe	Mn
T_1	50 NPK	0.49	4.38	8.42	11.57
T_2	100 NPK	0.51	4.08	8.64	12.12
T_3	150 NPK	0.57	4.43	8.93	12.85
T_4	100 NPK S free	0.48	2.97	8.66	12.09
T_5	100 NPK + Zn @ 2.5 kg ha^{-1}	0.63	2.98	8.61	12.76
T_6	100 NP	0.52	3.48	8.44	12.09
T_7	100 N	0.48	2.97	8.37	11.61
T_8	100 NPK+FYM@ 5 t ha^{-1}	0.67	3.52	9.54	13.39
T_9	100 NPK +S @ 37.5 kg ha^{-1}	0.56	2.93	8.57	12.70
T_{10}	FYM @10 t ha^{-1}	0.69	3.27	9.77	13.68
T_{11}	75 NPK + 25 N through FYM	0.66	2.97	9.28	13.14
T_{12}	Control(No manures and fertilizer)	0.44	2.91	7.49	11.06
	SE m) ±	0.025	0.14	0.29	0.24
	CD at 5	0.072	0.43	0.84	0.23

Conclusion
Thus, it finally concluded that balanced fertilization with NPK and comprised used of FYM along with NPK and super optimal dose of NPK fertilization resulted in enhanced soil fertility status and increased crop productivity as well as soil health in sustainable manner and its helps to arrest the degradation of soil quality.

References

1. Behera SK, Singh D. Effect of 31 years of continuous cropping and fertilizer use on soil properties and uptake of micronutrients by Maize *Zea mays*)-wheat *Triticum aestivum*) system. Indian. J Agric. Sci. 2009;79:264-267.
2. Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, RK Gupta. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. Soil Sci. Soc. Am. J. 2002 Jan 1;66(1):162-170.
3. Bhatt MK, Raverkar KP, Labanya R, Bhatt CK. Effects of long-term balanced and imbalanced use of inorganic fertilizers and organic manure FYM) on soil chemical properties and yield of rice under rice-wheat cropping system. J. Pharm. and Phyto. 2018;7(3):703-708.
4. Dhaliwal SS, Ram H, Walia SS, Walia MK, Kumar B, Dhaliwal MK. Long-term influence of nutrient management on carbon and nutrients in Typic-ustochrept soils. Comm. Soil Sci. and Plant Analysis. Ok. 2019;50(19):2420-28.
5. Dhaliwal SS, Manchanda JS, Walia SS, Dhaliwal MK. Differential response of manures in transformation of DTPA and total zinc and iron in rice transplanted on light textured soils of Punjab. Int. J Sci. Environ. Technol. 2013;2(3):300-312.
6. Gawde N, Singh AK, Agrawal SK, Kumar R. Long term effect of integrated nutrient management on soil nutrient status under rice-wheat cropping system in Inceptisols. Inter. J Chemi. Studi. 2017;5(4):1050-1057.
7. Gupta V, Sharma RS, Vishwakarma SK. Long-term effect of integrated nutrient management on yield sustainability and soil fertility of rice *Oryza sativa*)-wheat *Triticum aestivum*) cropping system. Indi. J of Agron. 2006;51(3):160-164.
8. Jadhao SD, Mali DV, Kharche VK, Singh M, Bhoyar SM, Kadu PR, *et al*. Impact of Continuous Manuring and Fertilization on Changes in Soil Quality under Sorghum-Wheat Sequence on a Vertisols. J Indian Soc. Soil Sci. 2019;67(1):55-64.
9. Jadhao SD, Dipali Arjun, Mali DV, Muneshwar Singh, Kharche VK, Wanjari RH, *et al*. Effect of Long-Term Manuring and Fertilization on Depth Wise Distribution of Potassium Fractions under Sorghum-Wheat Cropping Sequence in Vertisol. J Indian Soc. Soil Sci. 2018;66(2):172-18.
10. Kharche VK, Patil SR, Kulkarni AA, Patil VS, Katkar RN. Long-term integrated nutrient management for enhancing soil quality and crop productivity under intensive cropping system on vertisols. J Indian Soc. Soil Sci. 2013;61(4):323-332.
11. Kushwaha S, Sawarkar SD, Thakur R, Khamparia NK, Singh M. Impact of long-term nutrient management on soil N dynamics under soybean-wheat cropping sequence on a Vertisol. J Indian Soc. Soil Sci. 2017;65(3):274-282.
12. Ladha JK, Dawe D, Pathak H, Padre AT, Yadav RL. How extensive are yield declines in long-term rice-wheat experiments in Asia. Field Crops Res. 2003;81:159-180.
13. Lal R, Soil carbon sequestration for climate change mitigation and food security. Souvenir, Platinum Jubilee Symposium on Soil Science in Meeting the Challenges to Food Security and Environmental Quality. J Indian Soc. Soil Sci., New Delhi, 2009, 39-46.
14. Lal R, Sequestering carbon in soils of agro-ecosystems. Food Policy, 2011;36:S33-S39.
15. Meena HM, Sharma RP, Long-Term Effect of Fertilizers and Amendments on Different Fractions of Organic Matter in an Acid Alfisol. Comm. In Soil Sci. and Plant Analysis, 2016;(47)11:1430-1440.
16. Mishra B, Sharma A, Singh SK, Prasadand J, Singh BP, Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Aflisol of Jharkhand. J Indian Soc. Soil Sci. 2008;56:71-75.
17. Mulvaney RL, Khan SA, Elloworth TR, Sysnthetic nitrogen fertilizers deplete soil nitrogen: A global dilemma for sustainable cereal production. J Environ. Qual. 2009;38:2295-2314.
18. Pant P, Shri Ram K, Singh V, Mishra A, Pallavi Bhatt, Change in soil chemical properties under different depths after 42 years rice-wheat cropping system in sub-tropical Mollisols of India. Indian J Soil Cons. 2020;48(1):11-19.
19. Prasad J, Karmakar S, Kumar R, Mishra B, Influence of integrated nutrient management on yield and soil properties in maize-wheat cropping system in an Alfisol of Jharkhand. J Indian Soc. Soil Sci. 2010;58(2):200-204.
20. Saha PK, Ishaque M, Saleque MA, Miah MAM, Panaullah GM, Bhuiyan NI. Long-term integrated nutrient management for rice-based cropping pattern: effect on growth, yield, nutrient uptake, nutrient balance sheet, and soil fertility. Comm. in Soil Sci. and Plant Analysis, 2007;38:579-610.
21. Sawarkar SD, Khamparia NK, Thakur R, Dewda MS, Singh M. Effect of long term application of inorganic fertilizers and organic manures on yield, potassium uptake and profile distribution of potassium fractions in vertisol under Soybean- wheat cropping system. J Indian Soc. Soil Sci. 2013;61(2):94-98.
22. Sepehya S, Subehia SK, Rana SS, Negi SC. Effect of integrated nutrient management on rice-wheat yield and soil properties in a north western Himalayan region. Indi. J Soil Consr. 2012;40(2):135-140.
23. Setia R, Sharma K. Effect of continuous cropping and long term differential fertilization on profile stratification of DTPA-extractable micronutrients. Food Agriculture and Environment, 2004;2:260-265.
24. Shahid M, Shukla AK, Bhattacharya P, Tripthi R, Mohanty S, Das B, *et al*. Micronutrients Fe, Mn, Zn and Cu) balance under long-term application of fertilizer and manure in a tropical rice-rice system. Journal of soils and sediments, 2015. DOI: 10.1007/s 11368-015-1272-6.
25. Sharma U, Paliyal SS, Sharma SP, Sharma GD. Effects of continuous use of chemical fertilizers and manure on soil fertility and productivity of maize-wheat under rainfed conditions of the Western Himalayas. Comm. Soil Sci. and Plant Analysis. 2014;45:2647-59.
26. Singh M, Wanjari RH, Dwivedi A, Dalal R, Yield response to applied nutrients and estimates of N2 fixation in 33 year old soybean–wheat experiment on a Vertisol. Experimental Agriculture 2012;48,311-325.

27. Srinivasarao CH, Deshpande AN, Venkateswarlu B, Lal R, Singh AK, Kundu S, *et al*. Grain yield and carbon sequestration potential of post monsoon sorghum cultivation in Vertisols in the semi-arid tropics of central India. Geoderma. 2012;175-176:90-97.
28. Subehia SK, Sepehya S, Influence of Long-term integrated nitrogen substitution through organics on yield, uptake and available nutrients in rice wheat system in acid soil. J Indian Soc. Soil Sci. 2012;60:213-217.
29. Thakur R, Kauraw DR, Singh M. Profitable distribution of micronutrients cations in a Vertisols as influenced by long-term application of manure and fertilizer. J India. Soci. of Soil Sci; 2011;59(3):239-244.
30. Urkurkar JS, Tiwari A, Chitale S, Bajpai RK, Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice *Oryza sativa*) and wheat *Triticum aestivum*) in inceptisols. Indian J of Agri. Sci. 2010;80(3):208-212.
31. Verma, G, Mathur AK, Effect of continuous application of organic and inorganic fertilizers on micronutrient status in maize-wheat system on Typic Ustochrept. An Asian J of Soil Sci. 2007;2:146-9.
32. Walia MK, Walia SS, Dhaliwal SS, Long-term effect of integrated nutrient management on properties of Typic Ustochrept after 23 cycles of an irrigated rice *Oryza sativa* L.) – wheat *Triticum aestivum* L.) system. J of Sustai. Agric. 2010;34(7):724-43.
33. Ladha JK, Fischer KS, Hossain M, Hobbs PR, Hardy B. Improving the. Productivity and Sustainability of Rice-Wheat Systems of the lndo-Gangetic Plains: A Synthesis of NARS-IRRI Partnership Research; c2000.
34. Regmi A, Ladha J, Pasuquin E, Pathak H, Hobbs P, Shrestha L, *et al*. The role of potassium in sustaining yields in a long-term rice-wheat experiment in the Indo-Gangetic Plains of Nepal. Biology and Fertility of Soils. 2002 Oct;36(3):240-7.
35. Horie N, Aiba H, Oguro K, Hojo H, Takeishi K. Functional analysis and DNA polymorphism of the tandemly repeated sequences in the 5'-terminal regulatory region of the human gene for thymidylate synthase. Cell structure and function. 1995;20(3):191-7.
36. Fortuna A, Harwood R, Kizilkaya K, Paul EA. Optimizing nutrient availability and potential carbon sequestration in an agroecosystem. Soil Biology and Biochemistry. 2003 Aug 1;35(8):1005-13.
37. Singh S, Prasad SM. Growth, photosynthesis and oxidative responses of *Solanum melongena* L. seedlings to cadmium stress: mechanism of toxicity amelioration by kinetin. Scientia Horticulturae. 2014 Sep 11;176:1-0.
38. Sawarkar M, Solanke A, Mhasal GS, Deshmukh SB. Combining ability and heterosis for seed cotton yield, its components and quality traits in Gossypium hirsutum L. Indian Journal of Agricultural Research. 2015;49(2):154-9.
39. Sarkar A, Pramanik K, Mitra S, Soren T, Maiti TK. Enhancement of growth and salt tolerance of rice seedlings by ACC deaminase-producing Burkholderia sp. MTCC 12259. Journal of plant physiology. 2018 Dec 1;231:434-42.
40. Sharma D, Bisht DM. tuberculosis hypothetical proteins and proteins of unknown function: Hope for exploring novel resistance mechanisms as well as future target of drug resistance. Frontiers in microbiology. 2017 Mar 21;8:465.
41. Singh D, Young RK. Body weight, waist-to-hip ratio, breasts, and hips: Role in judgments of female attractiveness and desirability for relationships. Ethology and Sociobiology. 1995 Nov 1;16(6):483-507.
42. Dhiman S, Dixit SP, Sepehya S. Effect of amendments on different forms of soil aluminum and acidity in an acid alfisol of western Himalayas. Research on Crops. 2014 Sep 1;15(3).